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Comparative diagnostic value of carotid colour Doppler ultrasound and carotid magnetic resonance angiography in detecting carotid artery stenosis

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Abstract

Aim: To compare the diagnostic value of carotid colour Doppler ultrasound (CDO) and magnetic resonance angiography (MRA) in detecting carotid vascular stenosis, using digital subtraction angiography (DSA) as the gold standard. **Materials and methods:** A total of 120 patients admitted between January 2022 and December 2024 were divided into two groups of 60 based on the initial imaging modality. The CDO group underwent carotid CDO followed by DSA for suspected stenosis, while the MRA group received MRA first, with DSA performed for confirmed cases. DSA served as the reference standard. Stenosis severity was graded using NASCET criteria, and sensitivity, specificity, accuracy and agreement (Kappa) with DSA were calculated. **Results:** CDO showed excellent agreement with DSA (Kappa = 0.823), with 97.67% sensitivity, 88.24% specificity and 95.00% accuracy, demonstrating high consistency across all stenosis grades and occlusion. MRA showed moderate agreement with DSA (Kappa = 0.657), achieving 97.30% sensitivity, 65.22% specificity and 85.00% accuracy, with notable overestimation in mild stenosis. **Conclusion:** Both CDO and MRA are valuable non-invasive tools for evaluating carotid vascular stenosis. CDO is simple, cost-effective and suitable for large-scale screening, whereas MRA provides detailed vascular anatomy and is better suited for confirmatory assessment of complex lesions. Appropriate selection or combined use can improve diagnostic accuracy and clinical decision-making.

Keywords: carotid stenosis; magnetic resonance angiography; colour Doppler ultrasound; digital subtraction angiography

Introduction

Carotid vascular stenosis refers to the narrowing of arterial vessels in the neck, caused by various factors, which affects the blood supply to the brain. This condition has a high incidence rate among people over 50 and is one of the leading causes of ischemic encephalopathy [1]. Without timely and effective treatment, carotid vascular stenosis may lead to severe consequences, including stroke and death. Therefore, early diagnosis and accurate assessment of carotid vascular stenosis are crucial for ensuring patient safety and improving prognosis. Currently, digital subtraction angiography (DSA) is considered the gold standard for diagnosing carotid vascular stenosis. However, its invasive nature and high cost limit its clinical application [2]. Consequently, developing a non-invasive, cost-effective diagnostic method has become particularly important. Carotid colour Doppler ultrasound (CDO) and magnetic resonance angiography (MRA) are two standard non-invasive examination methods [3,4] widely used in screening and diagnosis of carotid vascular stenosis due to their simplicity, radiation-free operation and good repeatability. However, controversy remains regarding the diagnostic value of these methods in carotid vascular stenosis. This study aims to compare the accuracy and clinical value of carotid CDO and MRA

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in diagnosing carotid vascular stenosis using DSA results as the gold standard.

Materials and methods

This study enrolled patients who underwent carotid CDO or neck MRA examinations at our hospital between January 2022 and December 2024, with stenosis findings confirmed through DSA. Patients were divided into two independent groups based on examination methods: Group 1 (carotid CDO group) included 60 patients initially evaluated with carotid ultrasound, followed by DSA confirmation if stenosis was suspected. Group 2 (neck MRA group) comprised 60 patients who were initially assessed with neck MRA, followed by DSA confirmation when stenosis was identified. *Inclusion criteria*: Age ≥18 years; Presence of one or more vascular risk factors, including hypertension, diabetes, or hyperlipidemia; Informed consent and agreement to participate. *Exclusion criteria*: Severe cardiac, hepatic, or renal insufficiency; Severe coagulation disorders; Presence of metal implants or contraindications to MRI; Inability to complete examinations.

This study protocol was approved by the Ethics Committee of Lixin County People's Hospital, Bozhou, Anhui, 236702, China (Reg. 2021/11/MRH/5623)

Carotid CDO examination

CDO examinations are performed using equipment such as Samsung HERAX W9, Mindray DC-8, Philips EPIQ 5G and Acuson 2000 systems. These devices are equipped with 5-12 MHz ultra-wideband linear array probes and 2-5 MHz convex array probes, administered by specialised ultrasound physicians. Patients are required to lie flat during the examination to optimise neck exposure for detailed imaging. The procedure sequentially examines the major vessels, including the common carotid, internal, and external carotid arteries, to assess vascular health. This includes detecting plaque formation and evaluating its size, shape and location. Colour Doppler flow imaging (CDFI) was used to determine potential stenosis; the absence of blood flow signals indicates a possible arterial occlusion.

