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ORIGINAL PAPER

High Frequency Ultrasound and Color Doppler Evaluation of Carotid Artery Atherosclerosis in Hypertensive Patients Compared with Normotensives

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ABSTRACT

***Objective**: To evaluate the relationship between hypertension and carotid atherosclerosis by high-frequency ultrasound and color Doppler with a comparison to normotensive.*

***Method**: Using high frequency ultrasound technology and color Doppler to detect 60 cases of patients with hypertension and 40 cases with normal blood pressure of carotid artery intima-media thickness, atherosclerotic plaque size, echo intensity. Compared the difference of above indicators of hypertensive patients and normal blood pressure and blood pressure.*

***Result**: Intima media thickness of hypertensive patients (0.95±0.09), Resistive Index of hypertensive patients (0.77 ± 0.03) was significantly higher than normal blood pressure group (P 0.01). The higher of blood pressure levels (systolic blood pressure), the greater carotid intima-media thickness.*

***Conclusion**: The hypertensive patients with carotid atherosclerosis are significantly higher than patients with normal blood pressure, and the higher blood pressure levels.*

***Keywords**: High frequency ultrasound, color doppler, carotid artery, atherosclerosis*

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INTRODUCTION

Depending on methods of patient ascertainment, 80–95% of hypertensive patients are diagnosed as having "essential" hypertension. In the remaining 5–20% of hypertensive patients, a specific underlying disorder causing the elevation of blood pressure can be identified.[1] In India, hypertension is the leading non-communicable disease risk and estimated to be attributable for nearly 10 per cent of all deaths.[2]

Elevated blood pressure is an independent cause of serious cardiovascular diseases and premature mortality from such diseases.[5] Hypertension plays an important and critical role in atherosclerotic cardiovascular disease, but its impact is greatly influenced by coexistent contributors, particularly abnormalities in blood lipid and glucose metabolism. Atherosclerotic cardiovascular sequelae including stroke, coronary disease and peripheral arterial disease, all occur with two- three fold frequencies in hypertensive compared to normotensives of the same age.[6]Increase in **Intima-media thickness** [IMT] of an artery has been used as a surrogate marker of the early atherosclerotic process.[7]

The development of noninvasive techniques such as high-resolution ultrasound imaging allows the measurement of combined IMT.[8] The areas open to investigate with high-resolution ultrasound technique are mainly carotid and femoral arteries. Many studies have shown that the atherosclerotic process start to develop in the carotids approximately at the same time as in aorta, actually preceding plaque occurrence in coronary arteries.

Thickening of Intima media complex not only reflects the local morphological alterations in the carotid arteries but also corresponds to generalized atherosclerosis as suggested by several studies showing significant correlation between carotid artery atherosclerosis and coronary artery atherosclerosis.[9]

Carotid artery distensibility, which diminishes with increasing severity of atherosclerosis, also shows similar correlation with generalized atherosclerotic changes. However, assessment of an arterial distensibility requires relatively arduous procedure and is subject to inter observer and intra observer variability. In contrast, the **Resistive index** [**RI**] according to Pourcelot is a hemodynamic parameter that is easily determined by Doppler sonography basically reflecting the vascular resistance, which in turn depends on distensibility of the vessel. Thus, during assessing the atherosclerosis of vascular system, IMT and RI play complementary role to each other. [10]

The present cross sectional study was undertaken to assess the Carotid IMT changes and associated changes in RI in hypertensive patients using high frequency ultrasound and color Doppler and to compare the findings in hypertensive subjects with normotensive subjects.

MATERIAL AND METHOD

This study was carried out in the department of Radio-diagnosis of Gauhati Medical College, Guwahati with clinically diagnosed hypertension from mid September 2014 to mid September 2015.

A structured proforma was used to enter the clinical history, physical examination findings, investigations - hematological, urinary and duplex sonography findings.Ultrasonography was performed on Siemens Acuson Antares Color Doppler Ultrasound System with VFX13-5 linear transducer of frequency 5-13 MHz.

RESULT

Out of 100 cases we selected 60 hypertensive patients aged between 35-55 years and 40 normotensive subjects of same age group.

Compared to normotensive, hypertensive showed significantly higher systolic BP, diastolic BP, Mean arterial pressure, total cholesterol, LDL cholesterol and triglycerides (**Table 1)**. Whereas BMI, glucose levels, age and sex distribution and HDL cholesterol were similar in both groups.

