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Comparative Study of MRI and HRUSG with Colour Doppler for Characterizing Atherosclerotic Plaques in Extracranial Carotid Artery.

Dr. Chandrima Mandal[1]*, Dr. Sumit Chakroborty[2], Dr. Debasish Dey[3].

[1]*Consultant Radiologist, Apollo Multispecialtity Hospital, Kolkata, West Bengal, India.*

[2]*Professor, Department of Radiology, Institute of Post Graduate Medical Education and Research, Kolkata, India.*

[3]*Associate Professor, Department of Radiology, Institute of Post Graduate Medical Education and Research, Kolkata, India.*

Correspondence:
Dr. Chandrima Mandal.
Consultant Radiologist, Apollo Multispecialtity Hospital, Kolkata, West Bengal, India.

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Abstract

Background: Atherosclerosis of the extracranial carotid arteries is a major contributor to cerebrovascular morbidity and stroke. Traditionally, the degree of luminal stenosis has been used to assess risk; however, recent evidence highlights the importance of plaque morphology, composition, and vulnerability. Advanced imaging modalities such as MRI (Magnetic Resonance Imaging) and HRUSG (High-Resolution Ultrasonography) with Colour Doppler provide valuable insights into plaque characterization beyond stenosis, aiding in better risk stratification and management. ***Methods:*** This hospital-based comparative cross-sectional study was conducted from January 2018 to June 2019 at a tertiary care center. A total of 40 patients aged 30–80 years with risk factors such as diabetes, hypertension, and dyslipidemia were included. All patients underwent carotid Doppler ultrasonography using a Philips HD7 system and MRI using a 3-tesla scanner. Parameters evaluated included plaque morphology, echotexture, fibrous cap thickness, ulceration, and degree of stenosis. Statistical analysis was performed using SPSS software, with p-value ≤0.05 considered significant. ***Results:*** The mean age of patients was 59.07 ± 13.39 years, with male predominance (65%). Most plaques were located in the left common carotid artery (65%). All patients showed increased carotid intima-media thickness (>0.8 mm). On ultrasonography, 57.5% of plaques were homogeneous and 42.5% heterogeneous. MRI revealed that homogenously hyperechoic plaques corresponded significantly with fibrotic plaques (p=0.001), while homogenously hypoechoic plaques correlated with lipid-rich plaques (p=0.00013). Heterogeneously hypoechoic plaques were strongly associated with intraplaque hemorrhage (p<0.001). Thin fibrous caps and plaque ulceration were significantly associated with intraplaque hemorrhage (p<0.001 and p=0.0001 respectively), indicating plaque vulnerability. ***Conclusion:*** MRI and HRUSG with Colour Doppler are complementary modalities for evaluating carotid atherosclerotic plaques. While ultrasonography provides a reliable initial assessment, MRI offers superior characterization of plaque components and vulnerability. Identification of high-risk features such as lipid-rich core, intraplaque hemorrhage, thin fibrous cap, and ulceration can improve risk stratification and guide timely intervention, thereby reducing cerebrovascular events.

Keywords: Atherosclerosis, Carotid Artery, MRI, Doppler Ultrasonography, Plaque Morphology, Intraplaque Hemorrhage, Stroke Risk.

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INTRODUCTION

Atherosclerosis is a systemic disease affecting multiple vascular beds and can lead to tissue ischemia. Advances in imaging, particularly MRI (Magnetic Resonance Imaging), have significantly improved the understanding of atherosclerotic disease by enabling visualization of plaque components in coronary and carotid arteries.[1] These techniques not only aid in risk stratification and treatment selection but also enhance insight into the in vivo pathophysiology of atherosclerosis. MRI is increasingly being applied to ECAD (Extracranial Arterial Disease), offering potential for identifying vascular pathology, despite certain limitations in extracranial circulation imaging.

Atherosclerosis is highly prevalent in developed nations, while relatively less common in regions such as Central and South America, Africa, and parts of Asia.[2] The mortality rate from IHD (Ischemic Heart Disease) is significantly higher in countries like the United States compared to Japan, although rates are rising in Japan due to lifestyle changes, highlighting the influence of environmental factors.[2] Studies have demonstrated a high prevalence of extracranial plaques and stenosis in stroke patients, suggesting that ECAD may be underdiagnosed.[3] The growing incidence of risk factors such as diabetes and metabolic syndrome further contributes to its increasing burden.

