



Relationship Between Early Neurological Deterioration and Transcranial Doppler Parameters in Mechanical Thrombectomy

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ABSTRACT

Objective: Mechanical thrombectomy is an effective treatment method for stroke patients with large vessel occlusion. Hemorrhagic transformation and edema can be observed during patient follow-up after mechanical thrombectomy. Transcranial Doppler (TCD) is a method used to evaluate hemodynamic changes following endovascular treatment (EVT), and the examination of patients with TCD contributes to the assessment of early neurological deterioration.

Methods: Patients who presented to University of Health Sciences Türkiye, İzmir Tepecik Training and Research Hospital with acute ischemic stroke and underwent mechanical thrombectomy for anterior circulation occlusion were included in the study. Demographic data were recorded, along with initial and 24th-hour National Institutes of Health Stroke Scale (NIHSS) scores, post-procedural revascularization scores, and whether intravenous thrombolysis was performed. Patients were evaluated using TCD within the first 12 hours after EVT, and parameters in the ipsilateral and contralateral vessels were compared to examine their impact on hemorrhagic transformation and edema. Clinical outcomes were assessed using the 3-month modified Rankin scale (mRS).

Results: The pulsatility index, peak systolic velocity, and end-diastolic velocity on TCD examination did not significantly affect hemorrhagic transformation and edema when comparing ipsilateral and contralateral vessels. A higher 24-hour NIHSS score was significantly associated with hemorrhagic transformation. Patients with edema were found to have higher mRS scores and an association with clinical outcomes.

Conclusion: In our study, the evaluation of early clinical response by TCD examination after mechanical thrombectomy did not demonstrate a significant contribution.

Keywords: Acute ischemic stroke, thrombectomy, transcranial doppler, pulsatility index, hemorrhagic transformation

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INTRODUCTION

Stroke is defined as a neurological deficit that occurs following an acute focal injury to the central nervous system due to a vascular event, and is one of the leading causes of morbidity and mortality worldwide.¹ Significant advances have been made in recent years in the diagnosis and treatment of acute stroke.

Mechanical thrombectomy is the most effective treatment for acute ischemic stroke and is recommended within

the first 6 hours for patients with large vessel occlusion (LVO).^{2,3} Recent studies have indicated that under suitable criteria, this procedure can be performed within 24 hours.^{2,4,5} Although mechanical thrombectomy yields good functional outcomes, some patients may experience early neurological deterioration, particularly within the first 72 hours.⁶ Hemorrhagic transformation and edema are complications associated with poor functional outcomes in acute stroke patients and managing cerebral



autoregulation in the early phase has become a target to prevent these complications.⁷

Transcranial Doppler (TCD) is an easily accessible, cost-effective and non-invasive diagnostic method used to evaluate hemodynamic changes following reperfusion therapies.^{8,9} In the acute phase of stroke, TCD is used to assess vascular occlusion and cerebral perfusion, to detect microembolic signals, and to evaluate collateral circulation.⁹ Parameters such as pulsatility index (PI), peak systolic flow, and end-diastolic flow in the vessel are examined using TCD; the PI, in particular, is associated with increased intracranial pressure.⁶⁻¹⁰ In our study, we aimed to investigate the relationship between early neurological deterioration and TCD findings in patients undergoing mechanical thrombectomy.

METHODS

Scope of the Study

Prospective

The study included 20 patients who were admitted to University of Health Sciences Türkiye, İzmir Tepecik Training and Research Hospita with a diagnosis of acute ischemic stroke between July 2022 and July 2023 and who met the inclusion criteria. Patients over 18 years of age who underwent mechanical thrombectomy for anterior circulation strokes were included (regardless of whether they received intravenous thrombolytic therapy). Patients were excluded from the study if they had no TCD window, had a final Thrombolysis in Cerebral Infarction (TICI) score of 0-1, or were referred to another center post-procedure.

Clinical Evaluation

This prospective study was conducted to evaluate the relationship between TCD data and early neurological response in patients admitted to University of Health Sciences Türkiye, İzmir Tepecik Training and Research Hospita with acute ischemic stroke and undergoing mechanical thrombectomy between July 2022 and July 2023.