Carotid MRA examination

The MRA examination was performed using the Achieve 1.5T superconducting MRI imaging system. Before undergoing carotid contrast-enhanced magnetic resonance angiography (CE-MRA), coronal, sagittal and axial scans were performed to obtain baseline information on brain structure. The scan parameters were set as follows: TR (repetition time): 1.65 ms, TE (echo time): 1.37 ms, matrix acquisition: 256×256, matrix field of view: 330mm and slice thickness: 0.9mm. A three-dimensional time-of-flight (3D TOF) technique was employed for cerebral artery angiography. The absence of vascular visualisation on MRA may indicate arterial occlusion.

DSA check-up

A Siemens AXIOM dTA angiography system was used for DSA. The patient lay flat on the examination table for femoral or radial artery puncture. The puncture site was routinely disinfected and sterile drapes were applied. Local anesthesia with 2% lidocaine was administered to minimise discomfort during the procedure. The Seldinger technique was employed for femoral or radial artery puncture – a standard vascular access method that reduces the risk of complications. After successful puncture, a 5F catheter sheath was placed to provide access for subsequent procedures. Using a guidewire, a 5F pigtail catheter was inserted through the sheath into the aortic arch for carotid angiography. The catheter was then switched to perform imaging of the subclavian artery and vertebral artery on both sides to detect stenosis, plaques, or occlusions. When arterial narrowing was identified, the stenosis rate was calculated to assess severity. Plaque morphology and potential complications, such as ulceration, were documented. Following all necessary imaging, the catheter and sheath were carefully withdrawn, with appropriate compression applied to prevent bleeding or hematoma formation.

Image analysis

All CDO, neck MRA and DSA images were independently reviewed by experienced imaging physicians and neurologists. Interpreters had access to patients' basic clinical information, and image interpretation was not blinded between imaging modalities. Stenosis assessment and grading were performed strictly according to standardized NASCET criteria to minimize subjective bias.

Diagnostic criteria

According to the North American Symptomatic Carotid Endarterectomy Trial (NASCET) criteria [5], vascular stenosis severity is classified into four categories: 1) Mild stenosis (<50%); 2) Moderate stenosis (50%-69%); 3) Severe stenosis (70%-89%); and 4) Complete occlusion (90%-100%). Using DSA findings as the gold standard, diagnostic results from carotid Doppler ultrasound and neck MRA were compared with DSA outcomes.

Statistical analysis

Statistical analysis was performed using SPSS software. Numerical data were presented as mean ± standard deviation (x±s), with t-tests used for intergroup comparisons. Categorical data were expressed as percentages (%) and analysed through χ^2-tests. The kappa consistency test was used to evaluate agreement among carotid CDO,

Table I. Comparison of baseline clinical and biochemical characteristics between the carotid colour Doppler ultrasonography (CDO) and carotid magnetic resonance angiography (MRA) groups.

Variable	CDO group (n = 60)	Carotid MRA group (n = 60)	Statistic	p-value
Sex (male/female)	39/21 (65.00% / 35.00%)	37/23 (61.67% / 38.33%)	$\chi^2 = 0.234$	0.465
Age (years)	62.53 ± 10.53	62.07 ± 10.05	$t = 0.684$	0.123
Vascular risk factors			$\chi^2 = 0.725$	0.435
Smoking	25 (41.67%)	24 (40.00%)	—	—
Alcohol consumption	12 (20.00%)	11 (18.33%)	—	—
Hypertension	38 (63.33%)	36 (60.00%)	—	—
Coronary heart disease	11 (18.33%)	10 (16.67%)	—	—
Hyperlipidaemia	41 (68.33%)	39 (65.00%)	—	—
Carotid artery stenosis	35 (58.33%)	34 (56.67%)	—	—
IMT thickening	47 (78.33%)	46 (76.67%)	—	—
Biochemical indicators			$t = 0.654$	0.425
Blood glucose (mmol/L)	6.33 ± 2.71	6.23 ± 2.67	—	—
Total cholesterol (mmol/L)	5.12 ± 1.47	4.91 ± 1.21	—	—
Triglycerides (mmol/L)	2.01 ± 1.48	1.94 ± 1.35	—	—
HDL-cholesterol (mmol/L)	1.13 ± 0.39	1.05 ± 0.29	—	—
LDL-cholesterol (mmol/L)	3.04 ± 1.26	2.96 ± 1.08	—	—

neck MRA, and DSA. A kappa value >0.75 indicates good agreement, while $p<0.05$ signifies statistically significant differences.

Results

Clinical characteristics of patients

A total of 120 patients were included in the study, with 60 patients in the CDO group and 60 patients in the carotid MRA group. The baseline demographic and clinical characteristics of the two groups are summarised in Table I. The sex distribution was similar between groups, and the mean age was also comparable. No statistically significant differences were observed in vascular risk factors, including smoking, alcohol consumption, hypertension, coronary heart disease, hyperlipidemia, carotid artery stenosis and intima–media thickness (overall hazard comparison, p=0.435). Similarly, biochemical indicators did not differ significantly between groups (p=0.425).

