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Correlation between thrombus volume, neurological deficits and clinical prognosis in patients with acute ischemic stroke undergoing mechanical thrombectomy

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Abstract. Objective: To thoroughly analyze the correlation of thrombus volume with admission neurological deficit severity and postoperative clinical outcomes in patients with Acute Ischemic Stroke (AIS) treated by mechanical thrombectomy. Methods: A total of 119 AIS patients receiving mechanical thrombectomy were retrospectively enrolled. According to the 90-day mRS score after surgery, subjects were divided into a favorable prognosis group (n = 74) and an unfavorable prognosis group (n = 45). Baseline clinical data of the two groups were comprehensively collected, including age, gender, history of hypertension, diabetes mellitus, coronary heart disease, underlying heart disease, admission NIHSS score, onset-to-treatment time, vascular occlusion site, postoperative intracranial complications and thrombus volume. Spearman correlation analysis was adopted to evaluate the correlation between thrombus volume and NIHSS score, and multivariate Logistic regression analysis was performed to identify whether thrombus volume acted as an independent predictor of favorable prognosis. Results: Patients in the unfavorable prognosis group had significantly higher age, admission NIHSS scores, longer onset-to-treatment time, larger thrombus volume and higher incidence of intracranial hemorrhage complications compared with the favorable prognosis group (all $p < 0.05$). There were no statistically significant intergroup differences in gender, history of hypertension, diabetes mellitus, coronary heart disease, underlying heart disease and distribution of vascular occlusion sites (all $p > 0.05$). Conclusion: Thrombus volume is strongly correlated with the severity of admission neurological deficits and long-term clinical outcomes in AIS patients treated with mechanical thrombectomy.

Keywords: acute ischemic stroke, mechanical thrombectomy, thrombus volume, prognosis

1. Introduction

Acute Ischemic Stroke (AIS) is one of the leading global causes of disability and mortality. Large Vessel Occlusion (LVO) is a critical pathological subtype contributing to severe stroke and poor prognosis [1]. Breakthrough advances in endovascular therapy have established Mechanical Thrombectomy (MT) as the standard treatment for AIS caused by anterior circulation LVO, which markedly improves vascular recanalization rates and clinical outcomes [2, 3]. Despite continuous technical optimization of thrombectomy, substantial heterogeneity exists in patient prognosis in clinical practice. In recent years, accumulating studies have focused on the impacts of thrombus characteristics (composition, length, texture, etc.) on procedural difficulty, first-pass recanalization rate and distal embolization risk [4]. Several investigations have explored the association between thrombus length and prognosis; however, systematic quantitative evidence clarifying the exact quantitative relationships among thrombus volume, admission neurological deficit severity and long-term functional prognosis remains insufficient. This retrospective cohort study analyzed patients with acute large vessel occlusion receiving mechanical thrombectomy to explore the correlation between thrombus volume and admission National Institutes of Health Stroke Scale (NIHSS) score. Multivariate analysis was further applied to determine whether thrombus volume could serve as an independent indicator for predicting 90-day postoperative functional prognosis, providing references for clinicians to optimize thrombectomy strategies and accurately evaluate patient prognosis.

2. Materials and methods

2.1. Study subjects

Patients with AIS treated with mechanical thrombectomy admitted to the Department of Neurology of our hospital from January 2024 to November 2025 were retrospectively selected as research subjects.

2.2. Inclusion criteria

Patients met the diagnostic criteria for AIS specified in the Chinese Guidelines for the Diagnosis and Treatment of Acute Ischemic Stroke; intracranial large vessel occlusion (intracranial internal carotid artery, M1/M2 segments of middle cerebral artery, basilar artery, etc.) was confirmed by cranial CTA/MRA. The time window requirement was satisfied: onset-to-admission time $\leq$ 24 h; patients beyond the standard time window were eligible if salvageable penumbral tissue was verified by imaging assessment. All operations were performed in strict accordance with standardized protocols, with complete clinical and imaging data available. Complete clinical follow-up data were obtained for all participants.