During this period, patients with measurable neurological deficits who presented to University of Health Sciences Türkiye, İzmir Tepecik Training and Research Hospita with acute ischemic stroke were assessed, with National Institutes of Health Stroke Scale (NIHSS) scores calculated based on initial examination findings. In the acute phase, brain computed tomography (CT), with or without computer tomography angiography (CTA), was performed, and endovascular treatment (EVT) was applied according to guidelines for patients with anterior circulation LVO. The grade of revascularization was evaluated using the TICI score, with TICI 0, 1, 2a, and 2b defined as unsuccessful

revascularization, and TICI 2c and 3 defined as successful revascularization. The Tan collateral grading system was used to evaluate the collateral system in CTA. According to this system, 0 indicates no collateral support, 1 corresponds to filling 50% or less of the occluded middle cerebral artery (MCA) region, 2 indicates filling between 50% and 100% of the occluded MCA region and 3 represents complete filling of the occluded region. For patients with successful revascularization, TCD was performed within the first 12 hours post-procedure, and the time of Doppler assessment was recorded. To ensure consistency of the results, TCD was performed by a single operator. All flow parameters in the affected vessel (peak systolic flow, end-diastolic flow, PI, resistance index) were calculated and compared with the contralateral vessel.

Data on patients' age, gender, smoking and alcohol use; chronic conditions such as hypertension, diabetes, atrial fibrillation, hyperlipidemia, coronary artery disease; and history of stroke or transient ischemic attack were recorded.

Post-procedure, patients' vital signs were measured in the intensive care unit and NIHSS scores were recorded at the 24 hours. For patients with clinical deterioration (a decrease of 4 or more points in the NIHSS score), non-contrast brain CT scans were obtained either immediately post-procedure or at 24 hours post-procedure to assess hemorrhagic transformation, ischemic progression, and edema.

During follow-up in the stroke outpatient clinic, patients' 3-month modified Rankin Scale (mRS) scores were recorded. An mRS score of 0-2 at 3 months was considered a good clinical outcome (functional independence); an mRS score of 0-3 was considered to represent ambulatory independence; and an mRS score of 3-6 was considered a poor clinical outcome.

Ethics

This study was conducted in accordance with the ethical guidelines approved by the Non-Interventional Research Ethics Committee of University of Health Sciences Türkiye, İzmir Tepecik Training and Research Hospital, with decision number 2022/06-31 dated June 15, 2022. Informed consent was obtained from all participating patients.

Statistical Analysis

Data were evaluated using IBM SPSS Statistics Standard Concurrent User V 26 (IBM Corp., Armonk, New York, USA). Descriptive statistics were presented as number of units (n), percentage (%), mean \pm standard deviation, median, minimum, maximum and interquartile range values. For comparisons between groups regarding numerical variables, the independent samples t-test was used when

the data showed normal distribution, while the Mann-Whitney U test, employing the exact method for small sample comparisons, was used when the data did not show normal distribution. Chi-square analyses (Pearson chi-square, Yates chi-square, Fisher exact test) were used to compare categorical variables between groups. Multiple binary logistic regression analyses were used to identify factors affecting hemorrhagic transformation and edema. Variables with $p < 0.25$ in univariate analyses were included in the logistic regression models. The Wald backward-

elimination method was applied to select the final model. The goodness of fit for regression analyses was assessed using the Hosmer-Lemeshow test, while the percentage of explanation was evaluated with the Nagelkerke R^2 coefficient. A p value of < 0.05 was considered statistically significant.

RESULTS

A total of 20 patients who underwent EVT for acute ischemic stroke and met the inclusion criteria were included in the study between July 2022 and July 2023 (Table 1).

After EVT, the vital signs in the intensive care unit showed a systolic blood pressure (SBP) of 131.5 ± 19.1 , a diastolic blood pressure (DBP) of 78.1 ± 14.8 , and a pulse of 80 (56.0-132.0). No statistically significant relationship was found between SBP, DBP, and mean arterial pressure (MAP) values and ipsilateral and contralateral flow parameters. The SBP, DBP, and MAP values in patients with hemorrhagic transformation and edema did not differ significantly.

