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Original Research Paper

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# COMPARATIVE EVALUATION OF DOPPLER ULTRASOUND AND MAGNETIC RESONANCE IMAGING IN THE ASSESSMENT OF CAROTID ARTERY STENOSIS AND PLAQUE CHARACTERISTICS: A CROSS-SECTIONAL OBSERVATIONAL STUDY

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## ABSTRACT

**Background:** Carotid artery stenosis is a major risk factor for ischemic stroke. Early and accurate evaluation of stenosis severity and plaque vulnerability is essential to guide management. Doppler ultrasound is widely used as the first-line tool due to its accessibility, while magnetic resonance imaging (MRI) offers superior soft tissue characterization. A comparative assessment of these modalities can optimise diagnostic precision. **Aim:** To compare and evaluate steno-occlusive disease of the carotid artery using high-resolution Doppler ultrasound and MRI, focusing on stenosis grading and plaque characterization. **Methods:** A hospital-based, comparative, cross-sectional observational study was conducted in the Department of Radiodiagnosis at Sri Aurobindo Medical College & Postgraduate Institute, Indore, from July 2023 to December 2024. Fifty patients with clinical suspicion of carotid artery stenosis underwent both Doppler ultrasound and MRI. Data included demographic details, comorbidities, and imaging findings. Stenosis severity and plaque features (ulceration, intraplaque haemorrhage, neovascularisation) were compared. Digital subtraction angiography (DSA) was used as a reference. Statistical analysis was performed using Stata version 17.0. **Results:** The mean carotid stenosis was 56.6% on Doppler, 59% on MRI, and 61% on DSA. Doppler slightly underestimated stenosis severity compared to DSA, while MRI values closely matched DSA. Moderate stenosis was most common (55% Doppler, 62% MRI, 61% DSA). Severe stenosis was overestimated by Doppler (24%) compared to MRI (17%) and DSA (19%). MRI demonstrated higher sensitivity, while Doppler showed better specificity. Both modalities showed excellent agreement in detecting plaque neovascularisation (31%) and intraplaque haemorrhage (24%), with statistically significant concordance ($p < 0.0001$). **Conclusion:** Doppler ultrasound remains a reliable, accessible first-line tool for assessing carotid stenosis and plaque vulnerability. MRI offers higher diagnostic accuracy, particularly in grading stenosis and characterising high-risk plaques. Combined use of Doppler and MRI improves diagnostic confidence and can guide appropriate management to reduce stroke risk.

**KEYWORDS :** Carotid artery stenosis; Doppler ultrasound; Magnetic resonance imaging; Plaque vulnerability; Intraplaque haemorrhage; Neovascularisation; Stroke risk; Diagnostic accuracy

## INTRODUCTION

Carotid artery stenosis is a significant risk factor for ischemic stroke, a leading cause of morbidity and mortality worldwide(1,2). Early diagnosis and accurate assessment of stenosis severity and plaque vulnerability are essential for effective risk stratification and timely intervention(1,2). Current diagnostic tools, such as Doppler ultrasound and magnetic resonance imaging (MRI), play critical roles in evaluating carotid artery disease, but each has inherent limitations that necessitate a comparative approach to achieve optimal diagnostic accuracy.

Doppler ultrasound is widely used as the initial modality for carotid artery assessment due to its cost-effectiveness, accessibility, and non-invasive nature. It allows for real-time evaluation of blood flow velocities and provides insights into stenosis severity(3). However, it is operator-dependent and has limitations in visualizing distal segments and plaque morphology. In cases where stenosis is moderate or plaques are calcified, Doppler findings may be inconclusive or imprecise. MRI, on the other hand, provides superior soft tissue contrast and allows for detailed characterization of plaque components, such as lipid cores, fibrous caps, and intraplaque hemorrhage(4). It can identify features of plaque vulnerability, which are critical for predicting future cerebrovascular events. However, MRI is more expensive, time-consuming, and may not be feasible for all patients due to contraindications like metallic implants or claustrophobia. A comparative evaluation of Doppler ultrasound and MRI can provide a comprehensive diagnostic approach that leverages the strengths of both modalities. Accurate diagnosis of carotid artery stenosis and plaque vulnerability is critical for determining appropriate treatment strategies. Patients with high-grade stenosis or vulnerable plaques may benefit from surgical interventions such as carotid endarterectomy (CEA) or carotid artery stenting (CAS)(5). Conversely, patients with stable plaques and low-grade stenosis may be managed conservatively with medical therapy and lifestyle modifications.