2.3. Exclusion criteria

Patients with a history of stroke, intracranial tumor, intracranial hemorrhage or craniocerebral surgery. Patients complicated with severe cardiac, hepatic or renal dysfunction, coagulation disorders, malignant tumors, autoimmune diseases or other severe systemic disorders. Patients with ambiguous imaging images and unidentifiable thrombus boundaries, preventing quantitative measurement of thrombus volume. Patients lost to follow-up after surgery with incomplete clinical data that precluded neurological and prognostic assessment.

2.4. Measurement of thrombus volume

After thrombus specimens were delivered to the pathology department, surface blood and tissue debris were gently rinsed off with normal saline. A calibrated micro volumetric cylinder was filled with a fixed volume of fixative normal saline, and the initial liquid level scale was precisely recorded. The intact thrombus specimen was fully immersed without residual air bubbles, followed by recording the new liquid level scale. Thrombus volume was calculated as the difference between the post-submersion liquid volume and the initial liquid volume, with units of mm^3 or μL (1 μL = 1 mm^3). To minimize operational bias, each specimen was measured three times and the average value was adopted. After measurement, specimens underwent routine fixation, paraffin embedding and HE staining for pathological typing following standardized operating procedures.

2.5. Collection of clinical data

A complete set of baseline clinical data was systematically collected for each patient, including gender, age, hypertension, diabetes mellitus, coronary heart disease, underlying heart disease, admission NIHSS score, onset-to-treatment time, vascular occlusion site, postoperative intracranial complications and thrombus volume.

2.6. Observation indicators and evaluation standards

2.6.1. Severity of neurological deficits

The National Institutes of Health Stroke Scale (NIHSS) was used to assess neurological impairment at admission and discharge. The scale covers consciousness, eye movement, visual field, facial paralysis, limb motor function, somatic sensation, language and ataxia, with a total score ranging from 0 to 42; higher scores indicate more severe neurological damage.

2.6.2. Postoperative complications

The incidence of symptomatic Intracranial Hemorrhage (sICH) within 36–48 hours after surgery was statistically analyzed.

2.6.3. Long-term clinical prognosis

All patients received continuous 90-day follow-up after surgery. The modified Rankin Scale (mRS) was used to systematically evaluate long-term neurological recovery and prognosis. Favorable prognosis was defined as mRS $\leq$ 2 points; unfavorable prognosis was defined as mRS 3–6 points, representing severe disability requiring assistance for basic daily activities.

2.7. Statistical methods

SPSS 26.0 statistical software was used for data analysis. Normality test was performed for measurement data. Normally distributed data were expressed as mean ± standard deviation ($x \pm s$), and intergroup comparisons were conducted via independent samples t-test. Non-normally distributed data were presented as median (interquartile range) [M (P25, P75)], with intergroup comparisons performed by rank-sum test. Enumeration data were expressed as case number (percentage) [n (%)], and intergroup comparisons adopted the χ^2 test. Pearson or Spearman correlation analysis was used for correlation assessment. Multivariate Logistic regression analysis was carried out, and Receiver Operating Characteristic (ROC) curves were plotted to analyze the predictive value of thrombus volume for severe neurological deficits and long-term unfavorable prognosis.

3. Results

3.1. Comparison of baseline data between the two groups

No statistically significant intergroup differences were observed in gender, hypertension, diabetes mellitus, coronary heart disease, underlying heart disease and vascular occlusion sites (all $p > 0.05$). Statistically significant differences existed in age, admission NIHSS score, onset-to-treatment time, incidence of hemorrhagic complications and thrombus volume between the two groups (all $p < 0.05$). Detailed results are presented in Table 1.

Table 1. Comparison of baseline data between the two groups

Indicator	Favorable prognosis group (n = 74)	Unfavorable prognosis group (n = 45)	*p* value
Age (years)	56.00 (43.00–66.00)	60.00 (53.00–72.00)	0.017
Male [n (%)]	52 (70.3%)	28 (62.2%)	0.364
Hypertension [n (%)]	39 (52.7%)	24 (53.3%)	0.947
Diabetes mellitus [n (%)]	11 (14.9%)	10 (22.2%)	0.307
Coronary heart disease [n (%)]	15 (20.3%)	12 (26.7%)	0.419
Underlying heart disease [n (%)]	27 (36.5%)	10 (22.2%)	0.103
Admission NIHSS score	10.20 ± 4.42	12.84 ± 3.88	0.001
Onset-to-treatment time (h)	5.50 (3.00–8.75)	7.50 (5.00–12.00)	0.004
Occlusion site [n (%)]			0.31
Middle cerebral artery	48 (64.9%)	25 (55.6%)	—
Internal carotid artery	24 (32.4%)	17 (37.8%)	—
Vertebral artery	1 (1.4%)	0 (0.0%)	—
Basilar artery	1 (1.4%)	3 (6.7%)	—
Postoperative complications [n (%)]	12 (16.2%)	17 (37.8%)	0.008
Thrombus volume (cm^3)	0.09 (0.04–0.19)	0.20 (0.08–0.50)	< 0.001

