

Evaluation of the MAPH score in predicting acute ischemic stroke severity and major vessel occlusion in the emergency department

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ABSTRACT

Aims: This study aimed to evaluate the utility of the MAPH score, a biomarker combining blood viscosity indicators such as mean platelet volume (MPV), total protein, and hematocrit, in differentiating acute ischemic stroke (AIS) from transient ischemic attack (TIA) and predicting major vessel occlusion in patients presenting to the emergency department with suspected stroke.

Methods: A retrospective analysis was conducted on 226 patients presenting to the emergency department with focal neurological symptoms. Patients were categorized into AIS and TIA groups based on diffusion-weighted magnetic resonance imaging findings. Data collected included demographic characteristics, vital signs, laboratory parameters, and imaging results. MPV, age, hematocrit, and total protein levels were recorded. High-shear rate and low-shear rate were calculated from total protein and hematocrit values. ROC curve analysis was performed to evaluate diagnostic performance.

Results: The ROC analysis demonstrated the diagnostic accuracy of the MAPH score in differentiating AIS from TIA and predicting major vessel occlusion. Additionally, the score showed a significant correlation with NIHSS ≥ 20 , indicating its association with stroke severity.

Conclusion: The MAPH score is a simple and practical tool that aids in distinguishing AIS from TIA and predicting major vessel occlusion, thus improving stroke management in emergency settings.

Keywords: MAPH score, acute ischemic stroke, transient ischemic attack, major vessel occlusion, emergency medicine

INTRODUCTION

Cerebrovascular diseases continue to be a significant cause of mortality and disability in public health. Acute stroke occurs as a result of neuronal damage caused by reduced blood flow to the brain and is a common medical emergency encountered in emergency departments.¹ Globally, approximately 80% of strokes are ischemic, while 20% are hemorrhagic.² Following cardiovascular diseases and cancer, stroke ranks as the third leading cause of death worldwide and is the most prevalent cause of disability.³

Acute ischemic stroke (AIS) occurs due to etiologies such as thrombosis, embolization, and lacunar infarction resulting from small vessel disease. Increased whole blood viscosity (WBV) and the subsequent formation of thrombus are among the primary risk factors for ischemia.⁴ The severity of ischemia may vary depending on the persistence and size of the thrombus, as well as underlying risk factors such as the patient's gender, age, and smoking habits. In some cases, the patient's symptoms may be transient. When symptoms resolve within 24 hours without evidence of tissue infarction on diffusion-weighted magnetic resonance imaging (MRI), the condition is referred to as a transient ischemic attack (TIA).⁵ Factors such as the patient's clinical condition, the size

of the ischemic area, and eligibility for reperfusion strategies necessitate treatment decisions to be made in the emergency department as quickly as possible. The first hours in AIS are critical for preserving brain tissue. While thrombolytic therapies can be administered to eligible patients within the first 4-5 hours of symptom onset, endovascular thrombectomy may be considered in selected patients during extended time windows of up to 24 hours. Clinical criteria are required to grade the severity of ischemic stroke, assess changes during the follow-up process, ensure uniform communication among healthcare professionals and predict prognosis. One of the most commonly used scales, the National Institutes of Health Stroke Scale (NIHSS), evaluates neurological findings by assigning scores and provides valuable information about long-term prognosis. The MAPH score, defined by Abacıoğlu et al.,⁶ incorporates blood viscosity biomarkers such as mean platelet volume (MPV), total protein, hematocrit, and age, and has been used to assess thrombus burden in myocardial infarction (MI) patients. This score was later investigated in the context of thrombus risk in pulmonary thromboembolism (PTE).⁷ Similarly, increased plasma viscosity and alterations in blood rheology can be associated with thrombus formation in ischemic strokes.

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The aim of this study is to evaluate the relationship between major vessel occlusion, AIS, and less critical TIA with the MAPH score in patients presenting to the emergency department with suspected ischemic stroke. Furthermore, this practical score is aimed to contribute to the management protocols for AIS in the emergency department.