Among those with progression of ischemia, 1 (33%) was female and 2 (66.7%) were male; their ages were significantly lower than those of individuals without progression. There was no statistically significant difference in the values of ipsilateral and contralateral flow parameters concerning progression of ischemia.

According to Table 2, The smoking rate in patients without hemorrhagic transformation was statistically higher than in those with it. The 24-hour NIHSS values in patients with hemorrhagic transformation were significantly higher than in patients without hemorrhagic transformation.

In the comparisons in Table 2, variables such as gender, smoking, alcohol, ipsilateral time-averaged maximum velocity (TAMAX) pulse, 24-hour NIHSS, 3-month mRS, which had $p < 0.25$ were included in the multiple binary logistic regression analysis, as they were considered to potentially affect hemorrhagic transformation. The 24-hour NIHSS was found to be effective in predicting hemorrhagic transformation. For each unit increase in the 24-hour NIHSS, the risk of hemorrhagic transformation increased by 1.274 times [odds ratio (OR) confidence interval (CI) 1.002-1.619]. The relationship between hemorrhagic transformation and the elevation of ipsilateral flow parameters is shown in Table 3.

The 24-hour NIHSS values of patients with edema are significantly higher than those of patients without edema. In the comparisons presented in Table 4, variables such as smoking, cardiac diseases, stroke, CTA collateral score, TCD assessment time, ipsilateral PSV, TAMAX, PI, contralateral PSV, 24-hour NIHSS, and 3-month mRS, which have $p < 0.25$ values were included in the multiple binary logistic regression analysis considering their potential effects on

Table 1. Demographic and clinical variables of participants

Variables	n
Gender	
Female	6 (30%)
Male	14 (70%)
Age	62.8±13.5 (34-89)*
Smoking	13 (65%)
Alcohol	4 (20%)
Comorbidities	
Hypertension	10 (50%)
Diabetes mellitus	5 (25%)
Atrial fibrillation	7 (35%)
Cardiac diseases	11 (55%)
Hyperlipidemia	1 (5%)
Stroke	3 (15%)
Other	8 (40%)
Admission NIHSS	14.5 (8-21)
Admission time (min)	120 (6-360)
lv-tPA	
Yes	14 (70%)
No	6 (30%)
CTA collateral score	1 (0-3)
TICI score	
2C	4 (20%)
3	16 (80%)
TCD evaluation time	6 (1-12)
24-hour NIHSS	7 (0-24)
3-months mRS	1 (0-6)
Progression of ischemia	3 (15%)
Hemorrhagic transformation	10 (50%)
Edema	6 (30%)

NIHSS: National Institutes of Health Stroke Scale, lv-tPA: Intravenous thrombotic therapy, TICI: Thrombolysis in cerebral infarction, TCD: Transcranial Doppler, mRS: Modified Rankin scale, min: Minutes, CTA: Computer tomography angiography
n: Number of patients, %: Percentage, Numeric variables are summarized as median (minimum-maximum) values,
*mean ± standard deviation (minimum-maximum)