Table 1 Demographic data of two groups

Demographic characteristics	Normotensive	Hypertensive	p value
Age	49.02± 5.71	50.02±5.35	0.379
Sex	Female-45% Female-43.33%	Male-55% Male-56.67%	>0.05
SBP	111.95±6.38	151.43±4.46	<0.01
DBP	75.65±4.94	97.47±3.33	<0.01
MAP	87.75±5.06	115.45±3.33	<0.01
HR	79.35±4.95	79.36±4.65	0.99
BMI	23.6±1.10	23.86±1.31	0.30
TC	146.5±7.77	169.1±5.49	<0.01
TG	115.6±11.74	169.18±7.28	<0.01
LDL	66.9±3.68	71.52±4.07	<0.01
HDL	51.05±3.38	49.55±4.02	0.055
Glucose	94.38±6.25	94.2±5.95	0.89

SBP-Systolic blood pressure; DBP-Diastolic blood pressure; MAP-Mean arterial pressure; HR-Heart rate; BMI-Body mass index; TC-Plasma total cholesterol; and TG-Plasma triglycerides. Mean±SD is reported.

Age distributions of the subjects are shown in **Figure 1.** Both hypertensive and normotensive groups were proportionately distributed in all age groups

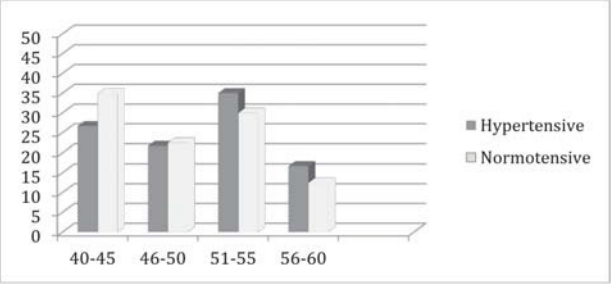

Figure 1 Age distribution of Normotensives and Hypertensive (n=100)

Sex distribution of hypertensive and normotensive groups are shown in **Figure 2.**

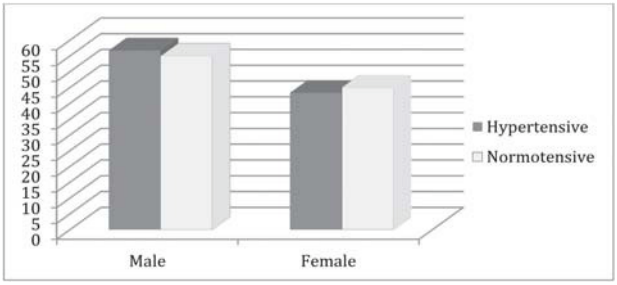

Figure 2 Sex distributions of Normotensives and Hypertensive (n-100)

Table 2 Blood Pressure parameters in Normotensives and Hypertensive

Blood pressure	Normotensive (Mean± SD)	Hypertensive (Mean ± SD)	ANOVA p value
Systolic	111.95±6.38	151.43±4.47	<0.01
Diastolic	75.65±4.94	97.47±3.33	<0.01
MAP	87.75±5.06	115.46±3.33	<0.01

Different blood pressure parameter status in hypertensive and normotensive groups is shown in **Table 2**. Compared to normotensives, hypertensive showed significantly higher systolic BP, diastolic BP and Mean arterial pressure [MAP].

Table 3 shows the **Mean Intima media thickness** [M-IMT] measurement of right side, left side and combined values of both sides in hypertensive and in normotensives. There is highly significant increase in IMT on both sides in hypertensive compared to normotensives.

Table 3 Effect of Hypertension on Intima media thickness

M-IMT	Normotensive	Hypertensive	ANOVA p value
LEFT	0.6±0.09	0.94±0.10	< 0.01
RIGHT	0.62±0.09	0.95±0.09	< 0.01
COMBINED (Average)	0.61±0.08	0.95±0.09	< 0.01

M-IMT - Mean Intima media thickness

Table 4 shows **Mean Resistive index** [M-RI] of right side, left side and combined value of both sides in normotensives and hypertensive. There is highly significant increase in Resistive index [RI] on both sides in hypertensive compared to normotensives.