METHODS

Study Design and Setting

The study was conducted with approval from the Ankara Etlik City Hospital Scientific Researches Ethics Committee (Date: 25.09.2024, Decision No: AEŞH-BADEK-2024-891). As this was a retrospective file review and did not involve patient identification, informed consent was not required. The study was conducted in accordance with the Declaration of Helsinki. This retrospective study was conducted at the Emergency Medicine Clinic of Ankara Etlik City Hospital between December 1, 2023, and May 1, 2024. The study included male and female patients aged 18 years and older who presented with focal neurological symptoms at least 24 hours after their last known well state. Focal neurological symptoms were defined as the sudden onset of new neurological signs such as asymmetric weakness, sensory changes, dysarthria, facial paralysis, altered mental status, dizziness, and visual impairment. During triage, a critical pathway was activated to facilitate rapid communication with the neurology team for patients suspected of having a stroke. Patients were excluded from the study if they were under 18 years of age, pregnant, had a diagnosis of cerebrovascular disease, pulmonary thromboembolism, or acute coronary syndrome within the past month, were using anticoagulants, or had incomplete laboratory results. A total of 412 patients presenting with suspected acute stroke were evaluated during the specified dates. Stroke was ruled out in 101 of these patients. Additionally, 45 patients who did not meet the inclusion criteria and 40 patients diagnosed with hemorrhagic stroke were excluded from the study. Consequently, a total of 226 patients were included in the study (Figure 1).

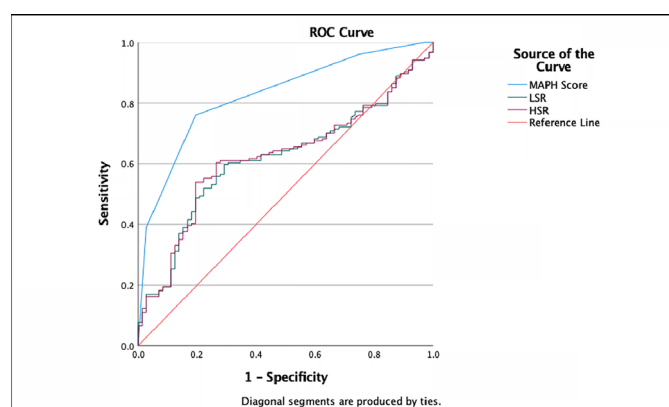


Figure 1. Flow diagram of patient selection and study enrollment

Data Collection and Research Protocol

All patient data were obtained from the hospital database and patient records. Sociodemographic characteristics (age, gender, comorbidities), vital parameters [systolic and diastolic blood pressure (SBP, DBP), body temperature, heart rate

(HR), respiratory rate (RR), peripheral oxygen saturation (SpO_2)], Glasgow Coma Scale (GCS), complete blood count parameters [leukocyte, hemoglobin, hematocrit, platelet, MPV], glucose, blood urea nitrogen (BUN), creatinine, total protein (TP), albumin, aspartate aminotransferase (AST), alanine aminotransferase (ALT), sodium, cholesterol, triglycerides, NIHSS, MAPH score, low-shear rate (LSR), high-shear rate (HSR), brain computed tomography (CT), brain computed tomography angiography (CTA), diffusion MRI findings, admission status, and in-hospital mortality data were recorded. All data were reviewed and verified by two emergency medicine specialists. Patients were initially divided into two groups based on diffusion MRI findings: those with pathological findings were classified as the AIS group, while those without pathological findings were classified as the TIA group. The MAPH score, LSR, and HSR values were compared between these two groups. Additionally, in the AIS group, subgroups were formed based on brain CTA findings as patients with and without major vessel occlusion, and the MAPH scores of these subgroups were compared.

Definition

The diagnosis of AIS is supported by radiological imaging and confirmed by the presence of vascular occlusion or detection of diffusion restriction. On the other hand, TIA is defined as a transient episode of neurological dysfunction caused by focal ischemia of the brain, spinal cord, or retina, which resolves rapidly within 24 hours and shows no evidence of tissue infarction on diffusion-weighted MRI.⁵

In AIS, major vessel occlusion was defined as occlusion of the internal carotid artery, middle cerebral artery (M1 and proximal M2 segments), basilar artery, and intracranial vertebral arteries, as identified on brain CTA. Distal M2, A2, and P2 segments were not included in the LVO definition, as these are generally classified as medium vessel occlusions.