A comparative evaluation of Doppler ultrasound and MRI can improve diagnostic precision, enabling clinicians to tailor interventions based on a comprehensive understanding of stenosis severity and plaque characteristics.

### Aim

To compare and evaluate the steno-occlusive disease of the carotid artery using high-resolution Doppler ultrasound and magnetic resonance imaging (MRI) in terms of stenosis grading and plaque characterization.

## MATERIAL AND METHODS

- **Study Design:** A single centre, hospital-based, comparative, cross-sectional observational study.
- **Study Setting:** Department of Radiodiagnosis at Sri Aurobindo Medical College & Postgraduate Institute, Indore.
- **Ethical Clearance:** The study protocol, including the data collection form and informed consent form, underwent a thorough review by the Institute's Ethical Committee to ensure ethical soundness and adherence to research guidelines.
- **Study Duration:** 18 months: July 2023 to December 2024.
- **Study Participants:** The participants for the present study were patients with clinical suspicion of carotid artery stenosis who underwent imaging evaluation.

### Inclusion Criteria:

1. Patients of any age and sex with clinical suspicion of carotid artery stenosis.
2. Patients referred for Doppler ultrasound and MRI evaluation of the carotid arteries.
3. Patients who provided written informed consent to participate in the study.

**Exclusion Criteria:**

1. Patients who did not give consent to participate in the study.
2. Patients who did not undergo both Doppler ultrasound and MRI imaging.
3. Patients with contraindications for MRI (e.g., metallic implants, severe claustrophobia).
4. Patients with incomplete imaging data or poor-quality scans that hinder accurate evaluation.

- **Sample Size:** a total of 50 participants (100 observations; 50 of right and left side) were enrolled in the present study.
- **Sampling Methodology:** A non-probability convenience sampling method was used for this study.
- **Data Collection Procedure:** The data collection for this study followed a systematic and stepwise process to ensure accuracy, completeness, and ethical compliance. The procedure was carried out in the following sequential steps:

1. **Obtaining Informed Consent:** Eligible patients presenting with clinical suspicion of carotid artery stenosis were identified in the Department of Radiodiagnosis at Sri Aurobindo Medical College & Postgraduate Institute, Indore. The principal investigator provided a detailed explanation of the study's purpose, procedures, potential benefits, and risks in a language the participants understood (Hindi or English). A bilingual consent form (Hindi and English) was presented to each participant.
2. **Demographic And Clinical Data Collection:** After obtaining consent, participants' demographic details, including name, age, sex, and hospital registration number, were recorded in a pre-structured data collection form. Clinical history was collected, including details of presenting symptoms, risk factors (e.g., hypertension, diabetes, smoking), and any previous history of cerebrovascular events such as transient ischemic attacks (TIA) or stroke.
3. **Doppler Ultrasound Examination:** High-resolution Doppler ultrasound was performed using the General Electric LOGIQ E9, F8 machine with a 7.5-15 MHz frequency linear probe. Both common carotid arteries (CCA), internal carotid arteries (ICA), and external carotid arteries (ECA) were evaluated.
4. **MRI Examination:** Following the Doppler ultrasound, participants were scheduled for MRI evaluation in the MRI suite. Participants were screened for contraindications (e.g., metallic implants, claustrophobia). MRI scans were performed using a Siemens 1.5 T MAGNETOM Symphony with Tim technology. Routine sequences included axial T1-weighted, axial/sagittal T2-weighted, and time-of-flight (TOF) magnetic resonance angiography (MRA) sequences.

- **Statistical Analysis:** Descriptive statistics, including means, standard deviations, and percentages, were used to summarize continuous and categorical data. The degree of stenosis was categorized based on standardized criteria, and the frequencies of different plaque characteristics (e.g., echogenicity, ulceration, intraplaque hemorrhage) were calculated for both Doppler ultrasound and MRI. For comparative analysis, the chi-square test was used to identify the association between the imaging modalities and categorical variables such as plaque morphology. The paired t-test was employed to compare continuous measurements of stenosis severity between Doppler ultrasound and MRI. A p-value of less than 0.05 was considered statistically significant.
- **Funding:** There was no external funding for this study.
- **Conflict Of Interest:** The authors declare no conflict of interest in the design, implementation, and interpretation of the findings of this study.

