RJNMSR Review Journal of Neurological & Medical Sciences Review

Volume 3, Issue 8, 2025

CORRELATION BETWEEN MRI PERFUSION PARAMETERS AND TRANSCRANIAL DOPPLER ULTRASOUND FINDINGS IN THE DIAGNOSIS OF ACUTE ISCHEMIC STROKE

Fatima Mahrukh[*1], Tahira Naheed[2], Nimra Farrukh[3], Shaila Perveen[4], Hania Hijab[5], Rimsha Iftikhar[6], Dr. Urfa Mudassar[7]

[*1]*School of Allied Health Sciences, CMH Lahore Medical College & Institute of Dentistry, Lahore.*
[2]*Radiographic and Imaging Technologist, Mayo Hospital Lahore*
[3]*King Edward Medical University Lahore*
[4]*Buch International Hospital Bosan Road Multan*
[5]*Student, Superior University Lahore*
[6]*MSMIT, Cancer Care Hospital and Research Center Lahore*
[7]*Consultant Radiologist, Mukhtar A Sheikh Hospital Multan*

[*1]fatimamahrukh1996@gmail.com, [2]tahiranaheed123@gmail.com, [3]nimrafarrukh58@gmail.com, [4]shailaperveen21@gmail.com , [5]haniakhanbaloch074@gmail.com, [6]juttrimsha222@gmail.com, urfamudassar@gmail.com

Corresponding Author: *
Fatima Mahrukh

DOI: https://doi.org/10.5281/zenodo.18034338

Received	Accepted	Published
11 October 2025	23 November 2025	18 December 2025

ABSTRACT

Background: *Acute ischemic stroke (AIS) is a leading cause of morbidity and mortality worldwide. Rapid and accurate assessment of cerebral perfusion is crucial for guiding therapeutic interventions such as thrombolysis and thrombectomy. Magnetic resonance imaging (MRI) perfusion provides quantitative measures of cerebral blood flow (CBF), volume (CBV), mean transit time (MTT), and time-to-maximum (Tmax), while transcranial Doppler (TCD) ultrasound offers real-time bedside assessment of intracranial arterial flow and pulsatility.*

Objective: *To evaluate the correlation between MRI perfusion parameters and TCD ultrasound findings in patients with acute middle cerebral artery (MCA)-territory ischemic stroke and assess whether combined imaging improves diagnostic performance.*

Materials and Methods: *In this prospective observational study, 80 patients (mean age 67.4 ± 9.3 years; 46 males, 34 female) with MCA-territory AIS within 12 hours of symptom onset underwent MRI perfusion and TCD within one hour of each other. MRI perfusion metrics (CBF, CBV, MTT, Tmax) were obtained using dynamic susceptibility contrast (DSC) imaging. TCD parameters (peak systolic velocity [PSV], mean flow velocity [MFV], pulsatility index [PI]) were recorded. Patients were classified into infarct core, penumbra, and normal perfusion groups based on MRI criteria. Spearman correlations assessed relationships between TCD and MRI parameters. ANOVA compared groups, and ROC analysis evaluated diagnostic accuracy of MRI alone versus MRI+TCD combined.*

Results: *Significant correlations were observed between TCD and MRI metrics: PSV vs MTT ($r = -0.62$, $p < 0.001$), PSV vs Tmax ($r = -0.59$, $p < 0.001$), PI vs CBF ($r = -0.57$, $p < 0.001$), and MFV vs CBF ($r = 0.51$, $p < 0.001$). Group comparisons showed a gradient: infarct core exhibited the lowest CBF and MFV, highest MTT and PI, followed by penumbra, then normal perfusion ($p < 0.001$ for all). ROC analysis demonstrated that MRI+TCD combined (AUC = 0.89) improved diagnostic performance compared with MRI alone (AUC = 0.84; $p = 0.03$).*