The MAPH score consists of four parameters: MPV (M), age (A), total protein (P), and hematocrit (H).⁶ Cut-off values for each parameter of the score were determined using receiver operating characteristic (ROC) curve analysis and the Youden Index. A score of 1 was assigned for values equal to or above the cut-off, and a score of 0 for values below the cut-off. The total MAPH score was calculated by summing the scores of each parameter.

The NIHSS is a scale used to assess neurological status and determine stroke severity.⁸ It consists of an 11-step evaluation system, including parameters such as level of consciousness, eye movements, visual fields, facial paralysis, motor strength (upper and lower extremities), ataxia, sensation, speech, dysarthria, and neglect.

WBV was calculated from Hct and plasma TP at a LSR (0.5 s^{-1}) and a HSR (208 s^{-1}) using the previously validated de Simone formulae.⁹ In our dataset, TP values were originally recorded in g/dL from hospital laboratory records and were converted to g/L ($\times 10$) prior to calculation, while Hct was expressed as a percentage. Therefore, the equations were applied using the correct units as follows:

$$\text{HSR: WBV } (208 \text{ s}^{-1}) = (0.12 \times \text{HCT}) + 0.17 \times (\text{TP} - 2.07)$$

$$\text{LSR: WBV } (0.5 \text{ s}^{-1}) = (1.89 \times \text{HCT}) + 3.76 \times (\text{TP} - 78.42)$$

Statistical Analysis

Descriptive statistics were presented as frequencies (percentages) for categorical variables and as means with standard deviations for numerical variables. The normality assumption for numerical variables was evaluated both analytically and graphically. Comparisons of patient characteristics were performed using the chi-square test for categorical variables and either the Independent Samples T test or the Mann-Whitney U test for numerical variables. The diagnostic ability of laboratory parameters with statistically significant p-values from group comparison tests was assessed using the area under the ROC curve. Cut-off values for potential biomarkers were determined using the Youden Index and diagnostic performance metrics, with sensitivity, specificity, and corresponding 95% confidence intervals, were calculated. Pairwise comparison of ROC curves was performed using the DeLong test. A post-hoc power analysis was also performed for the independent samples T test. Assuming a medium effect size (Cohen's $d=0.5$), an alpha error probability of 0.05, and sample sizes of $n=154$ (group 1) and $n=72$ (group 2), the achieved statistical power ($1-\beta$) was calculated as 93.7%, indicating that the study had sufficient power to test the relevant hypothesis. Statistical analyses were conducted using the Statistical Package for Social Sciences (SPSS, Version 23, Inc., Chicago, IL) software, and a $p<0.05$ was considered statistically significant.

RESULTS

A total of 226 patients were included in the study. Based on clinical findings and diffusion MRI results, 154 patients with acute diffusion restriction were classified as the AIS group, while 72 patients were classified as the TIA group. Sociodemographic data, symptom and examination findings, scores such as NIHSS and GCS, and other findings related to the patients are presented in detail in Table 1. In the AIS group, Hct and MPV values were found to be higher, and this difference was statistically significant.

Based on brain CTA findings, major vessel occlusion was detected in 61 patients (39.6%) in the AIS group. Intravenous thrombolytic therapy with recombinant tissue plasminogen activator (rTPA) was administered to 12 patients (5.3%), and mechanical thrombectomy was performed on 31 patients (13.7%). Among all patients, 44 (19.5%) were discharged from the emergency department, 106 (46.9%) were admitted to the ward, and 76 (33.6%) were transferred to the intensive care unit. In-hospital mortality occurred in 34 patients (19.9%).

In the ROC analysis performed for the MAPH score, the cut-off values were determined according to the Youden index as follows; 11 for MPV, 60 for age, 6.49 for TP, and 43.1 for Hct. The cut-off value for the MAPH score was found to be 3. Comparisons of MAPH, LSR, and HSR values between AIS and TIA patients based on these cut-off values are presented in Table 2.

The ROC analysis demonstrated that the MAPH score, LSR, and HSR could predict the diagnosis of AIS. Table 3 presents all potential cut-off points for the continuous variables that could be used for AIS diagnosis, along with their predictive performance metrics. A comparison of the ROC curves for

the continuous variables revealed that the MAPH score was significantly superior to the others in predicting AIS based on the dataset, followed by LSR and HSR (Figure 2).

