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Original Article

Comparable efficacy and safety of bridging therapy versus direct mechanical thrombectomy in anterior circulation large vessel occlusion stroke

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Abstract: Objective: To compare the clinical and procedural outcomes, as well as complication rates, between bridging therapy (BT) and direct mechanical thrombectomy (D-MT) in patients with acute ischemic stroke (AIS) due to anterior circulation large vessel occlusion (LVO). Methods: In this retrospective cohort study, 169 patients who underwent endovascular therapy (EVT) between January 2021 and January 2024 were included. Patients were divided into a BT group (n=96, intravenous alteplase followed by thrombectomy) and a D-MT group (n=73, thrombectomy alone). Baseline characteristics, procedural data, and 90-day functional outcomes were compared. Multivariable logistic regression identified predictors of 90-day favorable outcome (modified Rankin Scale score 0-2). Results: Baseline characteristics were balanced between the groups (all $P>0.05$). The BT group showed a numerically higher rate of 90-day favorable functional outcome (56.25% vs. 46.58%, $P=0.212$) and lower mortality rate (4.17% vs. 10.96%, $P=0.089$), but differences were not statistically significant. Recanalization rates (modified Thrombolysis in Cerebral Infarction (mTICI) 2b/3: ~95%) and complication rates (hemorrhagic transformation, post-awakening stroke) were similar between the groups (all $P>0.05$). In regression analysis, smoking history, baseline National Institutes of Health Stroke Scale (NIHSS) score, and collateral circulation grade were independent predictors of outcome, while treatment modality was not. Conclusion: BT and D-MT demonstrate comparable efficacy and safety in treating anterior circulation LVO. The choice of strategy should consider patient-specific factors such as baseline neurological status and collateral circulation, rather than presumed superiority of either modality.

Keywords: Acute ischaemic stroke, bridge therapy (BT), direct mechanical thrombectomy (D-MT), endovascular therapy (EVT), functional prognosis, complications

Introduction

As a major contributor to global mortality and long-term disability, stroke exerts substantial pressure on healthcare infrastructures, driven by its elevated incidence, persistent disability burden, and high risk of recurrence [1]. WHO estimates indicate an annual global incidence of stroke exceeding 15 million, of which acute ischemic stroke (AIS) constitutes approximately 87% [2]. Stroke is now the top cause of mortality in China's population, with an estimated 2.4 million incident cases reported each year. The condition is increasingly affecting younger populations, with a prevalence rate of 2.32% among those aged 40 and above, imposing a heavy economic burden on society and families [3].

The pathological core of AIS is neuronal ischemic necrosis caused by interrupted cerebral blood perfusion. Brain tissue exhibits extremely poor tolerance to ischemia-after complete cessation of cerebral blood flow, each minute of delayed reperfusion can result in the death of up to 1.9 million neurons. This directly underpins the "time is brain" principle in treatment [4, 5]. Endovascular thrombectomy is now considered standard-of-care for patients with AIS with large vessel occlusion (LVO) presenting within 6 hours of onset, given that this stroke subtype accounts for a substantial proportion

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of all AIS cases [6]. Compared to small vessel occlusion, patients with anterior circulation LVO present with more severe disease and greater baseline neurological deficits (typically with a median National Institutes of Health Stroke Scale (NIHSS) score ≥ 10). Their natural prognosis is extremely poor: without timely intervention, 90-day mortality can reach 30-50%, and approximately 70% of survivors will experience moderate to severe disability.

Advances in endovascular therapy have fundamentally transformed the therapeutic landscape for anterior circulation LVO. Pivotal clinical trials consistently show that, when administered within 6 hours of onset, endovascular therapy (EVT) leads to higher rates of successful recanalization, improved functional independence at 90 days, and lower disability burden [7]. Based on this evidence, current international guidelines universally classify EVT as a Class I recommended treatment for anterior circulation LVO [8]. However, controversy persists regarding the optimal EVT strategy, with the debate over whether bridging therapy (BT) or direct mechanical thrombectomy (D-MT) is superior remaining a focal point in the stroke field.

EVT has become a key treatment modality for AIS, particularly in managing LVO in the anterior circulation [9-12]. Multiple studies have demonstrated the efficacy of EVT, including MR CLEAN [9, 10], ESCAPE [9], EXTEND-IA [9, 10]. These studies evaluated the efficacy of endovascular therapy for ischemic stroke, employing different selection criteria and vascular recanalization devices [10]. However, the relative advantages of BT and D-MT in pre-cycle therapy remain a subject of ongoing debate.