Table 4 Effect of Hypertension on RI

M-RI	Normotensive	Hypertensive	ANOVA p value
LEFT	0.65±0.03	0.77±0.03	P< 0.01
RIGHT	0.65±0.03	0.77±0.04	P<0.01
COMBINED (AVERAGE)	0.65±0.03	0.77±0.03	P<0.01

M-RI- Mean Resistive index

Table 5 and **Figure 3** shows relationship between various blood pressure parameters and IMT and RI in normotensive and hypertensive group.

Table 5 Relationship between blood pressure parameters and IMT and RI in both groups

Blood pressure status	Normotensive (Pearson correlation)		Hypertensive (Pearson correlation	
	IMT	RI	IMT	RI
Systolic	-0.22 (0.174)	0.236 (0.143)	0.113 (0.389)	-0.076 (0.566)
Diastolic	-0.209 (0.195)	0.001 (0.993)	0.158 (0.228)	0.023 (0.864)
MAP	-0.228 (0.156)	0.1 (0.538)	0.156 (0.234)	-0.019 (0.887)

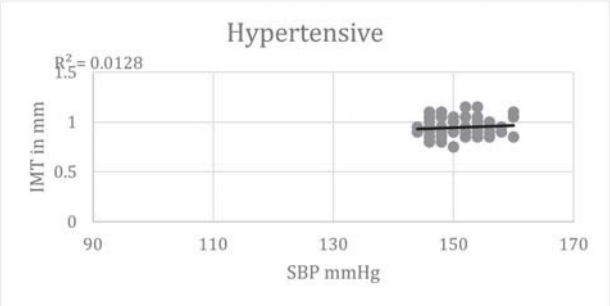

Figure 3a Relationship between Systolic blood pressure and IMT in Hypertensive group

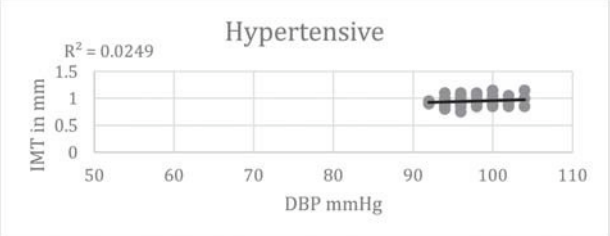

Figure 3b Relationship between Diastolic blood pressure and IMT inhypertensive group

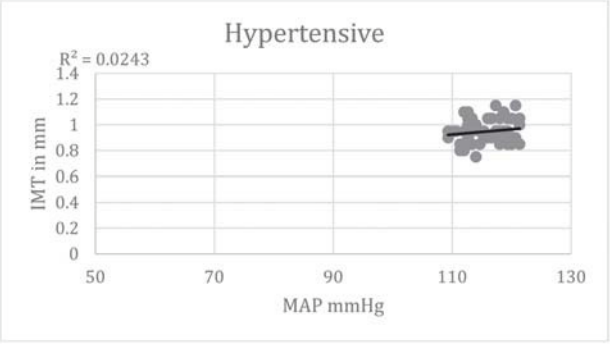

Figure 3c Relationship between Mean arterial pressure and IMT inhypertensive group

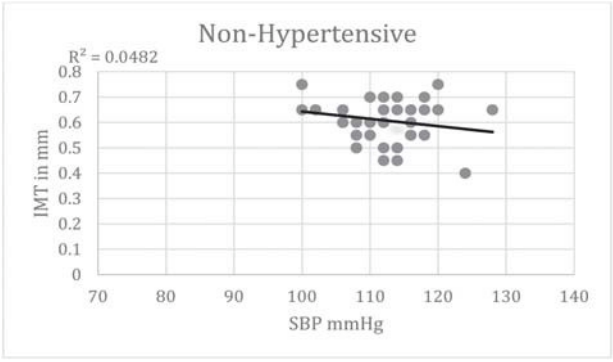

Figure 3d Relationship between Systolic blood pressure and IMT innormotensive group

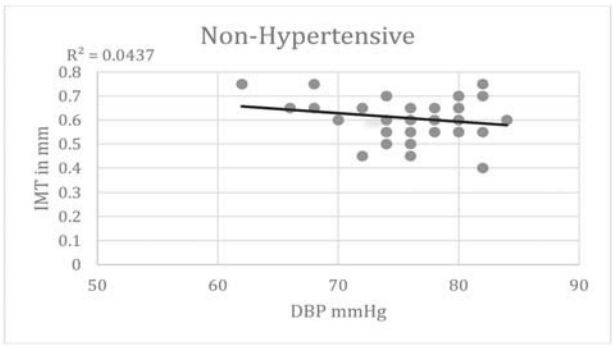

Figure 3e Relationship between Diastolic blood pressure and IMT innormotensive group