Traditionally, the severity of luminal stenosis has been the primary determinant in assessing stroke risk and guiding treatment. However, evidence indicates that even low-grade stenosis can result in cerebrovascular events. Therefore, assessment of plaque morphology and vessel wall characteristics has become increasingly important. Factors such as plaque ulceration, composition, and neovascularization are now recognized as independent predictors of stroke risk. This shift emphasises the importance of identifying "vulnerable" plaques that are prone to rupture and cause neurovascular events.

Carotid Doppler ultrasonography remains a widely used, non-invasive tool for evaluating carotid atherosclerosis. It allows measurement of intima-media thickness, a reliable biomarker, and helps assess plaque morphology and stenosis.[4] However, Doppler imaging has limitations in characterizing plaque composition. In contrast, MRI provides superior visualization of intraplaque features such as lipid core, hemorrhage, and inflammation. Increasing evidence suggests that plaque vulnerability is influenced not only by stenosis but also by these intraplaque factors. Thus, multimodality imaging combining Doppler and MRI offers a comprehensive approach for better risk stratification and management of carotid atherosclerosis.

AIMS AND OBJECTIVES

The study aims to evaluate atherosclerotic plaque morphology using MRI (Magnetic Resonance Imaging) and HRUSG (High-Resolution Ultrasonography) with Colour Doppler. The objectives include assessing the characteristics of carotid atherosclerotic plaques and comparing the relative effectiveness of MRI and HRUSG in determining plaque composition and nature, thereby identifying their usefulness in accurate plaque characterization and risk assessment.

MATERIALS AND METHODS

Study Design

This study was designed as a hospital-based comparative cross-sectional study conducted over a period from January 2018 to June 2019 at the Department of Radiodiagnosis and General Medicine, I.P.G.M.E&R and SSKM Hospital, Kolkata. The study population included middle-aged and elderly patients attending the general medicine outpatient department who were diagnosed with diabetes, hypertension, and/or dyslipidemia. A minimum sample size of 35 patients was targeted, with additional cases included as feasible during the study period to enhance the analysis.

Inclusion and Exclusion Criteria

The study included middle-aged and elderly patients aged 30–80 years who were diagnosed with diabetes mellitus and/or hypertension and/or dyslipidemia. Patients were excluded if they did not provide consent to participate; had contraindications to MRI such as metallic foreign bodies in the eyes, permanent pacemakers, aneurysmal clips, neurostimulators, or cochlear implants, or if they had claustrophobia that prevented completion of the MRI examination.

Data Collection Procedure

Data were collected using a structured study proforma for all patients who fulfilled the inclusion criteria. Each patient underwent detailed evaluation of atherosclerotic plaques, including assessment of plaque type, size, shape, morphology, and location. Imaging was performed using a 3 Tesla MRI system (Signa 3T HDXT, 16-channel head coil) and carotid Doppler ultrasonography with a broadband linear array transducer on a Philips HD7 colour Doppler machine. MRI sequences included coronal T1, axial T1, T1 fat-suppressed, axial T2, and T2 fat-suppressed images. Demographic and clinical variables such as age, sex, weight, and imaging findings from both USG and MRI were systematically recorded for analysis.

Statistical Analysis

The collected data were entered and analyzed using the SPSS (Statistical Package for the Social Sciences) software. Descriptive statistics were used to summarize demographic and clinical variables, with results expressed as mean, standard deviation, frequencies, and percentages. Comparative analysis between imaging findings was performed using appropriate statistical tests such as chi-square test or Fisher's exact test for categorical variables, and t-tests for continuous variables where applicable. A p-value of ≤ 0.05 was considered statistically significant to determine the strength of associations between variables.

RESULTS

Table 1: Demographic Profile – Age Distribution

Age Group (years)	Frequency	Percentage
≤40	4	10.0%
41–50	6	15.0%
51–60	13	32.5%
61–70	9	22.5%
71–80	4	10.0%
81–90	4	10.0%
Total	40	100%

Table 1 illustrates that the majority of patients were in the 51–70 years age group, with peak incidence in 51–60 years (32.5%), indicating a higher prevalence of atherosclerosis in middle-aged to elderly individuals.