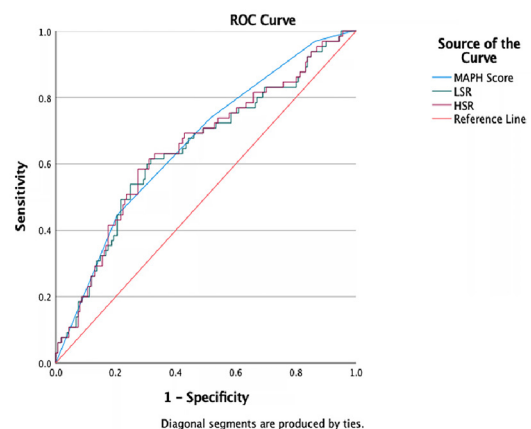


Figure 2. ROC curve of MAPH for patients diagnosed with acute ischemic stroke major vessel occlusion

ROC: Receiver operating characteristic, MAPH: MPV, age, total protein, and hematocrit, LSR: Low shear rate, HSR: High shear rate

Comparisons of MAPH, LSR, and HSR values with the presence of major vessel occlusion in the AIS group are presented in Table 4. ROC analysis demonstrated that the MAPH score, LSR, and HSR could predict the presence of major vessel occlusion in AIS patients. Table 5 details all potential cut-off points for the continuous variables used to determine the presence of major vessel occlusion and the accuracy of these variables in prediction. A comparison of the ROC curves for the continuous variables revealed that MAPH, LSR, and HSR were statistically significant in predicting the presence of major vessel occlusion based on the dataset (Figure 3). According to the DeLong test, there was no statistically significant difference between the MAPH score and LSR ($p=0.657$) or between the MAPH score and HSR ($p=0.777$) in predicting major vessel occlusion. However, the comparison between LSR and HSR demonstrated a statistically significant difference ($p=0.030$), suggesting that these two viscosity-based measures may differ slightly in their diagnostic performance. Overall, the MAPH score showed comparable discriminative ability to both LSR and HSR in this context (Table 6).

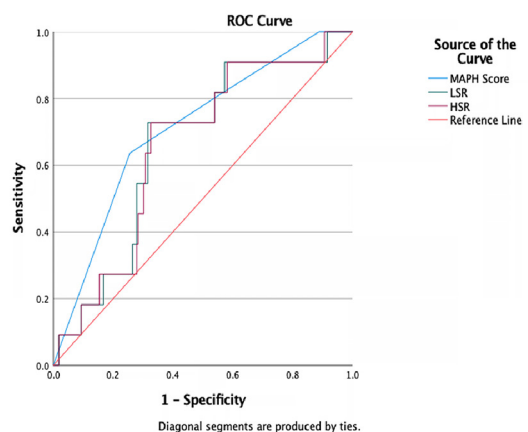


Figure 3. ROC analysis curves of MAPH, LSR and HSR for major vessel occlusion

ROC: Receiver operating characteristic, MAPH: MPV, age, total protein, and hematocrit, LSR: Low shear rate, HSR: High shear rate