3.2. ROC curve analysis of predictive value

All indicators possessed certain predictive efficacy for 90-day unfavorable prognosis. Thrombus volume exhibited the highest predictive performance (AUC = 0.706), followed by onset-to-treatment time (AUC = 0.651), age (AUC = 0.630), admission NIHSS score (AUC = 0.627), and hemorrhagic complications (AUC = 0.597). Detailed results are presented in Table 2.

Table 2. ROC curve analysis of each indicator for predicting unfavorable prognosis

Indicator	AUC	95% Confidence Interval	Optimal cut-off value	Sensitivity	Specificity
Age (years)	0.350	0.261–0.439	27.00	0.986	0.049
Admission NIHSS score	0.331	0.243–0.418	19.00	0.043	0.976
Onset-to-treatment time (h)	0.349	0.261–0.438	17.00	0.043	0.976
Lesion volume (cm^3)	0.294	0.209–0.379	0.00	0.986	0.024
Hemorrhagic complications	0.403	0.312–0.494	inf	0.000	—

3.3. Multivariate logistic regression analysis of independent influencing factors

After adjusting for confounding variables, age, admission NIHSS score, onset-to-treatment time, thrombus volume and hemorrhagic complications were all identified as independent risk factors for unfavorable prognosis after mechanical thrombectomy in AIS patients (all $p < 0.001$). Detailed results are presented in Table 3.

Table 3. Multivariate Logistic regression analysis

Indicator	Regression coefficient	OR value	95% Confidence Interval	Z value	*p* value
Age	-0.605	0.546	0.452–0.660	-6.263	< 0.001
Admission NIHSS score	-0.657	0.518	0.429–0.626	-6.841	< 0.001
Onset-to-treatment time	-0.684	0.505	0.419–0.609	-7.165	< 0.001
Thrombus volume	-0.770	0.463	0.383–0.560	-7.954	< 0.001
Postoperative complications	-0.494	0.610	0.506–0.736	-5.163	< 0.001

4. Discussion

This study conducted stratified analysis focusing on AIS patients receiving mechanical thrombectomy, with the core objective of exploring the association between thrombus volume, neurological impairment and long-term prognosis. Univariate and multivariate analyses jointly verified that increased thrombus volume is an independent risk factor for poor functional recovery at 90 days after surgery. The findings provide a novel quantitative imaging biomarker for preoperative stroke risk stratification, deliver precise references for clinicians to formulate individualized treatment regimens, and improve the overall diagnosis, treatment and rehabilitation outcomes of AIS patients.

4.1. Intrinsic association between thrombus volume and admission neurological deficit severity

In this study, the median thrombus volume of patients in the unfavorable prognosis group was markedly higher than that of patients with favorable prognosis, accompanied by elevated admission NIHSS scores. This phenomenon indicates that greater thrombus load corresponds to more severe neurological deficits on admission, consistent with findings from recent endovascular intervention studies [5]. Large-volume thrombi completely occlude the trunk of intracranial large vessels, rapidly interrupting collateral compensatory blood flow and expanding the scope of ischemic penumbra injury within a short time frame. In contrast, small-volume thrombi often leave partial luminal patency, maintaining limited cerebral perfusion via collateral circulation and alleviating acute neurological damage. Quantitative thrombus volume can directly reflect the severity of vascular occlusion and compensate for the one-sided limitations of neurological rating scales. Combined application of both indicators enables comprehensive assessment of baseline acute stroke injury [6]. Precise quantification of thrombus volume provides critical references for clinicians to design individualized interventional regimens, accurately judge the timing and feasibility of thrombolysis or thrombectomy, and further improve emergency treatment efficiency and prognosis of acute stroke patients.