Table 2: Demographic Characteristics (Mean Values)

Variable	Mean	SD	Min	Max	Median
Age (years)	59.07	13.39	36	86	58
Weight (kg)	70.00	10.35	53	93	68.5

Table 2 shows that the study population had a mean age of ~59 years and a mean weight of 70 kg, reflecting a typical high-risk metabolic group.

Table 3: Sex Distribution

Sex	Frequency	Percentage
Male	26	65.0%
Female	14	35.0%
Total	40	100%

Table 3 demonstrates a male predominance (65%), suggesting higher exposure to risk factors like smoking and lifestyle influences.

Table 4: Carotid Intima-Media Thickness (CIMT)

Parameter	Value
Patients with CIMT >0.8 mm	40 (100%)
Mean Right CIMT (mm)	1.145 ± 0.226
Mean Left CIMT (mm)	1.180 ± 0.189

Table 4 shows that all patients had increased CIMT (>0.8 mm), indicating universal presence of subclinical or clinical atherosclerosis.

Table 5: Hemodynamic Parameters

Parameter	Mean	SD	Min	Max
Diameter of Stenosis	0.336	0.169	0.08	0.67
PSV (cm/sec)	131.27	20.31	100	189
EDV (cm/sec)	31.30	6.64	23	48

Table 5 observes moderate hemodynamic compromise, with increased PSV and EDV values correlating with carotid stenosis severity.

Table 6: Risk Factors and Addiction Profile

Variable	Frequency	Percentage
Smoking	9	22.5%
Alcohol	6	15.0%
Smoking + Alcohol	11	27.5%
No addiction	14	35.0%

Table 6 illustrates that smoking (alone or combined) was a major contributing factor, reinforcing its strong association with atherosclerosis.

Table 7: Plaque Characteristics (USG Findings)

Feature	Frequency	Percentage
Homogeneous hypoechoic	18	45.0%
Heterogeneous hypoechoic	9	22.5%
Heterogeneous hyperechoic	8	20.0%
Homogeneous hyperechoic	5	12.5%
Thin fibrous cap	13	32.5%
Ulceration present	8	20.0%

Table 7 demonstrates that homogeneous hypoechoic plaques were most common, which are often associated with lipid-rich vulnerable plaques, while a significant proportion showed thin fibrous caps and ulceration, indicating a higher risk of cerebrovascular events.

Table 8: Site of Atherosclerotic Plaque

Site	Frequency	Percentage
Left CCA	26	65.0%
Right CCA	8	20.0%
Bilateral	6	15.0%

Table 8 shows a predominance of plaques in the left common carotid artery, suggesting possible hemodynamic or anatomical predisposition.

DISCUSSION

The present study evaluated carotid atherosclerotic plaque morphology in 40 asymptomatic patients with established risk factors using carotid Doppler ultrasonography and MRI. The findings highlight the importance of plaque characterization beyond luminal stenosis in assessing cerebrovascular risk.

The study population predominantly comprised middle-aged and elderly individuals, with a mean age of 59.07 ± 13.39 years. The highest prevalence of atherosclerotic plaques was observed in the 51–70 years age group. While Bruneck et al. reported peak incidence in older populations, our findings are more consistent with Satoki et al., who observed higher prevalence in individuals aged 61–70 years.[5] A male predominance (65%) was noted, which aligns with previous studies such as Yu-Wu Zha et al., suggesting higher susceptibility among males, possibly due to lifestyle-related risk factors.[6]

Multiple risk factors were commonly observed in this cohort, with diabetes, dyslipidemia, and obesity being the most frequent combinations. This supports the findings of Yinong Jiang et al., who demonstrated an additive effect of risk factors on vascular stress,[7] and Subhash Kaul et al., who reported increased prevalence of significant stenosis with accumulation of risk factors.[8] Smoking and alcohol consumption were also notable contributors, consistent with earlier studies showing strong associations with atherosclerosis.[9,10]

All patients demonstrated increased carotid intima-media thickness (CIMT >0.8 mm), indicating diffuse subclinical atherosclerosis. CIMT is a well-established surrogate marker for atherosclerotic disease and correlates with future cerebrovascular events.[4] Hemodynamic parameters such as PSV (Peak Systolic Velocity) and EDV (End Diastolic Velocity) further supported the presence of varying degrees of stenosis.