Table 1. Sociodemographic data and laboratory values

Total (n=226)		Acute ischemic stroke (n=154)	Transient ischemic attack (n=72)	p-value
Age-mean (±SD)		73±11	72±12	0.751
Gender (n, %)	Female	84 (54%)	39 (54%)	0.958
	Male	70 (46%)	33 (46%)	
Vital signs (mean±SD)				
Systolic blood pressure (mmHg)		169±26	153±27	<0.001*
Diastolic blood pressure (mmHg)		95±14	88±15	0.002*
Heart rate (beats/min)		84±48	80±13	0.955
Oxygen saturation (SpO ₂ , %)		93±3	94±3	0.026*
Body temperature (°C)		36.7±0.4	36.7±0.4	0.618
Respiratory rate (breaths/min)		17±4	16±3	0.096
NIHSS-median (IQR)		6 (3-12)	2 (1-4)	<0.001*
GCS scores (median, IQR)				
Eye response		4 (4-4)	4 (4-4)	0.039*
Verbal response		5 (4-5)	5 (5-5)	0.013*
Motor response		6 (5-6)	6 (6-6)	<0.001*
Comorbidities (n, %)				
Hypertension		140 (90.3%)	60 (84.5%)	0.203
Diabetes mellitus		58 (37.4%)	30 (42.3%)	0.489
Atrial fibrillation		73 (47.4%)	23 (31.9%)	0.028*
Smoking habit		49 (31.6%)	12 (16.9%)	0.021*
Laboratory findings				
White blood cell count (10 ³ /μL)		9.7±3.7	8.6±2.9	0.054
Hemoglobin (g/dl)		13±2.3	12.8±1.7	0.602
Hematocrit (%)		41±6	39±4	0.001*
Platelet count (10 ³ /μL)		240±79	265±156	0.254
Mean platelet volume (fL)		11±0.8	10.4±0.7	<0.001*
Glucose (mg/dl)		150±56	136±47	0.101
Total protein (g/L)		60.5±0.6	60.5±0.4	0.580
Albumin (g/L)		41.5±30	38.8±4	0.816
Blood urea nitrogen (mg/dl)		46±30	40±16	0.437
Creatinine (mg/dl)		1.1±0.9	0.9±0.3	0.364
Total cholesterol (mg/dl)		180±52	169±52	0.077
Low-density lipoprotein (mg/dl)		115±43	109±41	0.156
High-density lipoprotein (mg/dl)		48±15	48±13	0.727
Triglycerides (mg/dl)		129±73	123±61	0.779
*: Chi-square test Mann-Whitney U/T test, SD: Standard deviation, min: Minimum, NIHSS: National Institutes of Health Stroke Scale, IQR: Inter quartile range, GCS: Glasgow Coma Scale				

*: Chi-square test Mann-Whitney U/T test, SD: Standard deviation, min: Minimum, NIHSS: National Institutes of Health Stroke Scale, IQR: Inter quartile range, GCS: Glasgow Coma Scale

Table 2. Comparison of MAPH, LSR, and HSR between acute ischemic stroke and transient ischemic attack patients

Parameters	Acute ischemic stroke	Transient ischemic attack	p-value
MAPH-MPV	0.77 $\pm$ 0.4	0.19 $\pm$ 0.3	<0.001*
MAPH-age	0.90 $\pm$ 0.2	0.76 $\pm$ 0.4	0.005*
MAPH-protein	0.81 $\pm$ 0.3	0.81 $\pm$ 0.3	0.995
MAPH-hematocrit	0.64 $\pm$ 0.4	0.18 $\pm$ 0.3	<0.001*
MAPH	3.11 $\pm$ 0.8	1.94 $\pm$ 0.7	<0.001*
LSR	25 $\pm$ 12	22 $\pm$ 9	0.005*
HSR	4 $\pm$ 0.7	3.8 $\pm$ 0.5	0.003*

*: Mann-Whitney U/T test, MAPH: MPV, age, total protein, and hematocrit, MPV: Mean platelet volume, LSR: Low shear rate, HSR: High shear rate

In the ROC analysis, the MAPH score was compared with NIHSS and showed a significant correlation with patients having NIHSS $\geq$ 20 ($p=0.018$). A comparison of the ROC curves for the continuous variables demonstrated that the MAPH score was statistically significant in predicting NIHSS $\geq$ 20 based on the dataset (Figure 4).

Table 7 presents in-hospital mortality rates stratified by diagnosis groups and stroke severity (NIHSS). Mortality was 26.6% among patients with AIS and 5.6% among those with TIA. Chi-square analysis demonstrated a statistically significant association between diagnosis group and mortality (Pearson $\chi^2=13.656$, $df=1$, $p<0.001$). When stratified by stroke severity, patients with NIHSS $\geq$ 20 had a mortality rate of

Table 3. ROC analysis of MAPH, LSR, and HSR in acute ischemic stroke and transient ischemic attack patients

Parameters	AUC	Cut-off	Sensitivity (%)	Specificity (%)	PPV, %	NPV, %	95% CI (lower)	95% CI (upper)
MAPH	0.825	3	76	81	89	61	0.769	0.881
LSR	0.617	25.9	60	69	81	45	0.543	0.691
HSR	0.621	4.2	54	80	85	45	0.547	0.695