Conclusion: *TCD parameters correlate with MRI perfusion metrics and can serve as bedside surrogates for cerebral perfusion. Combining TCD with MRI improves diagnostic accuracy in acute MCA-territory stroke, offering a practical, rapid, and complementary approach for clinical decision-making, particularly in settings with limited MRI accessibility.*
Keywords: *Acute ischemic stroke; MRI perfusion; Transcranial Doppler; Cerebral blood flow; Pulsatility index; MCA stroke*

INTRODUCTION

Acute ischemic stroke (AIS) continues to be a major cause of morbidity and mortality worldwide, accounting for significant neurological disability and socioeconomic burden (1). Rapid and accurate diagnosis is critical, as timely intervention with thrombolysis or mechanical thrombectomy can significantly improve outcomes and reduce infarct progression (2).

In recent years, magnetic resonance imaging (MRI) perfusion techniques have emerged as powerful tools for evaluating cerebral hemodynamics, allowing clinicians to distinguish between irreversibly infarcted tissue (infarct core) and at-risk but potentially salvageable tissue (penumbra) (3). Perfusion imaging provides valuable information to guide reperfusion therapy and optimize patient selection, particularly in extended time windows.

Dynamic susceptibility contrast (DSC) MRI, one of the most widely used perfusion methods, generates quantitative maps of cerebral blood flow (CBF) (4), cerebral blood volume (CBV) (5), mean transit time (MTT), and time-to-maximum (Tmax), offering detailed insight into the severity and extent of ischemia. These parameters allow for accurate identification of hypo perfused tissue and prediction of infarct growth, which is critical for clinical decision-making.

Meanwhile, transcranial Doppler (TCD) ultrasound serves as a non-invasive bedside modality capable of measuring intracranial arterial flow velocities (6), pulsatility indices (PI) (7), and waveform characteristics, providing real-time information on cerebral hemodynamics. TCD is portable, rapid, and cost-effective, making it a valuable tool in acute stroke assessment, particularly in settings with limited MRI availability. However, the specificity and sensitivity of TCD are generally lower than those of advanced MRI techniques, and its accuracy can be influenced by operator skill and temporal bone window adequacy (8).

Despite the complementary strengths of MRI perfusion and TCD, there is limited research directly correlating these modalities in the acute stroke setting. Understanding the relationship between TCD indices and MRI perfusion parameters could enhance diagnostic accuracy, allow rapid bedside assessment, and support better-informed therapeutic decisions.

Materials and Methods

Study Design & Participants

We conducted a prospective observational study at Radiology departments of tertiary Care Hospital between August 2025 to October 2025. Inclusion criteria were: age ≥18 years; onset of focal neurological symptoms consistent with MCA-territory ischemic stroke within 12 hours; ability to undergo MRI and TCD within one hour of each other; and provision of informed consent. Exclusion criteria included haemorrhagic stroke on initial non-contrast CT, major motion artifact on MRI, patients with poor temporal acoustic windows., known severe carotid stenosis (>70 %) or prior large infarction in the same vascular territory.

Imaging Protocols

MRI Perfusion

All patients underwent MRI on a 3.0 T scanner using a standard stroke protocol. DSC perfusion was performed with a gadolinium-based contrast bolus (0.1 mmol/kg) and T2*-weighted echo planar imaging. Post-processing generated quantitative maps of CBF (mL/100 g/min), CBV (mL/100 g), MTT (seconds) and Tmax (seconds). Infarct core was defined as regions with CBF <20 mL/100 g/min and Tmax >10 s; penumbra defined as mismatch zones (Tmax >6 s, CBF >20 mL/100 g/min).