Table 2. Comparisons regarding hemorrhagic transformation				
Variables	Hemorrhagic transformation		Test statistics	
	No n=10	Yes n=10	Test value	p value
Sociodemographic variables, n (%)				
Female	1 (10.0)	5 (50.0)	3.810	0.14 [‡]
Male	9 (90.0)	5 (50.0)		
Age	60.5±13.9	65.1±13.4	0.750	0.463 [†]
Smoking	10 (100.0)	3 (30.0)	10.769	0.003[‡]
Alcohol	4 (40.0)	0 (0.0)	5.000	0.087 [†]
Hypertension	5 (50.0)	5 (50.0)	-	-
Diabetes mellitus	3 (30.0)	2 (20.0)	0.267	>0.999 [‡]
Atrial fibrillation	2 (20.0)	5 (50.0)	1.978	0.350 [†]
Cardiac diseases	5 (50.0)	6 (60.0)	0.202	>0.999 [‡]
Hyperlipidemia	1 (10.0)	0 (0.0)	1.053	>0.999 [‡]
Stroke	1 (10.0)	2 (20.0)	0.392	>0.999 [‡]
Other	4 (40.0)	4 (40.0)	-	-
Clinical variables				
Admission NIHSS	14.0 (7.3)	15.0 (6.0)	0.988	0.353 ^{&}
Admission time (min)	105.0 (165.0)	180.0 (225.0)	0.571	0.579 ^{&}
IV-TPA, n (%)				
No	8 (80.0)	6 (60.0)	0.952	0.628 [†]
Yes	2 (20.0)	4 (40.0)		
CTA collateral score	1.0 (1.0)	1.5 (1.0)	0.124	0.912 ^{&}
TICI score, n (%)				
2C	2 (20.0)	2 (20.0)	-	-
3	8 (80.0)	8 (80.0)		
TCD evaluation time	7.0 (9.3)	5.0 (8.8)	0.419	0.684 ^{&}
Ipsilateral flow parameters				
PSV	94.8 (60.2)	120.4 (63.6)	0.680	0.529 ^{&}
EDV	44.2 (33.1)	44.0 (27.8)	0.113	0.912 ^{&}
TAMAX	60.4 (41.0)	89.4 (38.9)	1.285	0.218 ^{&}
PI	0.98 (0.54)	0.92 (1.18)	0.151	0.912 ^{&}
RI	0.60 (0.27)	0.59 (0.52)	0.076	0.971 ^{&}
Contralateral flow parameters				
PSV	90.4 (47.8)	100.2 (31.6)	0.718	0.481 ^{&}
EDV	38.4 (33.0)	44.9 (21.4)	0.151	0.912 ^{&}
TAMAX	57.7 (39.1)	65.0 (22.8)	0.001	>0.999 ^{&}
PI	0.97 (0.80)	0.96 (0.89)	0.151	0.912 ^{&}
RI	0.60 (0.12)	0.59 (0.28)	0.001	>0.999 ^{&}
Other variables				
24-hour NIHSS	1.5 (3.8)	9.0 (12.3)	2.663	0.007[‡]
mRS 3-month	1.0 (3.0)	3.5 (5.3)	1.477	0.165 ^{&}

NIHSS: National Institutes of Health Stroke Scale, Iv-TPA: Intravenous thrombolytic therapy, TICI: Thrombolysis in cerebral infarction, TCD: Transcranial Doppler, mRS: Modified Rankin scale, PSV: Peak systolic velocity, EDV: End-diastolic velocity, TAMAX: Time averaged mean velocity, PI: Pulsatility index, RI: Resistance index, min: Minutes, CTA: Computer tomography angiography
n: Number of patients, %: Percentage, numeric variables are summarized as median (minimum-maximum) values, †: Independent samples t-test, ‡: Chi-square test, &: Exact Mann-Whitney U test

Table 3. Relationship between hemorrhagic transformation and elevation of ipsilateral flow parameters

Variables	Hemorrhagic transformation		Test statistics	
	No	Yes	Test value	p value
PSV, n (%)				
Low	4 (40.0)	5 (50.0)	0.202	>0.999
High	6 (60.0)	5 (50.0)		
EDV, n (%)				
Low	4 (40.0)	4 (40.0)	-	-
High	6 (60.0)	6 (60.0)		
TAMAX, n (%)				
Low	4 (40.0)	3 (30.0)	0.220	>0.999
High	6 (60.0)	7 (70.0)		
PI, n (%)				
Low	4 (40.0)	3 (30.0)	1.143	>0.999
Same	0 (0.0)	1 (10.0)		
High	6 (60.0)	6 (60.0)		
RI, n (%)				
Low	3 (30.0)	2 (20.0)	1.291	0.700
Same	1 (10.0)	3 (30.0)		
High	6 (60.0)	5 (50.0)		

PSV: Peak systolic velocity, EDV: End-diastolic velocity, TAMAX: Time averaged mean velocity, PI: Pulsatility index, RI: Resistance index. Difference = Ipsilateral-contralateral, n: Number of patients, %: Column percentage

edema. Accordingly, the risk of edema increased 3.705-fold with each unit increase in the 3-month mRS (OR CI: 1.155-11.881). The relationship between edema and elevation of ipsilateral flow parameters was shown in Table 5.