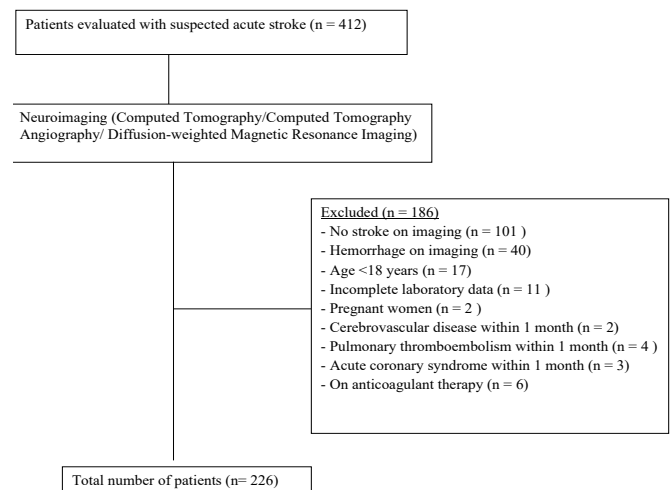
ROC: Receiver operating characteristic, MAPH: MPV, age, total protein, and hematocrit, MPV: Mean platelet volume, LSR: Low shear rate, HSR: High shear rate, AUC: Area under the curve, PPV: Positive predictive value, NPV: Negative predictive value, CI: Confidence interval

Table 4. Comparison of MAPH, LSR, and HSR in patients with and without major vessel occlusion

Parameters	Major vessel occlusion (+)	Major vessel occlusion (-)	p-value
MAPH-MPV	0.80±0.4	0.50±0.5	<0.001*
MAPH-age	0.85±0.3	0.86±0.3	0.738
MAPH-protein	0.78±0.4	0.81±0.3	0.618
MAPH-hematocrit	0.72±0.4	0.40±0.4	<0.001*
MAPH	3.15±0.8	2.5±0.9	<0.001*
LSR	27±11	22±11	<0.001*
HSR	4±0.7	3.8±0.7	<0.001*

*Mann-Whitney U/T test, MAPH: MPV, age, total protein, and hematocrit, MPV: Mean platelet volume, LSR: Low shear rate, HSR: High shear rate

72.7%, compared with 17.2% in those with NIHSS <20. This difference was also statistically significant (Pearson $\chi^2=20.226$, df=1, $p<0.001$).

Figure 4. ROC analysis of MAPH, LSR and HSR for NIHSS ≥ 20

ROC: Receiver operating characteristic, NIHSS: National Institutes of Health Stroke Scale, MAPH: MPV, age, total protein, and hematocrit, LSR: Low shear rate, HSR: High shear rate

Table 5. ROC analysis of MAPH, LSR, and HSR in patients with major vessel occlusion

Parameters	AUC	Cut-off	Sensitivity (%)	Specificity (%)	PPV, %	NPV, %	95% CI (lower)	95% CI (upper)
MAPH	0.661	4	45	80	47	78	0.584	0.739
LSR	0.644	27.8	61	68	44	81	0.563	0.726
HSR	0.650	4.25	58	72	46	81	0.569	0.731

ROC: Receiver operating characteristic, MAPH: MPV, age, total protein, and hematocrit, MPV: Mean platelet volume, LSR: Low shear rate, HSR: High shear rate, AUC: Area under the curve, PPV: Positive predictive value, NPV: Negative predictive value, CI: Confidence interval,

Table 6. Pairwise comparisons of ROC curves for major vessel occlusion (DeLong test)

Test pair	z	p (2-tailed)	AUC difference	SE (difference)	95% CI (lower)	95% CI (upper)
MAPH-LSR	0.443	0.657	0.017	0.279	-0.059	0.093
MAPH-HSR	0.284	0.777	0.011	0.279	-0.065	0.087
LSR-HSR	-2.174	0.030	-0.006	0.283	-0.012	-0.001

ROC: Receiver operating characteristic, AUC: Area under the curve, SE: Standard error, CI: Confidence interval, MAPH: MPV, age, total protein, and hematocrit, MPV: Mean platelet volume, LSR: Low shear rate, HSR: High shear rate