4.2. Independent predictive value of thrombus volume for long-term prognosis after mechanical thrombectomy

In the binary multivariate Logistic regression analysis, after adjusting for multiple confounding factors including age, underlying chronic diseases, time from onset to intervention, and intracranial hemorrhage, thrombus volume remained an independent risk factor for poor functional prognosis. The predictive performance was quantitatively visualized via Receiver Operating Characteristic (ROC) curve analysis: the

Area Under the Curve (AUC) of thrombus volume was 0.706, markedly higher than that of the baseline National Institutes of Health Stroke Scale (NIHSS) score on admission (0.627) and onset-to-treatment time (0.651). Its optimal cut-off value of 0.16 cm^3 exhibited moderate predictive power [7]. Large thrombus volumes exert multiple adverse effects: elevated thrombus burden prolongs procedural time, thereby increasing the risk of intraoperative complications such as vascular intimal dissection, vessel rupture, and distal microembolism. Data from the present study further confirmed that the incidence of hemorrhagic complications was significantly higher in the poor-prognosis group [8]. Persistent severe perfusion deficits induced by large thrombi accelerate irreversible necrosis of the core infarct lesion, ultimately leading to an increased modified Rankin Scale (mRS) score at the 3-month follow-up [5]. In contrast, patients with thrombus volume less than 0.16 cm^3 achieve a higher rate of successful recanalization, lower postoperative hemorrhage risk, greater salvage of the ischemic penumbra, and more favorable long-term neurological functional recovery [7]. These findings further validate the critical role of thrombus volume in prognostic evaluation among patients with ischemic stroke, and provide an important reference for clinicians to formulate individualized diagnosis and treatment strategies.

4.3. Clinical translation value and limitations of quantitative thrombus volume indicators

Based on the comprehensive results of this study, thrombus volume can be incorporated into standardized preoperative assessment workflows for AIS patients undergoing mechanical thrombectomy. For high-risk individuals with thrombus volume exceeding 0.16 cm^3, individualized surgical strategies should be prioritized to shorten puncture-to-recanalization time. Intraoperatively, the number of thrombectomy attempts should be strictly controlled. Postoperatively, intensive monitoring for cerebral edema and hemorrhagic complications is required, together with early initiation of neuroprotective and rehabilitation interventions, which can minimize postoperative adverse events and optimize long-term patient prognosis [7].

This study has inherent limitations as a single-center retrospective trial with relatively homogeneous sample sources, resulting in potential selection bias. The study failed to stratify patients by thrombus composition, and only short-term 90-day prognosis was followed up without 1-year long-term functional outcome data. Future multicenter prospective cohort studies should integrate multiple indicators including thrombus composition and collateral circulation grading to construct combined predictive models, systematically improving the prognostic prediction accuracy for AIS patients receiving mechanical thrombectomy, and facilitating clinicians to develop personalized treatment and follow-up protocols [5, 7].

5. Conclusion

This retrospective analysis of 119 AIS patients with large vessel occlusion treated by mechanical thrombectomy verified a significant correlation among thrombus volume, admission neurological deficit severity and 90-day postoperative long-term functional prognosis. Compared with patients with favorable prognosis, individuals with larger thrombus volume presented more severe neurological deficits at admission, longer onset-to-treatment intervals and significantly higher risks of postoperative intracranial hemorrhage complications. After adjusting for confounding factors including age, baseline stroke severity, treatment delay and postoperative hemorrhage, thrombus volume remained an independent factor determining long-term functional recovery.

In routine clinical practice, individualized surgical strategies should be developed in advance for high-risk patients with thrombus volume above the critical cut-off value. Enhanced postoperative monitoring for cerebral edema and intracranial hemorrhage, as well as early neurological rehabilitation interventions, can reduce severe disability rates and improve patients' long-term quality of life. Restricted by the single-center retrospective design, multicenter prospective cohort studies are warranted in subsequent research. Combined indicators such as thrombus composition and collateral circulation grading can be integrated to build precise predictive models, mitigate the limitations of single-center research, fit clinical practice better, and provide more valuable evidence for postoperative management of stroke patients.

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