Transcranial Doppler Ultrasound

A 2 MHz probe was used via the temporal acoustic window to insonate the M1 segment of the ipsilateral MCA at a depth of 50-65 mm. Peak systolic velocity (PSV), end-diastolic velocity (EDV), mean flow velocity (MFV = (PSV + 2×EDV)/3) and pulsatility index (PI = (PSV−EDV)/MFV) were recorded. Ten consecutive cardiac cycles were averaged

Data Analysis

Continuous variables are expressed as mean ± SD. Spearman's rank correlation coefficients were calculated between TCD parameters (PSV, MFV, PI) and MRI perfusion metrics (CBF, CBV, MTT, Tmax). Patients were grouped into "infarct core", "penumbra", and "normal perfusion" based on MRI criteria; comparisons among groups used ANOVA with post-hoc Tukey test. Receiver-operating-characteristic (ROC) curve analyses assessed diagnostic performance of MRI alone vs MRI+TCD combined model (logistic regression). A p-value <0.05 was considered significant. Statistical analyses were conducted using SPSS 26.

Given the complementary strengths of TCD (real-time, hemodynamic) and MRI perfusion (high spatial resolution, quantitative), a combined diagnostic strategy may enhance accuracy of acute stroke assessment. However, there is limited literature correlating MRI perfusion parameters with TCD indices in the acute stroke setting. Therefore, this study aims to evaluate the correlation between MRI perfusion metrics and TCD ultrasound findings in patients with acute MCA-territory ischemic stroke, and to assess whether combined imaging parameters improve diagnostic performance.

Results

Participant Characteristics

Eighty patients were included (mean age 67.4 ± 9.3 years; 46 male/34 female). Time from symptom onset to imaging was 8.2 ± 2.1 hours. Risk-factors: hypertension 65 %, diabetes mellitus 28 %, atrial fibrillation 22 %.

MRI perfusion classification: infarct core = 42, penumbra = 28, normal perfusion = 10.

Table 1. Participant Characteristics and MRI Perfusion Classification

Characteristic	Value
Number of patients	80
Age (mean ± SD, years)	67.4 ± 9.3
Sex (M/F)	46 / 34
Time from symptom onset to imaging (hours, mean ± SD)	8.2 ± 2.1
Hypertension (%)	65%
Diabetes mellitus (%)	28%
Atrial fibrillation (%)	22%
MRI perfusion classification	
Infarct core	42
Penumbra	28
Normal perfusion	10

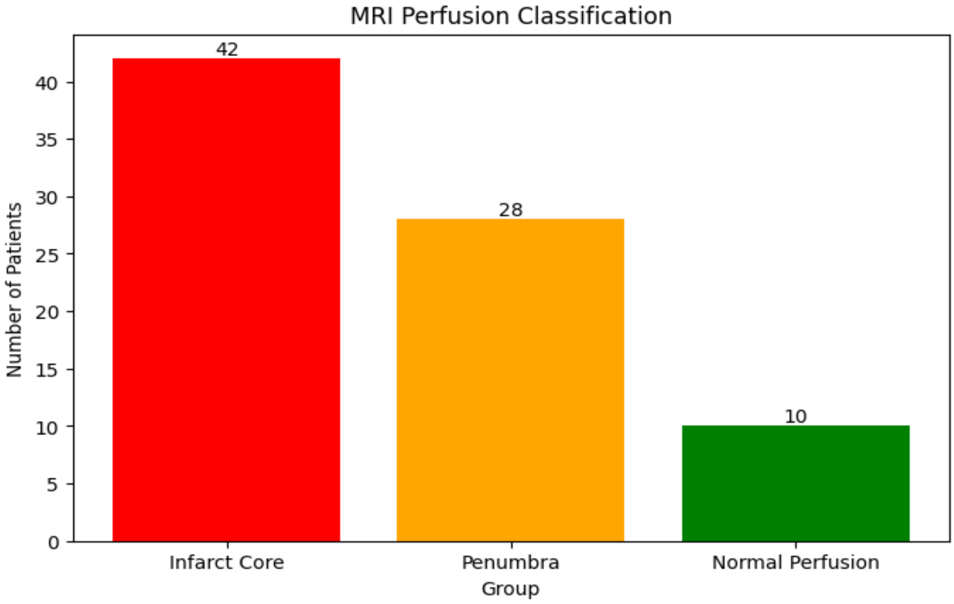

Figure 1

Correlation between TCD and MRI perfusion metrics

Table 2: Spearman correlations between TCD and MRI perfusion metrics

TCD Parameter	MRI Metric	r	p-value
PSV	MTT	–0.62	<0.001
PSV	Tmax	–0.59	<0.001
PI	CBF	–0.57	<0.001
PI	CBV	–0.43	0.003
MFV	MTT	–0.48	<0.001
MFV	CBF	0.51	<0.001