Table 7. Mortality stratified by diagnosis and stroke severity (NIHSS)

Mortality	AIS (n=154)	TIA (n=72)	Total (n=226)	p-value*
Survivors	113 (73.4%)	68 (94.4%)	181 (80.1%)	<0.001
Non-survivors	41 (26.6%)	4 (5.6%)	45 (19.9%)	
Total	154 (100%)	72 (100%)	226 (100%)	
Mortality	NIHSS <20 (n=215)	NIHSS ≥ 20 (n=11)	Total (n=226)	p-value
Survivors	178 (82.8%)	3 (27.3%)	181 (80.1%)	<0.001
Non-survivors	37 (17.2%)	8 (72.7%)	45 (19.9%)	
Total	215 (100%)	11 (100%)	226 (100%)	

*: Chi-square test (Pearson χ^2), NIHSS: National Institutes of Health Stroke Scale, AIS: Acute ischemic stroke, TIA: Transient ischemic attack

DISCUSSION

This study demonstrated that the MAPH score exhibited significant performance in differentiating AIS from TIA in patients presenting with suspected stroke and provided high diagnostic accuracy in predicting major vessel occlusion associated with disease severity. By combining parameters such as Htc and TP, which affect blood viscosity, with factors like MPV, reflecting systemic inflammation, and age, the MAPH score can be considered a biomarker aligned with the mechanisms involved in thrombus formation in AIS pathophysiology.

Platelets play an active role in the mechanism of AIS development. The production of thromboxane A2 by activated platelets and the surface presence of glycoprotein IIb/IIIa receptors constitute the primary mechanism of thrombosis formation. This mechanism explains how aspirin and clopidogrel provide antiplatelet effects by inhibiting thromboxane A2 synthesis and glycoprotein IIb/IIIa receptor activity, offering a significant therapeutic approach to reducing the risk of stroke. Although platelet aggregation is a specific method for evaluating platelet function, parameters such as MPV and Platelet Distribution Width also play an important role in the pathophysiology of AIS.¹⁰ MPV is a measure of platelet size and is considered a key indicator of platelet activity.¹¹ In our study, the ROC analysis identified an MPV cut-off value of 11 fL, determined based on the Youden index, which was significantly higher in the AIS group compared to the TIA group and in patients with major vessel occlusion compared to those without. This finding suggests that increased MPV values may be associated with thrombus burden. In another study, MPV was shown to be an independent predictor of stroke risk in 3,134 patients with cerebrovascular disease, and a positive association was observed between MPV and stroke risk in patients with a history of stroke or TIA.¹² Similarly, a meta-analysis conducted by Sadeghi et al.¹³ also identified higher MPV values in AIS patients.

In this study, the ROC analysis identified a hematocrit cut-off value of 43.1%, determined based on the Youden index, which was found to be higher in the AIS group compared to the TIA group and significantly higher in patients with major vessel occlusion compared to those without occlusion. One of the fundamental mechanisms of ischemic stroke is arterial thrombus formation. Increased WBV is a known risk factor for thrombosis, and elevated Htc levels are generally associated with increased WBV.¹⁴ While viscosity increases exponentially with Htc in major vessels, it shows a linear increase in small vessels.¹⁵ In this context, the observed elevation in hematocrit in the AIS group may be associated with the greater thrombus burden in this group compared to the TIA group. Studies on the MAPH score have shown that Htc levels are elevated in patients who have experienced myocardial infarction and have a high thrombus grade.^{6,16}

Total protein, consisting of albumin, fibrinogen, and globulins, is one of the most important serum components regulating plasma viscosity.¹⁷ In one study, higher serum protein levels were found in patients with acute stroke who had a higher degree of spontaneous echo contrast, indicating an increased risk of cardioembolic events.¹⁸ However, in our

study, no significant difference was found between the AIS and TIA groups regarding the determined cut-off value. This may be due to the characteristics of the patient population included in our study and the inability to clearly distinguish factors such as inflammation, hydration status, or nutritional deficiencies that could affect protein levels.