DISCUSSION

Assessment of patients presenting with acute stroke who undergo mechanical thrombectomy, using TCD in the acute post-procedure period, can serve as a technique to predict early neurological deterioration.¹¹ Previous studies in this area have primarily focused on patients who received intravenous thrombolytic therapy and studies involving patients who underwent mechanical thrombectomy are limited in number.¹²⁻¹⁴

In our study of mechanical thrombectomy patients, individual evaluation using TCD showed no significant relationship between ipsilateral and contralateral parameters and early neurological response. These results may be attributable to the small number of patients included in the study. For example, in the study conducted by He et al.,¹¹ 112 patients underwent EVT. Successful EVT was achieved in 80 of these patients. Early neurological deterioration was observed in 17 of the 80 patients; in those patients, the ipsilateral mean flow velocity (MFV)/contralateral MFV ratio was higher.

The PI reflects cerebrovascular resistance and serves as

an indirect indicator of intracranial pressure; increased PI indicates elevated intracranial pressure.^{11,15,16} A high PI has been associated with higher mRS scores and is used to predict poor functional outcomes.¹⁷ One study indicated that PI values reached their highest levels on day 3 and were associated with increased edema.¹⁸ In our study, while the ipsilateral PI values of patients with edema were higher compared to contralateral PI values, this difference was not statistically significant. This may be attributable to the examination of patients with TCD within the first 12 hours, as this timing may be too early to assess edema and increased intracranial pressure. In the study by Pan et al.,¹⁹ no significant difference in PI was found when comparing patients with or without edema, suggesting that ischemia and damage to the vascular endothelium could disrupt cerebral autoregulation, exacerbating the severity of ischemic injury and leading to edema. High PI values are associated with intracranial hemorrhage and serve as a determinant of poor clinical outcomes; however, as shown in another study and corroborated by our findings, no significant relationship was found between intracranial hemorrhage and PI.^{8,15}

Peak systolic velocity is associated with clinical outcomes and has been shown to be elevated in patients with hemorrhagic transformation.^{9,20} Previous studies have indicated that increases in blood pressure and PSV may lead to cerebral hyperperfusion.^{11,20} Although the PSV on

Table 4. Comparisons regarding edema				
Variables	Edema		Test statistics	
	No n=14	Yes n=6	Test value	p value
Sociodemographics variables, n (%)				
Female	3 (21.4)	3 (50.0)	1.633	0.303 [†]
Male	11 (78.6)	3 (50.0)		
Age	61.2±13.5	66.3±14.1	0.754	0.460 [†]
Smoking	11 (78.6)	2 (33.3)	3.778	0.122 [†]
Alcohol	4 (28.6)	0 (0.0)	2.143	0.267 [†]
Hypertension	7 (50.0)	3 (50.0)	-	-
Diabetes mellitus	4 (28.6)	1 (16.7)	0.317	>0.999 [†]
Atrial fibrillation	5 (35.7)	2 (33.3)	0.010	>0.999 [†]
Cardiac diseases	6 (42.9)	5 (83.3)	2.780	0.157 [†]
Hyperlipidemia	1 (7.1)	0 (0.0)	0.451	>0.999 [†]
Stroke	1 (7.1)	2 (33.3)	2.260	0.202 [†]
Clinical variables				
Admission NIHSS	14.5 (6.5)	14.5 (6.3)	0.290	0.779 ^{&}
Admission time (min)	120.0 (180.0)	90.0 (253.5)	0.457	0.659 ^{&}
IV-TPA, n (%)				
No	10 (71.4)	4 (66.7)	0.045	>0.999 [†]
Yes	4 (28.6)	2 (33.3)		
CTA collateral score	2.0 (1.0)	1.0 (0.5)	1.898	0.091 ^{&}
TICI score, n (%)				
2C	2 (14.3)	2 (33.3)	0.952	0.549 [‡]
3	12 (85.7)	4 (66.7)		
TCD evaluation time	10.0 (7.5)	1.5 (3.5)	2.787	0.003^{&}
Ipsilateral flow parameters				
PSV	94.8 (60.6)	125.5 (63.5)	1.485	0.153 ^{&}
EDV	45.2 (31.0)	42.7 (41.9)	0.701	0.494 ^{&}
TAMAX	60.4 (40.8)	92.0 (52.9)	1.650	0.109 ^{&}
PI	0.93 (0.67)	1.37 (1.30)	1.237	0.239 ^{&}
RI	0.59 (0.33)	0.74 (0.50)	1.077	0.312 ^{&}
Contralateral flow parameters				
PS	85.8 (39.5)	108.6 (19.8)	1.650	0.109 ^{&}
ED	38.4 (28.6)	47.5 (26.0)	0.577	0.602 ^{&}
TAMAX	60.0 (25.3)	72.4 (30.0)	0.495	0.659 ^{&}
PI	0.98 (0.76)	0.89 (0.94)	0.248	0.841 ^{&}
RI	0.60 (0.22)	0.57 (0.21)	0.580	0.602 ^{&}
Other variables				
24-hour NIHSS	3.5 (3.3)	14.5 (10.5)	3.237	<0.001^{&}
mRS 3-month	0.5 (1.5)	5.0 (3.0)	3.139	0.001^{&}
NIHSS: National Institutes of Health Stroke Scale, Iv-TPA: Intravenous thrombotic therapy, TICI: Thrombolysis in cerebral infarction, TCD: Transcranial Doppler, mRS: Modified Rankin scale, PSV: Peak systolic velocity, EDV: End-diastolic velocity, TAMAX: Time averaged mean velocity, PI: Pulsatility index, RI: Resistance index, min: Minutes, CTA: Computer tomography angiography				
n: Number of patients, %: Percentage, Numeric variables are summarized as median (minimum-maximum) values, †: Chi-square test, &: Exact Mann-Whitney U test				