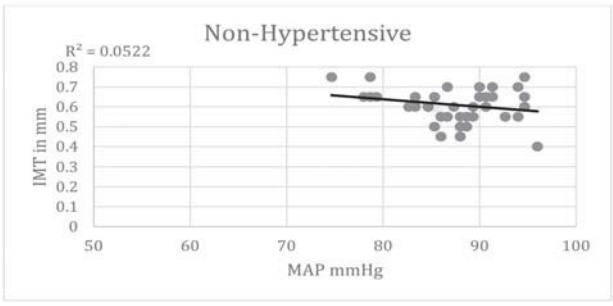

Figure 3f Relationship between Mean arterial pressure and IMT innormotensive group

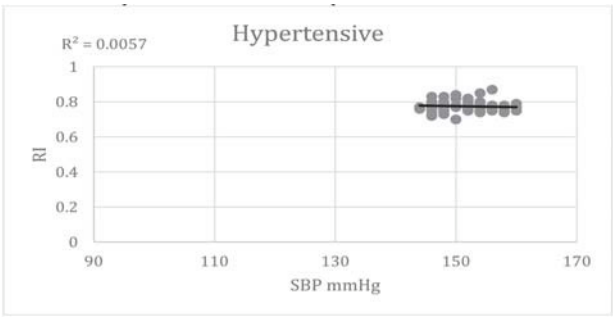

Figure 3g Relationship between systolic blood pressure and RI in hypertensive group

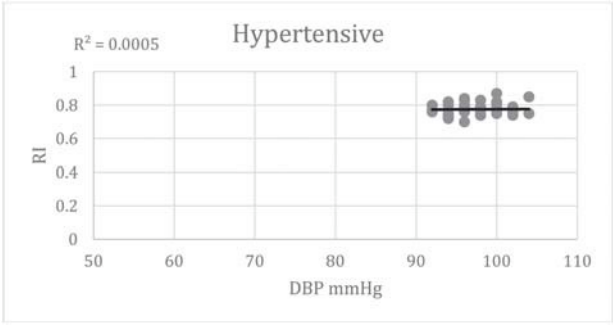

Figure 3h Relationship between diastolic blood pressure and RI inhypertensive group

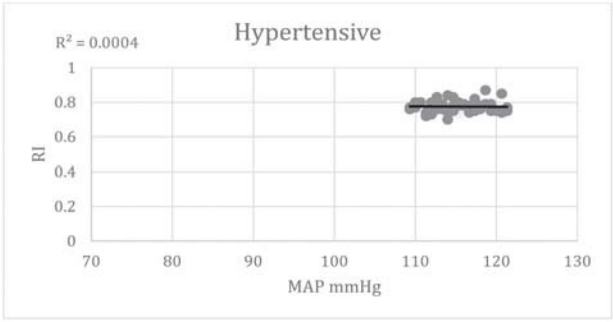

Figure 3i Relationship between Mean arterial pressure and RI inhypertensive group

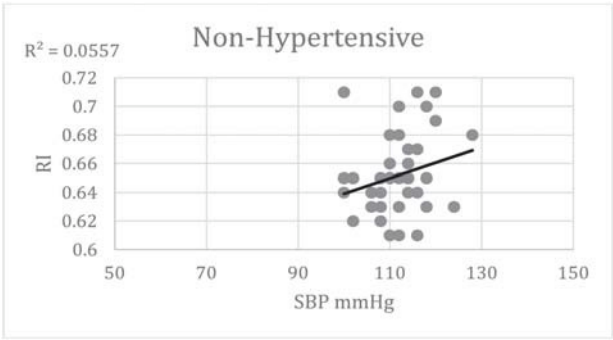

Figure 3j Relationship between systolic blood pressure and RI in normotensive group