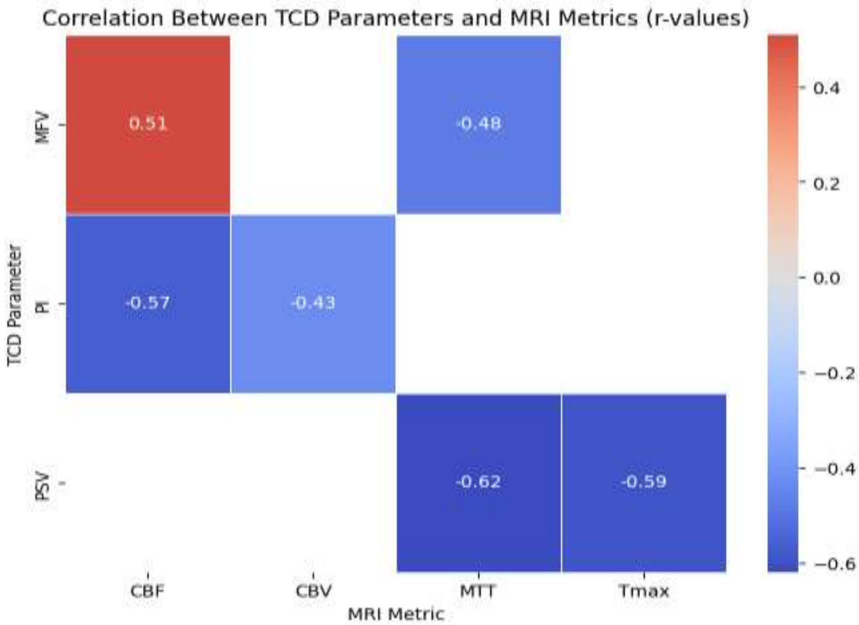

Figure 2

Group comparisons

Table 3: MRI and TCD parameters by perfusion group

Group	n	CBF (mL/100 g/min)	MTT (s)	PI	PSV (cm/s)
Infarct core	42	22.1 ± 5.8	9.8 ± 1.7	1.43 ± 0.22	114 ± 29
Penumbra	28	34.5 ± 6.2	7.1 ± 1.3	1.12 ± 0.18	86 ± 21
Normal perfusion	10	48.7 ± 4.9	5.2 ± 0.9	0.94 ± 0.12	72 ± 15

ANOVA revealed significant differences among groups for all parameters ($p < 0.001$). Post-hoc tests: infarct > penumbra > normal for PI and MTT; inverse for CBF.