BT is based on the synergistic concept of intravenous thrombolysis and mechanical thrombectomy. The procedure involves administering intravenous recombinant tissue plasminogen activator (rt-PA) for thrombolysis in eligible patients, followed by mechanical thrombectomy. Theoretically, this approach reduces thrombus burden, improves collateral circulation, and dissolves residual thrombi. Early randomized controlled trials (RCTs) provided key evidence supporting the adoption of bridge therapy. While demonstrating certain benefits in AIS management, limitations of BT have gradually emerged. First, intravenous thrombolysis is subject to strict time window constraints, with current guidelines recommending administration within 4.5 hours of symptom onset [13]. Patients beyond this window derive no benefit and may even face increased hemorrhagic risk [14]. For example, Wang et al. [14] demonstrated that hemorrhagic transformation significantly impacts prognosis in acute cerebral infarction patients receiving intravenous (IV) thrombolysis. Second, approximately 15-20% of patients have contraindications to thrombolysis (e.g., prior intracranial hemorrhage, recent surgery, coagulation disorders), rendering them ineligible for rt-PA therapy [15]. Zheng et al. [15] noted that in elderly patients with cerebral infarction, analysis of factors associated with early intracranial hemorrhage following intravenous rt-PA thrombolysis revealed multiple contraindications that increase bleeding risk. Furthermore, the interval between thrombolysis and thrombectomy may delay vascular recanalization. Studies indicate that the median time from initiation of intravenous thrombolysis to femoral artery puncture is approximately 40 minutes, and this delay may negate the benefits of thrombolysis. Groot et al. [16] emphasized that time management in out-of-hospital stroke is critical for reperfusion therapy efficacy, necessitating minimization of the time from hospital admission to treatment initiation. Finally, hemorrhagic transformation associated with intravenous thrombolysis, particularly symptomatic intracranial hemorrhage, remains a significant risk, occurring at a rate of approximately 3-6% and is strongly associated with poor outcomes [17, 18]. Chen et al. [17] investigated the temporal pattern between rt-PA administration and symptomatic intracranial hemorrhage (sICH) in AIS patients, highlighting the risk of sICH occurrence. Mori et al. also demonstrated that neurological deterioration within 24 hours after intravenous rt-PA administration in stroke patients correlates with poor outcomes [18].

D-MT omits the thrombolysis step, aiming to shorten time to reperfusion (TTR). It is indicated for patients beyond the thrombolysis time window, with contraindications to thrombolysis, or with unknown onset time. With iterative improvements in thrombectomy devices and technological advancements, its reperfusion rates can exceed 90%, comparable to those of BT [19, 20]. In recent years, several

RCTs have compared D-MT and BT. As the SKIP trial demonstrated, in anterior circulation LVO patients within 4.5 hours of symptom onset, D-MT and BT had no notable difference in 90-day favorable functional outcome proportions, but the D-MT group saw fewer symptomatic intracranial hemorrhages [21]. The DIRECT-MT trial verified that D-MT is not inferior to BT.

The DIRECT-MT trial confirmed D-MT's noninferiority to BT with shorter operative times [19, 22, 23], challenging BT's status as the "gold standard". These studies suggest that D-MT may be a superior option for certain patients [24]. However, controversies surrounding D-MT persist. On one hand, subgroup analyses of the aforementioned RCTs indicate that for patients with shorter onset times (<3 hours) and lower baseline NIHSS scores (<10 points), BT may still hold advantages [25]. On the other hand, long-term outcome data for D-MT (e.g., 1-year survival rates, reocclusion rates) remain insufficient. For patients with substantial thrombus burden or dense thrombus consistency, mechanical thrombectomy alone may require multiple attempts, thereby increasing the risk of vascular injury [26]. Furthermore, variations in patient inclusion criteria across studies (e.g., time-to-treatment windows, collateral circulation status) complicate direct comparison of results, contributing to the cautious stance maintained by relevant guidelines regarding D-MT recommendations [27].

In light of the clinical context outlined above, a cohort of 169 patients with confirmed acute anterior circulation LVO who received EVT at our institution's neurology and neurointerventional unit between January 2021 and January 2024 was retrospectively enrolled in this study. These patients were divided into two groups: the BT group (n=96) and the D-MT group (n=73). Through retrospective analysis of clinical data from anterior circulation stroke patients, this study compared differences between bridging therapy and direct mechanical thrombectomy in terms of clinical functional outcomes, procedure-related metrics, and complication rates. We performed multivariable logistic regression to determine which variables independently predicted clinical outcomes. The aim is to provide more targeted reference for clinical treatment decisions, optimize individualized treatment plans, ultimately improve stroke patient outcomes, and reduce disability and mortality rates.