## RESULTS

**Table 1: Characteristics of Participants**

| Age Group | Freq. | Percent |
|---|---|---|
| 41-50 | 4 | 8.00 |
| 51-60 | 13 | 26.00 |
| 61-70 | 23 | 46.00 |
| 71-80 | 10 | 20.00 |
| **Gender** | **Freq.** | **Percent** |
| Female | 12 | 24.00 |
| Male | 38 | 76.00 |
| Comorbidity | | |
| Hypertension | 24 | 48.00 |
| Diabetes | 17 | 34.00 |
| **BMI Category** | | |
| Normal | 5 | 10.00 |
| Overweight | 17 | 34.00 |
| Obese | 20 | 40.00 |
| Morbid Obese | 8 | 16.00 |

A total of 50 patients (100 carotid arteries) were evaluated in this study. The majority of patients were in the 61–70 year age group (46%), followed by 51–60 years (26%). Males constituted 76% of the study population, while females accounted for 24%. Hypertension was the most common comorbidity, observed in 48% of participants, followed by diabetes in 34%. Regarding body mass index (BMI), 40% of participants were obese, 34% overweight, 16% morbidly obese, and only 10% were in the normal range (Table 1).

**Table 2: Plaque Characteristics and Intima Media Thickness**

| | Doppler | MRI |
|---|---|---|
| Intima Media Thickness | 0.96 (±0.23) | 0.95 (±0.23) |
| Length of Plaque | 10.3 (± 3.75) | 9.72 (±3.21) |

The comparison of plaque characteristics between Doppler ultrasound and MRI showed almost identical values for intima-media thickness (0.96 ± 0.23 mm on Doppler vs 0.95 ± 0.23 mm on MRI). Similarly, plaque length measurements were consistent (10.3 ± 3.75 mm on Doppler vs 9.72 ± 3.21 mm on MRI), indicating good agreement between the two modalities (Table 2).

**Table 3: Association of MRI and Doppler Findings**

| MRI | Doppler | | |
|---|---|---|---|
| | No | Yes | Total |
| Hemorrhage | 6 | 18 | 24 |
| | 7.32 | 100.00 | 24.00 |
| Ulceration | 4 | 26 | 30 |
| | 5.48 | 96.30 | 30.00 |

When comparing Doppler and MRI findings for plaque vulnerability features, MRI identified 24 cases of intraplaque haemorrhage, all of which were also detected by Doppler. Likewise, MRI detected 30 cases of plaque ulceration, which Doppler identified in 26 cases, showing high concordance between the two modalities (Table 3).

**Table 4: Carotid stenosis (%)**

| | Doppler | MRI | DSA |
|---|---|---|---|
| % Carotid stenosis | 56.6 (±16.7) | 59 (±17.1) | 61 (±16.1) |
| **Severity of Stenosis** | | | |
| Mild | 21.0 | 21.0 | 20.0 |
| Moderate | 55.0 | 62.0 | 61.0 |
| Severe | 24.0 | 17.0 | 19.0 |

The mean percentage of carotid stenosis was 56.6% on Doppler, 59% on MRI, and 61% on digital subtraction angiography (DSA). Distribution by severity revealed that mild stenosis was present in 21% of cases on both Doppler and MRI, and 20% on DSA. Moderate stenosis was the most common, observed in 55% (Doppler), 62% (MRI), and 61% (DSA). Severe stenosis was more frequently detected by Doppler (24%) compared to MRI (17%) and DSA (19%), indicating that Doppler may overestimate severe stenosis (Table 4).

## DISCUSSION:

This hospital-based, cross-sectional comparative study was conducted in the Department of Radiodiagnosis at Sri Aurobindo Medical College and Postgraduate Institute, Indore. The main objective was to compare the accuracy and diagnostic performance of Doppler ultrasound and MRI in grading stenosis and identifying features of vulnerable plaques such as ulceration, intraplaque haemorrhage, and neovascularisation.