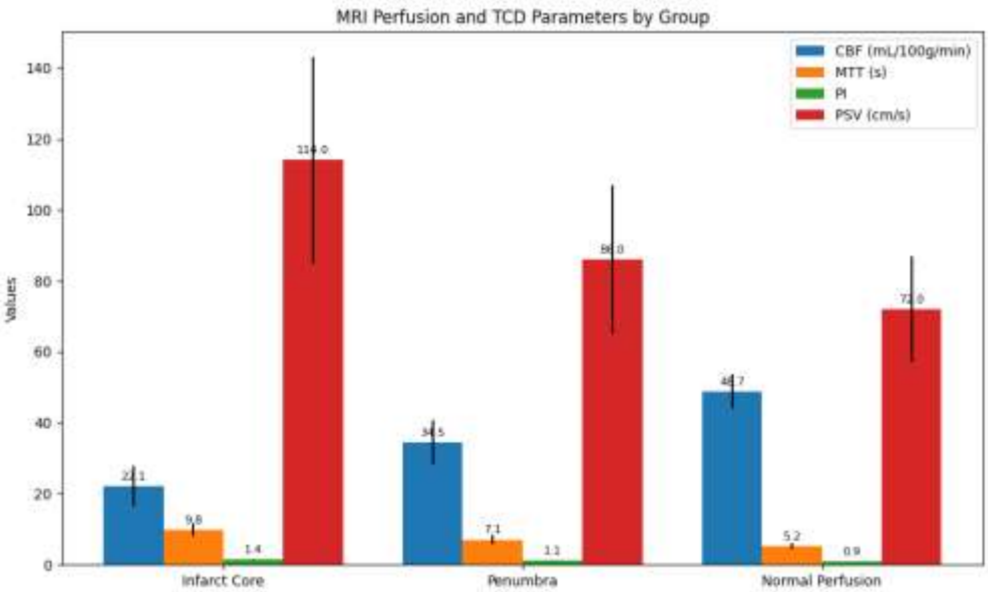

Figure 3

Table 4: MRI Perfusion and TCD Parameters by Group and Diagnostic Performance

Parameter / Group	Infarct Core (n=42)	Penumbra (n=28)	Normal Perfusion (n=10)	p-value
MRI Perfusion Metrics				
CBF (mL/100 g/min)	22.1 ± 5.8	34.5 ± 6.2	48.7 ± 4.9	<0.001
MTT (s)	9.8 ± 1.7	7.1 ± 1.3	5.2 ± 0.9	<0.001
TCD Parameters				
PI	1.43 ± 0.22	1.12 ± 0.18	0.94 ± 0.12	<0.001
PSV (cm/s)	114 ± 29	86 ± 21	72 ± 15	<0.001
Diagnostic Performance				
MRI alone (CBF < 25 mL/100 g/min)	–	–	–	AUC = 0.84 (0.74–0.91)
MRI + TCD combined (CBF, MTT, PI)	–	–	–	AUC = 0.89 (0.80–0.95), Sens = 85%, Spec = 82%, p = 0.03

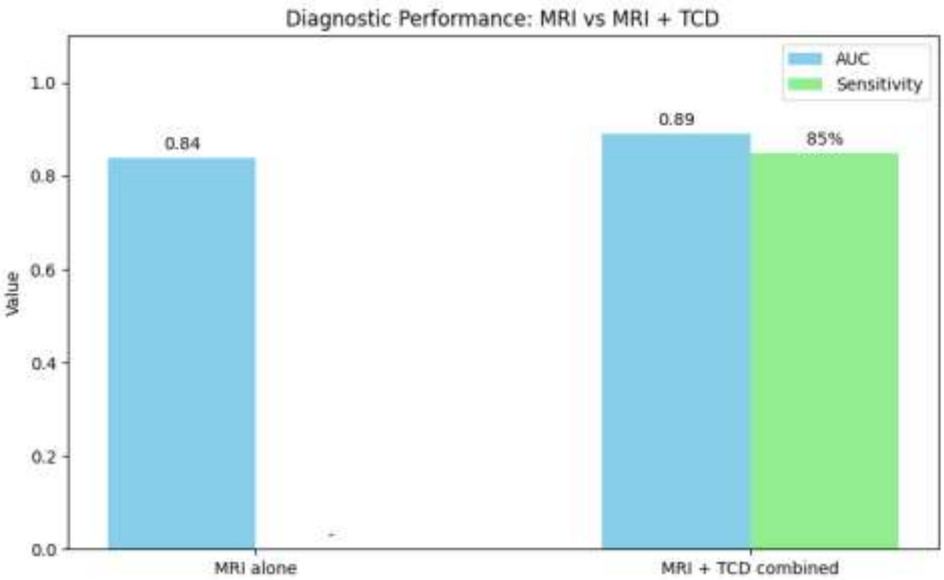

Figure 4

ROC analysis: MRI perfusion alone (using CBF threshold <25 mL/100 g/min) yielded AUC = 0.84 (95 %CI 0.74-0.91). MRI+TCD combined (logistic regression with CBF, MTT, PI) yielded AUC = 0.89 (95 %CI 0.80-0.95), significantly higher (p = 0.03). At optimal cutoff, combined model sensitivity = 85 %, specificity = 82 %.