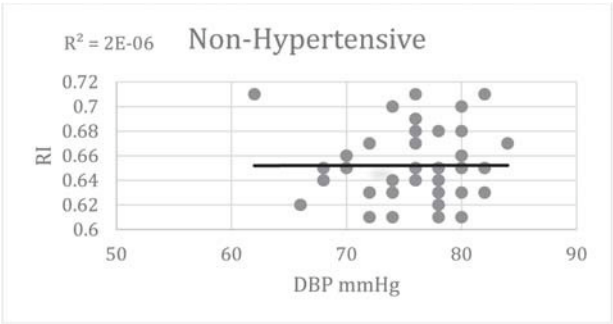

Figure 3k Relationship between diastolic blood pressure and RI in normotensive group

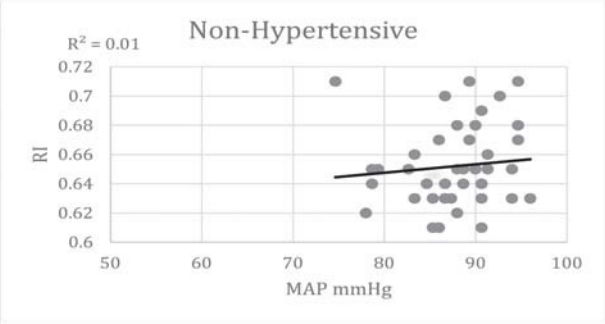

Figure 3l Relationship between mean arterial pressure and RI in Normotensive group

DISCUSSION

The mean systolic blood pressure, mean diastolic blood pressure, mean arterial pressure, mean total cholesterol, mean LDL cholesterol, mean HDL cholesterol and mean triglyceride levels in this study was151.43±4.46 mm Hg, 97.47±3.33 mm Hg, 115.45±3.33 mm Hg, 169.1±5.49 mg/dl, 71.52±4.07 mg/dl, 49.55±4.02 mg/dl and 169.18±7.28 mg/dl respectively in the hypertensive group whereas in the normotensive group the values were 111.95±6.38 mm Hg, 75.65±4.94 mm Hg, 87.75±5.06 mm Hg, 146.5±7.77 mg/dl, 66.9±3.68 mg/dl, 51.05±3.38 mg/dl and 115.6±11.74 mg/dl respectively. On statistical analysis it was found that mean systolic blood pressure, mean diastolic blood pressure and mean arterial pressure, mean total cholesterol, mean LDL cholesterol and mean triglyceride level were significantly high in hypertensive patients compared to the normotensive group.

We examined bilateral common carotid arteries of all patients with duplex sonography and IMT and RI were assessed. By measuring IMT and RI we assessed both morphological and hemodynamic [physiological] changes. When RI and IMT measurements are compared, the essential advantages of the former are the easier data acquisition by the use of simple duplex apparatuses, the tendency to have less interobserver and intraobserver variability, and the smaller side difference.[10] We assessed IMT from the distal common carotid artery proximal to carotid bulb. Although, some authors have found an even better correlation with the degree of atherosclerosis when using IMT values for combination of ICA and CCA values, we have restricted ourselves to the determination of IMT in the CCA. Because IMT measurements in the ICA have a massive scatter and IMT measurement of CCA is easier to obtain, more reliable, and have been proved by many studies. RI was also assessed at the same site. We found the mean IMT and RI to be 0.95±0.09 mm & 0.77±0.03 respectively in the hypertensive group whereas in the normotensive group the corresponding values were 0.61±0.08 mm and 0.65±0.03. The results obtained were analyzed statistically. The results of our study indicate highly significant relationship between hypertension and increase in IMTandRI [P<0.01] of CCA in hypertensive. The normotensive group however did not show any such increase in IMTandRI.

Pearson correlation test was used to show the relationship between blood pressures parameters [SBP, DBP and MAP] with IMT and RI values of CCA. However no significant relationship was found between the degree of hypertension and IMTandRI values of CCA.

The results of our study closely correlates with the results of the previous Indian study done by M Adaikkappan et al.in 2002.[11]They studied IMT of two hundred and sixty hypertensive patients over a period of three years and compared with seventy normotensive patients. They also studied the associated Doppler parameter changes along with IMT. They concluded that IMT is significantly elevated in hypertensive compared with normotensives. The mean value of IMT in hypertensive in their study was around 1.01mm and 1.09mm for the Right and Left sides respectively with P value of <0.01. In our study the mean IMT measurement in hypertensive was 0.95 and 0.94 with P value of <0.01, which is indicative of highly significant relationship. Their study also showed increase in resistive index in hypertensive patients compared to normotensives. Our study also showed similar increase in mean RI in hypertensivewith mean value of 0.77 with the P value of <0.01[highly significant] compared to normotensives. However in our study the resistive index of both hypertensive and normotensive groups were comparatively higher being 0.77 and 0.65 respectively. Our study showed significantly higher LDL cholesterol, total cholesterol and triglycerides levels in hypertensive, which was also seen in their study.