Research methods

Research subjects

This retrospective cohort study consecutively enrolled 169 patients diagnosed with acute anterior circulation LVO and undergoing EVT at our hospital's Department of Neurology and Neurointerventional Center between January 2021 and January 2024. Patients were categorized into the BT group (n=96) and D-MT group (n=73) based on treatment modality. BT Group: Patients first received intravenous rt-PA thrombolysis (dosage: 0.9 mg per kilogram of body weight, with a maximum dose of 90 mg; 10% was given as a bolus injection, and the remaining 90% was intravenously infused over 60 minutes), followed by mechanical thrombectomy during or after rt-PA infusion. D-MT group: Patients underwent direct mechanical thrombectomy without intravenous thrombolysis.

By comparing postoperative clinical indicators between the two patient groups (90-day modified Rankin Scale (mRS), 90-day mortality, NIHSS score, recanalization rate [modified Thrombolysis in Cerebral Infarction (mTICI) 2b/3 rate], Fazekas grade, and 90-day moderate-to-severe disability rate), this study provides a theoretical foundation for treating anterior circulation stroke patients in clinical practice. The detailed workflow is shown in **Figure 1**.

Inclusion criteria

(1) Patients met the diagnostic criteria for acute ischemic stroke and is confirmed as a LVO in the anterior circulation; (2) The pre-onset mRS score was less than 2; (3) The age was ≥ 18 years; (4) The clinical documentation was complete [28, 29].

Exclusion criteria

(1) Posterior circulation vascular occlusion [11]; (2) Absolute contraindications for IVT; (3) Severe hepatic or renal insufficiency, coagulation disorders; (4) Pregnant or lactating women; (5) Participants who discontinued treatment or were lost to follow-up.

Ethical statement

Ethical approval was granted by the Clinical Research Ethics Committee of the First Affiliated Hospital of Soochow University (Approval