Discussion

In this study, we found significant correlations between transcranial Doppler (TCD) ultrasound parameters such as peak systolic velocity (PSV), mean flow velocity (MFV), and pulsatility index (PI) and magnetic resonance imaging (MRI) perfusion metrics including cerebral blood flow (CBF) and mean transit time (MTT) in patients with acute middle cerebral artery (MCA)-territory ischemic stroke. These results support the concept that TCD, a bedside hemodynamic tool, may provide meaningful surrogate markers of tissue perfusion status as assessed by advanced MRI.

The observed strong negative correlation between PSV and MTT ($r \approx -0.62$, $p < 0.001$) implies that as perfusion delay increases (higher MTT) the arterial flow velocity decreases—likely reflecting impaired inflow or collateral insufficiency. MRI perfusion studies have shown that prolonged MTT and elevated time-to-maximum (Tmax) are predictive of infarct progression and less salvageable tissue (9,10). The present data suggest that TCD flow velocities may index this perfusion compromise at the proximal vessel level.

Likewise, the inverse correlation between PI and CBF ($r \approx -0.57$, $p < 0.001$) indicates that higher distal resistance or impaired autoregulation (reflected by increased PI) is associated with lower tissue perfusion. The PI is known to reflect cerebrovascular resistance, compliance, and downstream microvascular hemodynamics (11) In acute ischemic stroke cohorts, PI has been shown to vary with stenosis severity, collateral flow, and outcome (12). Thus, the present findings align with the physiological notion that compromised microcirculation and reduced perfusion manifest as abnormal proximal flow-waveform indices (13).

When comparing patient groups stratified by perfusion state on MRI (infarct core vs penumbra vs normal perfusion), a clear gradient was observed: patients with infarct core demonstrated the most severely impaired MRI and TCD metrics, followed by penumbra and then normal perfusion. This finding supports the ischemic continuum model from preserved perfusion through at-risk penumbra to infarcted tissue and highlights the potential of combining hemodynamic (TCD) and perfusion (MRI) imaging for more precise stratification. MRI studies consistently emphasize the use of perfusion-diffusion mismatch for identifying salvageable tissue (14).

Importantly, combining MRI perfusion metrics with TCD hemodynamic parameters improved diagnostic accuracy (AUC ~0.89) compared to MRI alone (AUC ~0.84), suggesting clinical relevance of a multimodal approach: TCD provides rapid, real-time information complementing the spatially detailed but time-consuming MRI. In resource-limited settings or when repeat assessments are necessary, TCD offers a practical adjunct. Previous work has highlighted challenges in MRI perfusion imaging, including software variability, scanner access, and post-processing time (15).

Although TCD provides rapid, bedside assessment of cerebral perfusion, its use is limited by the requirement of an adequate temporal acoustic window. In a subset of adults, particularly elderly patients and women, the temporal bone may be too thick to allow reliable insonation of the MCA. In this study, patients without an adequate temporal window were excluded, which may limit the generalizability of our findings. Therefore, while TCD can serve as a useful adjunct to MRI perfusion in many patients, it cannot fully replace MRI in those in whom insonation is not feasible.

Conclusion

This study confirms that transcranial Doppler (TCD) ultrasound parameters reflect cerebral perfusion status measured by MRI in acute middle cerebral artery-territory ischemic stroke. Patients with infarct core show the most severe abnormalities on both MRI and TCD, while penumbral tissue displays intermediate changes, consistent with the ischemic continuum model. Combining TCD with MRI perfusion imaging improves diagnostic accuracy by providing rapid, bedside hemodynamic information that complements MRI's detailed spatial assessment. This multimodal approach has the potential to guide timely clinical decision-making, especially in situations where MRI access is limited or repeated evaluations are needed. Future large-scale, multicenter studies are needed to validate this strategy and assess its impact on patient outcomes

Acknowledgement

Special thanks to the MRI and ultrasound technologists for their expertise and dedication, which made this study possible. We are also grateful to all the patients and their families for participating and supporting this research.