It is well known that AIS is more common, particularly in individuals aged 65 and older, and that mortality and morbidity increase with age. In our study, the >60 years cut-off value determined for predicting AIS was found to be higher in the AIS group compared to the TIA group. This finding is consistent with the literature, which identifies increasing age as a risk factor for thrombus formation and thromboembolic events.¹⁹

Changes in WBV are thought to play an important role in the development of ischemic stroke.²⁰ High WBV in HSR and LSR has been reported to be associated with apical thrombus, stent thrombosis, and poor outcomes in patients with ST-elevation myocardial infarction undergoing percutaneous coronary intervention, as well as an increased risk.²¹ Additionally, elevated WBV has been shown to be a risk factor for both primary and secondary stroke.¹⁴ High WBV at both shear rates has been associated with a high thrombus burden and has been identified as an independent predictor of high thrombus burden in patients with non-ST-elevation myocardial infarction.²² Simone et al.⁹ formulated simple equations using Htc and TP levels to determine WBV at various shear rates. In this study, the comparison of LSR, HSR, and MAPH scores between the TIA and AIS groups revealed that these values were significantly higher in the AIS group. Furthermore, in the AIS group, patients with major vessel occlusion had higher LSR, HSR, and MAPH scores compared to those without occlusion.

One of the most significant findings of the study emerged from the comparison of continuous variables using ROC analyses. The MAPH score, created by incorporating age into the parameters affecting viscosity, such as Htc and TP, demonstrated superior performance compared to known biomarkers like HSR and LSR, as well as its individual components- Htc, age, TP and MPV. This superiority was evident in both the differentiation of AIS and TIA and its association with a high thrombus burden in patients presenting with suspected stroke.

In the ROC analysis, the MAPH score was compared with the NIHSS and showed a significant correlation with patients having NIHSS ≥ 20 . The comparison of ROC curves for continuous variables demonstrated that the MAPH score was statistically significant in predicting high stroke severity at this cutoff. Although different NIHSS severity classifications exist in the literature, in this study NIHSS ≥ 20 was used as the analytic threshold for high severity.^{23,24} This finding is important because therapeutic decisions largely depend on stroke severity and the site of occlusion. Stroke severity may vary depending on the location of the occlusion and thrombus burden, and the MAPH score has the potential to correlate with thrombus load.^{6,16,25} The MAPH score may serve as a complementary tool alongside established assessments such as the NIHSS and neuroimaging modalities in emergency

settings. Early identification of patients at risk for major vessel occlusion is critical for timely reperfusion therapies. Incorporating the MAPH score into initial evaluation protocols could help prioritize patients for advanced imaging and interventions, particularly in resource-limited environments where immediate neuroimaging is not always available.

Limitations

This study has several limitations. One of them is the retrospective design and single-center nature of the study, which limits the generalizability of the results to different patient populations and geographic regions. Additionally, as the MAPH score is a novel biomarker, its validation in larger patient groups and various clinical settings is necessary. Lastly, the study did not thoroughly evaluate factors such as inflammation, hydration status, and nutritional deficiencies, which may influence total protein levels and could limit a comprehensive interpretation of this parameter. Therefore, carefully designed, multicenter prospective studies that also take these factors into account are warranted to strengthen the external validity and generalizability of the MAPH score.

CONCLUSION

This study demonstrated that the MAPH score, a novel indicator of WBV, provides high diagnostic accuracy in both differentiating between AIS and TIA groups and identifying major vessel occlusion. These findings suggest that the MAPH score, which is simple and easy to calculate, could aid in determining disease severity and contribute to patient management in individuals presenting to the emergency department with suspected stroke.

ETHICAL DECLARATIONS

Ethics Committee Approval

The study was carried out with the permission of the Ankara Etlik City Hospital Scientific Researches Ethics Committee (Date: 25.09.2024, Decision No: AEŞH-BADEK-2024-891).

Informed Consent

Because the study was designed retrospectively, no written informed consent form was obtained from patients.

Referee Evaluation Process

Externally peer-reviewed.

Conflict of Interest Statement

The authors have no conflicts of interest to declare.

Financial Disclosure

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Author Contributions

All of the authors declare that they have all participated in the design, execution, and analysis of the paper, and that they have approved the final version.

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