Carotid CDO examination

The diagnostic performance of CDO was evaluated against digital subtraction angiography (DSA), which served as the reference standard and the results are detailed in Table II. The results indicate a high degree of diagnostic agreement between CDO and DSA in detecting carotid artery stenosis.

The diagnostic performance of CDO was compared with DSA, the reference standard, for grading carotid artery stenosis and the results are detailed in Table III. The results indicate that CDO provides highly consistent results with DSA in detecting and grading carotid artery stenosis.

Table II. Comparison of positive and negative results of carotid colour Doppler ultrasound (CDO) and digital subtraction angiography (DSA) examination

CDO	DSA Check-up		Total
	Positive	Negative	
Positive	42	2	44
Negative	1	15	16
Total	43	17	60

Diagnostic performance of CDO (vs. DSA)
Sensitivity: 97.67% (95% CI: 87.7–99.9)
Specificity: 88.24% (95% CI: 63.6–98.5)
Accuracy: 95.00% (95% CI: 86.1–98.9)
Positive predictive value (PPV): 95.45% (95% CI: 84.5–99.4)
Negative predictive value (NPV): 93.75% (95% CI: 69.8–99.8)
95% CIs calculated using exact (binomial) methods.

Carotid MRA examination

Table IV presents the comparison of positive and negative case counts between neck magnetic resonance angiography (MRA) and digital subtraction angiography (DSA). The results indicate that neck MRA is highly sensitive for detecting carotid artery stenosis but shows relatively lower specificity, mainly due to overestimation in some negative cases.

Table V evaluates the diagnostic consistency between carotid MRA and DSA in assessing the severity of carotid artery stenosis. The results indicate that neck MRA shows good consistency with DSA in grading carotid

Table III. Assessment of carotid colour Doppler ultrasonography (CDO) and digital subtraction angiography (DSA) in assessing carotid artery stenosis

CDO	DSA Negative	DSA Mild	DSA Moderate	DSA Severe	DSA Complete occlusion	Total
Negative	15	1	0	0	0	16
Mild stenosis	1	2	0	0	0	3
Moderate stenosis	1	1	11	1	0	14
Severe stenosis	0	0	1	18	1	20
Complete occlusion	0	0	0	1	6	7
Total	17	4	12	20	7	60

artery stenosis. However, some discrepancies exist, particularly in cases of mild or moderate narrowing.

Discussion

Cerebral infarction, or ischaemic stroke, is a cerebrovascular condition that primarily affects older people and may be very dangerous to their lives if not treated quickly and well [6]. Numerous studies have demonstrated that arterial anomalies in the neck are a significant contributing factor to cerebral infarction [7]. Atherosclerosis, stenosis, or thrombosis in the carotid artery may cause poor blood flow to the brain, which can lead to a stroke [8]. So, it's incredibly crucial to have an accurate early diagnosis of carotid artery stenosis to halt and treat those who have had a cerebral infarction.

Imaging techniques are essential in diagnose cerebral infarction in real life. DSA remains the best method for detecting arterial stenosis in the neck [9]. DSA employs contrast agents administered into the blood arteries to provide comprehensive images that reveal anatomical features and the severity of stenosis [10,11]. But DSA is invasive, with high cost and technical difficulties [12]. CDO is a painless, radiation-free, highly accessible, and inexpensive technique and can be repeated how many times it needed. It shows anatomy of blood vessel walls, making it easy to identify vascular pathology [13]. However, caution is needed in complex cases [14]. MRA is a radiation-free imaging technique that uses specialised MRI sequences to produce three-dimensional vascular pictures, providing superior soft-tissue contrast and detailed anatomical visualisation [15]. However, MRA requires long scanning times, is more costly, and may be contraindicated in patients with metallic implants, while interpretation requires experienced radiologists [16].

The primary objective of this study was to evaluate the diagnostic accuracy and clinical value of two non-

Table IV. Comparison of positive and negative results of carotid magnetic resonance angiography (MRA) and digital subtraction angiography (DSA).

MRA	DSA check-up		Total
	Positive	Negative	
Positive	36	8	44
Negative	1	15	16
Total	37	23	60

Diagnostic performance of Neck MRA (vs. DSA)
Sensitivity: 97.30% (36/37; 95% CI: 85.8–99.9)
Specificity: 65.22% (15/23; 95% CI: 42.7–83.6)
Accuracy: 85.00% (51/60; 95% CI: 73.4–92.9)
Positive predictive value (PPV): 81.82% (36/44; 95% CI: 67.3–91.8)
Negative predictive value (NPV): 93.75% (15/16; 95% CI: 69.8–99.8)
95% confidence intervals were calculated using exact (binomial) methods.