Table 5. Relationship between edema and elevation of ipsilateral flow parameters

Variables	Edema		Test statistics	
	No	Yes	Test value	p value
PSV, n (%)				
Low	6 (42.9)	3 (50.0)	0.087	>0.999
High	8 (57.1)	3 (50.0)		
EDV, n (%)				
Low	6 (42.9)	2 (33.3)	0.159	>0.999
High	8 (57.1)	4 (66.7)		
TAMAX, n (%)				
Low	6 (42.9)	1 (16.7)	1.266	0.354
High	8 (57.1)	5 (83.3)		
PI, n (%)				
Low	6 (42.9)	1 (16.7)		
Same	1 (7.1)	0 (0.0)	2.059	0.533
High	7 (50.0)	5 (83.3)		
RI, n (%)				
Low	4 (28.6)	1 (16.7)		
Same	4 (28.6)	0 (0.0)	3.203	0.257
High	6 (42.9)	5 (83.3)		

PSV: Peak systolic velocity, EDV: End-diastolic velocity, TAMAX: Time averaged mean velocity, PI: Pulsatility index, RI: Resistance index. Difference = Ipsilateral-contralateral; n: Number of patients; %: Column percentage

the ipsilateral side was higher than on the contralateral side, no association with hemorrhagic transformation was demonstrated in our study. Additionally, the patients' blood pressure values were not associated with hemorrhagic transformation. Recording only a single measurement within the first 12 hours may have limited the ability to detect hyperperfusion. Furthermore, while our study found no difference between ipsilateral and contralateral sides in patients with edema, another study found that PSV on the affected side compared to the contralateral side was associated with an increased risk of edema.¹⁹ In 185 cases with acute anterior circulation LVO, Baracchini et al.²¹ assessed peak systolic velocity in the early phase at 48 h and 1 week following mechanical thrombectomy and found that a high ipsilateral/contralateral PSV ratio contributed to poor clinical outcomes but was not associated with edema. The lack of statistical significance in these results may be related to the small sample size, inappropriate timing of TCD assessments, and insufficient repetitions in our study.

Kneihsl et al.²² reported in a cohort of 123 ischemic stroke patients that a $\geq 30\%$ increase in MFV in the affected MCA within 72 hours after successful mechanical thrombectomy

was associated with hemorrhagic transformation and poor 90-day clinical outcomes. In contrast, Perren et al.,²³ in a study of 31 patients evaluated within 7 days after recanalization, found that a 35-40% increase in MFV in the affected MCA compared with the contralateral side was not associated with clinical deterioration. This discrepancy may be attributed to differences in the timing of TCD assessment, with earlier measurements potentially providing more prognostic value. Therefore, in our study, performing a TCD evaluation within the first 12 hours after EVT is an appropriate time to predict early neurological deterioration.