In the present study, the mean percentage of carotid stenosis was 56.6% on Doppler, 59% on MRI, and 61% on digital subtraction angiography (DSA). These findings show that Doppler tends to slightly underestimate the degree of stenosis, while MRI provides values more closely aligned with DSA. This suggests that MRI may offer a more accurate non-invasive estimate of stenosis severity. Mittl et al., (1994) reported similar observations in their comparative study. MRI demonstrated higher sensitivity (92.4%) than Doppler (81.0%) in detecting significant carotid stenosis. Although Doppler had marginally better specificity (82.2% vs 74.5%), MRI correctly identified all complete occlusions, whereas Doppler missed one and misclassified two open vessels(6).

Clevert et al., (2006) also found that both modalities underestimated stenosis in the 70–90% range and occasionally overestimated lesions near total occlusion(7). They noted that pseudo-occlusions could be misread as complete occlusions on MRI. Nonetheless, the authors concluded that using both MRI and Doppler together improved diagnostic accuracy. Xiao et al., (2020) reported a higher sensitivity (0.957) and accuracy (0.974) for MRA compared to duplex sonography (sensitivity 0.935, accuracy 0.920), using catheter angiography as the reference(8).

In the present study, moderate stenosis was the most common grade detected across all modalities: 55% on Doppler, 62% on MRI, and 61% on DSA. Mild stenosis was noted in 21% of cases on both Doppler and MRI, and in 20% on DSA. Severe stenosis was recorded less frequently by MRI (17%) and DSA (19%) compared to Doppler, which showed 24%. These findings suggest that Doppler may overestimate the severity of stenosis in some cases, particularly at the severe end, while MRI more closely matches the DSA grading. Clevert et al., (2006) also reported that Doppler ultrasound can overrate high-grade stenosis, especially in haemodynamically unstable plaques or those with disturbed flow patterns. Their study found improved accuracy when Doppler findings were supplemented with MRI. This supports the current observation that Doppler may classify some moderate lesions as severe. Mittl et al., (1994) found that MRI matched catheter angiography more accurately in grading stenosis, particularly in differentiating between surgical and non-surgical lesions(6). Doppler occasionally misclassified moderate stenoses as severe, which may lead to overestimation of disease severity. These findings are consistent with the present study, where Doppler recorded the highest percentage of severe stenosis. Xiao et al., (2020) showed that although both MRA and Doppler had good sensitivity, MRA had higher diagnostic accuracy in assessing the degree of stenosis(8).

In the present study, neovascularisation was detected in 31% of cases on MRI. All of these cases were also identified by Doppler, showing 100% agreement. No false positives were noted on Doppler, and the association between Doppler and MRI findings was statistically significant ($\chi^2 = 62.78$, $p < 0.0001$). Clevert et al., (2006) reported similar findings using contrast-enhanced ultrasound to detect intraplaque neovascularisation. They found that neovascularisation seen on ultrasound strongly correlated with histological findings. The study also highlighted that duplex ultrasound, when done by skilled operators, could identify microvascular flow within plaques, supporting its utility in assessing plaque vulnerability (4,9). Although Mittl et al., (1994) and Xiao et al., (2020) did not directly assess plaque neovascularisation, their overall conclusions supported the value of Doppler in evaluating morphological plaque features.

In the present study, intraplaque haemorrhage was detected in 24% of cases on MRI. All 24 cases were correctly identified by Doppler, showing 100% agreement with no false positives. The association between the two modalities was statistically significant ($\chi^2 = 69.51$, $p < 0.0001$), indicating excellent concordance. This suggests that Doppler ultrasound, when performed with adequate expertise, can reliably detect intraplaque haemorrhage. Clevert et al., (2006) reported comparable findings using contrast-enhanced ultrasound(7).

Although other studies such as Mittl et al., (1994) and Xiao et al., (2020) did not directly examine plaque haemorrhage, Clevert et al.'s findings reinforce the results of the present study(6–8). The evidence confirms that Doppler ultrasound is not only useful for grading stenosis but also effective in detecting high-risk plaque features such as intraplaque haemorrhage with high diagnostic agreement when compared to MRI(5,10,11).