Table V. Assessment between magnetic resonance angiography (MRA) and digital subtraction angiography (DSA) in assessing carotid artery stenosis

Neck MRA	DSA check-up					Total	Kappa	95% CI	p-value
	Negative	Mild narrowing	Moderate narrowing	Severe stenosis	Entirely shut				
Negative	15	1	0	0	0	16	0.657	0.653~0.828	< 0.001
Mild narrowing	5	0	3	0	0	8			
Moderate narrowing	3	0	7	1	0	11			
Severe narrowing	0	0	0	12	1	13			
Entirely shut	0	0	0	1	11	12			
Total	23	1	10	14	12	60			

Agreement analysis: Kappa = 0.657 (95% CI: 0.653–0.828), p<0.001

invasive methods – carotid CDO and neck MRA. The results demonstrated that carotid CDO performed exceptionally well in detecting carotid vascular stenosis, with high sensitivity (97.67%), specificity (88.24%), and accuracy (95.00%), and a low false-negative rate (2.33%). A strong agreement with DSA (Kappa = 0.823) confirms its reliability. As a simple, inexpensive and repeatable technique, CDO is ideal for mass screening and early detection. However, its specificity (88.24%) and misdiagnosis rate (11.76%) warrant confirmation of positive cases using additional modalities.

Neck MRA also demonstrated good diagnostic performance, with a sensitivity of 97.29%, a specificity of 65.22% and an accuracy of 85.00%. Despite a low false-negative rate (2.70%), the higher misdiagnosis rate (34.78%) may limit its routine use as a primary screening tool. The moderate concordance with DSA (Kappa = 0.657) suggests reliable diagnoses in most cases, although variability may occur. MRA excels in detailed anatomical evaluation and is especially valuable for assessing complex lesions [17].

This study provides a unique and clinically impactful comparison of carotid CDO and neck MRA using DSA as the reference standard in two matched patient groups. Unlike previous studies, which often rely on retrospective datasets or evaluate both modalities within the same cohort, the parallel-group design of this study reduces selection bias and better reflects real-world clinical practice. Comprehensive grading of stenosis using NASCET criteria offers deeper insight into the strengths and limitations of each modality, including the tendency of MRA to overestimate mild-to-moderate stenosis. The integration of multiple imaging techniques, detailed error analysis, and correlation with clinical and biochemical characteristics further enhances the validity of the findings. Nevertheless, CDO may have limitations in detecting severe stenosis or complete occlusion and is less effective than MRA in evaluating plaque characteristics [18]. In contrast, neck MRA provides superior visualization of vascular structures and plaques, particularly in cases of severe stenosis or occlusion, and has demonstrated higher sensitivity and specificity in several studies [19]. Therefore, in clinical practice, CDO should be prioritized for initial screening, with MRA recommended when ultrasound findings are inconclusive. For patients requiring intervention, DSA remains the definitive diagnostic modality. Carotid CDO and neck MRA demonstrated distinct and complementary diagnostic strengths. CDO showed excellent agreement with DSA and is well suited for initial screening, whereas MRA provides detailed vascular anatomy and is valuable for confirmatory assessment, particularly in complex or equivocal cases.

This study has several limitations. First, image interpretation was not fully blinded, as radiologists and clinicians had access to basic clinical information and were aware of the diagnostic workflow. Although standardized NASCET criteria were applied to minimize interpretation bias, the lack of complete blinding may have influenced diagnostic assessment. Future prospective studies with fully blinded image interpretation are warranted to further validate these findings.

Future studies should validate these results in larger, multicenter populations. Recent advances in MRA, including high-resolution black-blood imaging, contrast-enhanced techniques, and improved MRI hardware, may enhance diagnostic accuracy and reduce misclassification. The application of artificial intelligence for automated stenosis quantification represents a promising direction. Further investigation into the relationships among plaque composition, stability, and hemodynamics, as well as longitudinal studies linking imaging findings to stroke outcomes and cost-effectiveness, may further support optimized clinical decision-making.

Conclusion

CDO and neck MRA demonstrated distinct and complementary diagnostic strengths in the evaluation of carotid artery stenosis. In this study, carotid CDO showed excellent agreement with DSA, with high sensitivity, specificity, and overall diagnostic accuracy for detecting and grading stenosis. Neck MRA also exhibited very high sensitivity, but relatively lower specificity, primarily due to overestimation in mild-to-moderate stenosis. Considering diagnostic performance, accessibility, and clinical utility, an integrated, stepwise imaging approach – with carotid CDO for initial evaluation and MRA or DSA for confirmation and interventional planning – may optimize diagnostic accuracy and clinical decision-making.

Conflict of interest: none

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