Our study also correlates with the study conducted by Srinivas Prasad R. H. in 2005.[12] They also found highly significant increase in intima media thickness and resistive index in hypertensive patients compared to the non hypertensive people with similar elevation of LDL cholesterol and triglycerides in the hypertensive group.

The role of hypertension in the development of LDL cholesterol and triglycerides mediated atherosclerosis measured by Common carotid artery IMT was confirmed by the study of Sun et al in 2000.[12] They observed that elevated LDL cholesterol and triglycerides were associated

with increased IMT in higher blood pressure after adjustment for the other risk factors. This supports the response-to-injury model of hypertension-induced atherosclerosis. Another explanation for the IMT thickening along with increased LDL cholesterol and triglyceride levels occurring in hypertensive was suggested to be adaptive thickening of the intima and the media.[13] Such thickening is characterized by remodeling to counteract the rise in wall tension observed as medial hypertrophy in the presence of hypertension. In contrast, maladaptive thickening involving monocyte recruitment and lipid accumulation in the intima occurs in the high BP tertile group, in which endothelial damage is more likely to be sufficient to initiate atherogenesis. These findings were supported in the ACAPS study, where the effect of the lipid-lowering lovastatin intervention was larger in hypertensive patients than in the nonhypertensive group.[12, 13] P Sharma, et al.,in their study also supported this study. The age of the study population ranged from 35 to 65 years. Mean IMT was significantly high in hypertensive patients compared to the control group, p< 0.001.[14]

Massimo Puatoet al. also found that in grade I hypertensive subjects, both mean IMT and mean of maximum IMT were significantly higher compared with baseline values. Compared with normotensive subjects, both mean IMT and maximum IMT increased significantly (at least P<0.01) in each carotid artery segment. The increase in cumulative IMT was 3.4 fold for mean IMT and 3.2fold for mean of maximumIMT.[15]

The Plavnik et al. also showed intima media complex (IMC) of common carotid artery and femoral artery to be thicker in hypertensive patients than in normotensive subjects.[16] Similar results were obtained earlier by Jiang et al.[17] and Labrova et al.[18] in their studies. Mechanisms by which hypertension predisposes to atherosclerosis may include endothelial dysfunction, hyperinsulinemia, hemodynamic stress, and multiple metabolic alterations. Impaired production of endothelium-derived relaxing factors and increased activity of endothelium-derived contractile substances have been demonstrated in hypertensive patients, preceding overt atherosclerotic disease.[19]

Vicenzini E et al.assessed CCA IMT, the CCA RI, and the presence of carotid plaques in 1655 consecutive patients and found that risk factors for atherosclerosis including hypertension were independently associated with higher IMT values and an increase in the RI, which is similar to our findings. They further found that synergic action of risk factors might cause further deterioration of mechanical forces independent of carotid atherosclerosis.[20] Anna Skalska et al. on multiple regression analysis study they found that IMT-CCA was significantly influenced by the age and SBP while RI was influenced by SBP and DBP.[21]

CONCLUSION

High-resolution sonography using high frequency transducers gives superb resolution of vessel wall layers so that all layers of the vessel wall namely, intima, media and adventitia can be clearly visualized. Increase in thickness of Intima media complex can be clearly visualized with high-resolution sonography and IMT can be accurately measured. Alteration in the vessel wall also causes alteration in hemodynamics of vascular system. Color Doppler gives accurate hemodynamic information within the blood vessels. RI is the widely studied hemodynamic parameter that shows alteration in its value along with IMT as the atherosclerosis progresses.

IMT thus gives morphological information and RI gives hemodynamic information in atherosclerosis of the blood vessels. Moreover when both parameters are studied together they are less prone for interobserver and intraobserver variability and will be more accurate. These parameters can be better studied in superficial arteries like carotid or femoral artery.

Conflict of interest: None declared.

Ethical clearance: Taken

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