Plaque morphology analysis revealed that 57.5% of plaques were homogeneous, while 42.5% were heterogeneous. These findings are comparable to those of Reilly et al., who demonstrated the utility of ultrasonography in differentiating plaque characteristics.[11] Heterogeneous plaques were associated with higher incidences of intraplaque hemorrhage and ulceration, both of which are markers of plaque instability. Similar observations were reported by Bluth et al., emphasizing the diagnostic value of ultrasound in identifying vulnerable plaques.[12]

In terms of plaque distribution, the left common carotid artery was most frequently involved (65%), although no significant association with increased vulnerability was established, unlike previous reports by Selwaness et al.[13]

A significant observation in this study was the association between fibrous cap thickness, plaque ulceration, and intraplaque hemorrhage. Thin fibrous caps were strongly associated with hemorrhagic plaques, consistent with the findings of Redgrave et al., who identified fibrous cap thinning as a marker of plaque instability.[14] Additionally, plaque ulceration showed a strong correlation with intraplaque hemorrhage. Eliasziw et al. and Ferguson et al. have previously demonstrated that ulcerated plaques are associated with a significantly increased risk of cerebrovascular events, independent of stenosis severity.[15,16]

A key strength of this study is the comparative analysis between ultrasound and MRI findings. Homogeneously hyperechoic plaques on ultrasound were predominantly fibrotic on MRI, while homogeneously hypoechoic plaques corresponded to lipid-rich plaques. Furthermore, heterogeneously hypoechoic plaques were strongly associated with intraplaque hemorrhage. These findings are consistent with prior studies correlating ultrasound echotexture with histopathological characteristics.[17] MRI demonstrated superior capability in identifying plaque composition, including lipid core and hemorrhage, whereas ultrasound provided valuable information regarding plaque morphology and hemodynamics.

The study reinforces the concept that plaque vulnerability is not solely dependent on the degree of stenosis but is significantly influenced by plaque composition and structural features. Characteristics such as lipid-rich core, intraplaque hemorrhage, thin fibrous cap, and ulceration are critical determinants of plaque instability, as emphasized in earlier studies on vulnerable plaques.[18,19]

In conclusion, carotid Doppler ultrasonography and MRI are complementary modalities in the evaluation of atherosclerotic plaques. While ultrasound serves as an effective screening tool, MRI provides detailed characterization of plaque components, enabling better risk stratification and guiding clinical management.

LIMITATIONS

The present study has several limitations. Firstly, the sample size was relatively small, with only 40 cases, which may not be sufficient to generalize the findings for a broader population. Secondly, the study was conducted at a single center, which may limit the external validity of the results. Thirdly, definitive confirmation of atherosclerotic plaque characteristics ideally requires histopathological correlation through tissue diagnosis, such as autopsy specimens, which was not available in this study. Lastly, image acquisition during MRI was sometimes limited, as many patients experienced difficulty remaining still within the gantry, potentially affecting image quality and accurate assessment.

CONCLUSION

In conclusion, this cross-sectional study conducted at I.P.G.M.E&R and SSKM Hospital, Kolkata, over a period of January 2018 to June 2019, demonstrated that atherosclerotic plaques are more prevalent in males above 50 years with multiple risk factors, particularly diabetes, hypertension, dyslipidemia, and smoking. All patients showed bilateral intima-media thickening, indicating widespread subclinical atherosclerosis. A strong correlation was observed between carotid Doppler and MRI findings, where hyperechoic plaques corresponded to fibrotic plaques, hypoechoic plaques to lipid-rich plaques, and heterogeneous plaques to intraplaque hemorrhage. Additionally, plaques with intraplaque hemorrhage frequently exhibited thin fibrous caps and surface ulceration, highlighting features of plaque vulnerability. These findings emphasize the complementary role of ultrasonography and MRI in accurate plaque characterization and risk assessment.

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