## CONCLUSION

This study demonstrates that both Doppler ultrasound and magnetic resonance imaging (MRI) are valuable modalities for the evaluation of carotid artery stenosis and plaque characteristics. Doppler ultrasound, being widely available, non-invasive, and cost-effective, remains a reliable first-line diagnostic tool, particularly for the detection of neovascularisation and intraplaque haemorrhage, where it showed excellent concordance with MRI. However, Doppler tended to slightly underestimate stenosis severity compared with digital subtraction angiography (DSA) and occasionally overestimated severe stenosis. MRI, with its superior soft tissue resolution, provided more accurate grading of stenosis and better alignment with DSA findings. It also offered detailed characterization of plaque vulnerability features, which are essential for risk stratification. The combined use of Doppler ultrasound and MRI enhances diagnostic accuracy, minimizes misclassification of stenosis severity, and provides a more comprehensive assessment of plaque morphology.

## REFERENCES:


1. Smith WS, Johnston SC, Hemphill J. Claude III. Ischemic Stroke. In: Loscalzo J, Fauci A, Kasper D, Hauser S, Longo D, Jameson JL, editors. Harrison's Principles of Internal Medicine, 21e [Internet]. New York, NY: McGraw-Hill Education; 2022. Available from: http://accessmedicine.mhmedical.com/content.aspx?aid=1207825211
2. Smith WS, Johnston SC, Hemphill J. Claude III. Introduction to Cerebrovascular Diseases. In: Loscalzo J, Fauci A, Kasper D, Hauser S, Longo D, Jameson JL, editors. Harrison's Principles of Internal Medicine, 21e [Internet]. New York, NY: McGraw-Hill Education; 2022. Available from: http://accessmedicine.mhmedical.com/content.aspx?aid=1199142923
3. Gómez-Marcos MA, Recio-Rodríguez JI, Rodríguez-Sánchez E, Patino-Alonso MC, Magallón-Botaya R, Martínez-Vizcaino V, et al. Carotid Intima-Media Thickness in Diabetics and Hypertensive Patients. Rev Española Cardiol (English Ed. 2011;64(7):622–5.
4. Chin SO, Hwang JK, Rhee SY, Chon S, Hwang YC, Oh S, et al. Risk Factors for the Progression of Intima-Media Thickness of Carotid Arteries: A 2-Year Follow-Up Study in Patients with Newly Diagnosed Type 2 Diabetes. Diabetes Metab J [Internet]. 2013 Oct 17;37(5):365–74. Available from: https://doi.org/10.4093/dmj.2013.37.5.365
5. Bang OY. Intracranial atherosclerosis: current understanding and perspectives. J stroke. 2014 Jan;16(1):27–35.

6. Mittl RL, Broderick M, Carpenter JP, Goldberg HI, Listerud J, Mishkin MM, et al. Blinded-Reader comparison of magnetic resonance angiography and duplex ultrasonography for carotid artery bifurcation stenosis. Stroke. 1994;25(1):4–10.
7. Clevert DA, Johnson T, Michaely H, Jung EM, Flach PM, Strautz TI, et al. High-grade stenoses of the internal carotid artery: Comparison of high-resolution contrast enhanced 3D MRA, duplex sonography and power Doppler imaging. Eur J Radiol. 2006;60(3):379–86.
8. Xiao L, Chu W, Wang H. Color-coded duplex sonography vs. 3.0 Tesla magnetic resonance angiography for detection of intracranial stenosis of the internal carotid artery: A prospective cohort study. Exp Ther Med. 2019;473–80.
9. Guo HJ, Li CC, Bian XY, Hao Q. Correlation study on the relationship between dyslipidemia and carotid intima-media thickness in patients with diabetes mellitus. Pakistan J Med Sci. 2023;39(3):875–9.
10. Zhang DF, Chen YC, Chen H, Zhang WD, Sun J, Mao CN, et al. A High-Resolution MRI Study of Relationship between Remodeling Patterns and Ischemic Stroke in Patients with Atherosclerotic Middle Cerebral Artery Stenosis. Front Aging Neurosci [Internet]. 2017;9. Available from: https://www.frontiersin.org/journals/aging-neuroscience/articles/10.3389/fnagi.2017.00140
11. Sanchez S, Mossa-Basha M, Anagnostakou V, Liebeskind DS, Samaniego EA. Comprehensive imaging analysis of intracranial atherosclerosis. J Neurointerv Surg. 2024;311–20.