Conflict of Interest

There is no conflict of interest in this study.

REFERENCES

Copen WA, Caprihan A, Lin W, Buswell H, Reschner F, Williams D, et al. MR perfusion imaging in acute ischemic stroke. Neuroimaging Clin N Am. 2011;21(4):697-717.

Radiopaedia. Ischaemic stroke [Internet]. 2025 Oct 20. Available from: https://radiopaedia.org/articles/ischaemic-stroke-2

Wiesmann M, Ringelstein EB, Vogl TJ. Parametric perfusion imaging with contrast-enhanced MRI in acute ischemic stroke. Stroke. 2004;35(5):1153-8.

Chen L, Wang X, et al. Research progress of imaging technologies for ischemic cerebrovascular diseases. J Med Libr Assoc. 2021;30.

Zhang XH, Xu G, et al. Systematic review with network meta-analysis: diagnostic value of ultrasonography, CT and MRI in ischemic stroke. Medicine (Baltimore). 2019;98(30):e16276.

Pan Y, Guo Y, et al. Transcranial Doppler Ultrasonography as a diagnostic tool in cerebrovascular disorders including acute ischemic stroke. Front Hum Neurosci. 2022;16:841809.

Mohamed A, Elsharkawy M, Mohamed E. The diagnostic performance of transcranial Doppler ultrasound in cerebral small vessel disease. Egypt J Radiol Nucl Med. 2025;56:5.

Meyer-Wiethe K, et al. Ultrasound perfusion imaging: determination of cerebral perfusion deficits after UCA bolus. Ultrasound Med Biol. 2007;33(5):695-704.

Demeestere J, Hurford R, Widimsky P, et al. Review of perfusion imaging in acute ischemic stroke. Stroke. 2020;51(3):867-876.

Gopinath G, Srinivasan S, Dhananjayan M, et al. Role of magnetic resonance perfusion imaging in acute ischemic stroke. Neuroradiology. 2022;64(6):975-986.

Bill O, Lambrou D, Sotomayor GT, et al. Predictors of the pulsatility index in the middle cerebral artery of acute stroke patients. Sci Rep. 2020;10:17110.

Patel P, Panda S, Tiwari S. Early haemodynamic changes on transcranial Doppler as a predictor of functional outcome in acute ischemic stroke: a case series from India. Egypt J Neurol Psychiatr Neurosurg. 2025;61:58.

Bankole NDA, Al-Kindi S, Al-Harthy Z, et al. Transcranial Doppler ultrasonography in acute ischemic stroke predicts stroke subtype and clinical outcome. J Clin Monit Comput. 2024;38(1):75-84.

El Beheiry AA, Hanora MA, Youssef AF, Al Neikedy A, Elhabashy AR, Khater HM. Role of arterial spin-labeling magnetic resonance perfusion in acute ischemic stroke. Egypt J Radiol Nucl Med. 2023;54:43.

Deutschmann H, Hinteregger N, Wießpeiner U, et al. Automated MRI perfusion-diffusion mismatch estimation may substantially differ between software packages: implications for acute ischemic stroke decision-making. Eur Radiol. 2021;31(9):6865-6874.

Bill O, Lambrou D, Sotomayor GT, et al. Predictors of the pulsatility index in the middle cerebral artery of acute stroke patients. Sci Rep. 2020;10:17110.

Hashemilar M, Sadeghi M, Aghamohammadi M. Comparison of transcranial Doppler ultrasound indices in acute ischemic stroke: a cross-sectional study. Clin Neurol Neurosurg. 2021;208:106882.

Wan Y, Li X, Liu Y, et al. Application of transcranial Doppler in cerebrovascular disease: development and advances. Front Aging Neurosci. 2022;14:1035086.