Cerebral edema is a significant issue affecting mortality and morbidity in acute stroke patients. In our study, the average NIHSS score for patients with edema at 24 hours was found to be 14.5, consistent with the findings of Wu et al.,²⁴ who reported that high NIHSS values were associated with edema and that patients with an NIHSS score ≥ 15 were at risk for developing edema. Similarly, this study found that edema was associated with poor collateral circulation, and our findings support this: patients with edema had worse collateral circulation.²⁴ The HERMES meta-analysis indicated that a high NIHSS score creates a risk for edema, and that EVT and reperfusion are associated with better functional outcomes; however, reperfusion times were not related to edema in patients undergoing EVT.²⁵ The lack of recorded reperfusion times in our study may have limited the evaluation of the results. Consistent with the conclusions of the HERMES meta-analysis, our study found that patients with edema had poor clinical outcomes at three months.²⁵

Hemorrhagic transformation is a complication that leads to neurological deterioration and poor functional outcomes, particularly after thrombolytic therapy in acute ischemic stroke.^{26,27} Consistent with previous studies, our findings indicated that hemorrhagic transformation was associated with high NIHSS scores.^{26,28} Hemorrhagic transformation is classified as symptomatic or asymptomatic intracranial hemorrhage. In the DEFUSE and DAWN studies, the rates of symptomatic ICH did not differ significantly between patients treated with or without EVT.^{4,5} Tian et al.²⁶ found that a time of more than 280 minutes between stroke onset and revascularization was associated with an increased risk of hemorrhagic transformation. In our study, this time was recorded as 180 minutes, which is longer (by 105 minutes) compared to patients without hemorrhagic transformation, but not statistically significant. This may be related to the small sample size. Although previous studies have indicated that more than three passes with a stent retriever increase the risk of ICH, the absence of recorded data on the number of passes and on thrombectomy technique in our study limits our ability to comment further on this association.^{26,29} According to our results, systolic

and mean blood pressure values were not associated with hemorrhagic transformation; previous studies have shown that high SBP and hemodynamic variability within the first 24 hours after EVT are associated with hemorrhagic transformation and poor clinical outcomes.^{27,30,31} The failure to record serial blood pressure measurements in our study may have contributed to this issue.

The three-months mRS score is used to evaluate functional independence in acute ischemic stroke. The literature indicates that functional independence rates in patients undergoing mechanical thrombectomy range from 33% to 60%, and our study found a rate of 55%, which supports the existing literature.³²⁻³⁴

Study Limitations

The most significant limitation of our study is the small number of patients who underwent mechanical thrombectomy. Some patients could not be included in the assessment due to unsuitable TCD windows. Regarding the study design, evaluations within the first 12 hours after mechanical thrombectomy were not feasible in some patients. Mechanical thrombectomy was not assessed in our study; future studies could compare the effects of vascular endothelial damage on various indices and demonstrate vascular wall responses by examining patients who underwent stent-retriever and ADAPT techniques. Additionally, recording the time to revascularization and the number of passes during mechanical thrombectomy is necessary to provide insights into these aspects.

CONCLUSION

TCD is increasingly used in neurology practice and for the follow-up of patients who have undergone mechanical thrombectomy. In our study, early assessment with TCD of patients undergoing mechanical thrombectomy in the acute stroke setting did not contribute to an early clinical response. To clarify these findings, prospective studies with larger sample sizes are needed.

Ethics

Ethics Committee Approval: This study was conducted in accordance with the ethical guidelines approved by the Non-Interventional Research Ethics Committee of University of Health Sciences Türkiye, İzmir Tepecik Training and Research Hospital, with decision number 2022/06-31 dated June 15, 2022.

Informed Consent: Informed consent was obtained from all participating patients.

Footnotes

Authorship Contributions

Surgical and Medical Practices: U.Ş., Concept: T.G.G., Design: D.F.B., U.Ş., Data Collection or Processing: T.G.G., Ü.B., Analysis or Interpretation: D.F.B., Literature Search: T.G.G., Writing: T.G.G., D.F.B.

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