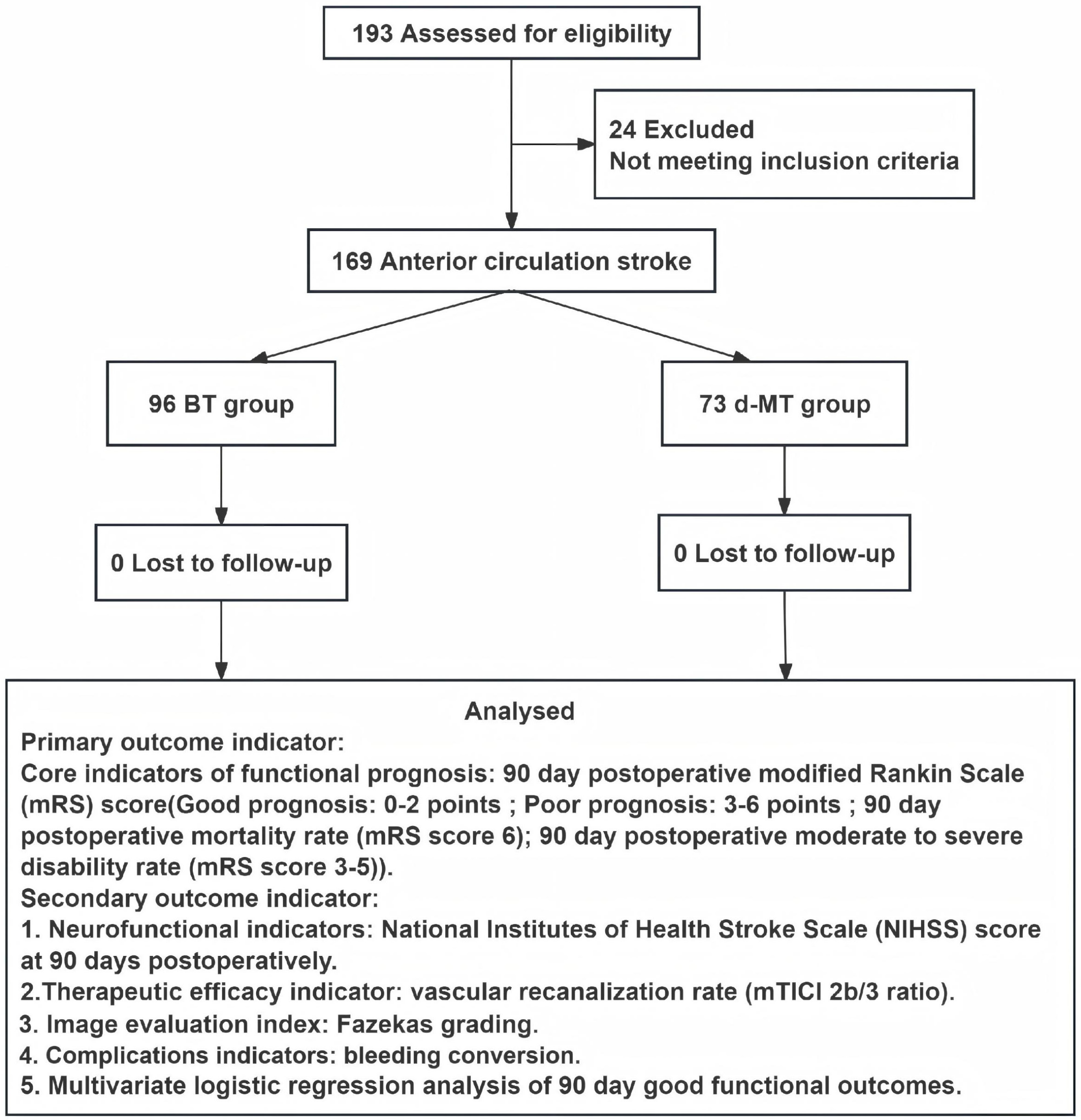

Figure 1. Research flowchart. Note: BT, bridging therapy; D-MT, direct mechanical thrombectomy.

No. 2024-022), and the study complied with the Declaration of Helsinki and international standards for medical research ethics [30]. As a retrospective analysis based on archived clinical data, the ethics committee granted a waiver of informed consent. All data were anonymized to fully protect participant privacy and confidentiality throughout the research.

Sample size calculation

Sample size calculations were done with G-Power software [31]. The study estimated a 50% rate of favorable patient outcomes after endovascular treatment. An effect size (Cohen's h) of 0.5 was chosen, representing a medium effect size commonly used in clinical research for comparing proportions [32]. The significance level (α) was set at 0.05 (two-tailed), and a statistical power (1-β) of 0.85 was targeted. These parameters showed that 59 participants per group were needed, totaling 118. Considering a 20% dropout rate, the adjusted sample size became 142. In the end, the study enrolled 169 participants, which was more than the target sample size and met the research's statistical requirements.

Research design

Participants were stratified into two cohorts according to the therapeutic approach received:

Bridge therapy group (BT Group) [33]: Patients first received intravenous rt-PA thrombolysis, followed by mechanical thrombectomy during or after rt-PA infusion.

Direct mechanical thrombectomy group [33]: Patients did not receive intravenous thrombolysis and underwent direct mechanical thrombectomy.

Treatment selection was determined by a multidisciplinary team (including neurointerventionalists, neurologists, and radiologists) based on individual patient factors (e.g., time since onset, baseline NIHSS score, imaging characteristics, family consent).

All patients underwent EVT under general anesthesia or local anesthesia with sedation. The femoral or radial artery was punctured using the Seldinger technique, followed by arterial sheath placement. Angiography was performed to identify the occlusion site and assess collateral circulation (using the ASITN/SIR collateral grading system). Thrombectomy devices were selected based on thrombus characteristics and vascular anatomy (e.g., Solitaire FR or Trevo XP stenting systems, or penumbra systems for aspiration; combined use when necessary). The procedural goal was to achieve vascular recanalization (mTICI ≥ 2b). Postoperatively, routine antiplatelet therapy was administered, and baseline parameters such as blood pressure and blood glucose were adjusted according to the patient's condition.

Observation indicators

Baseline data: Including age, gender, medical history (hypertension, diabetes, atrial fibrillation, etc.), smoking history, alcohol consumption history, baseline NIHSS score, etiological classification (macroarterial atherosclerosis, cardiogenic embolism), and collateral circulation grading.

Key indicators: Core functional prognosis indicator: 90-day mRS post-surgery [34]: The mRS score ranges from 0 to 6, with 0 being the lowest and 6 the highest. Higher scores indicate poorer clinical outcomes, with a score of 6 denoting death. (Further categorized as "favorable prognosis: 0-2 points" and "poor outcome: 3-6 points"; 90-day postoperative mortality rate [mRS 6 points]; 90-day postoperative moderate-to-severe disability rate [mRS 3-5 points]).

Secondary indicators: (1) Neurological function indicators: NIHSS Scores at 24 hours and 7 days post-surgery [35]: The NIHSS assesses stroke-related neurological deficits across 11 domains: consciousness, gaze, vision, facial movement, arm/leg strength, ataxia, sensation, language, articulation, and spatial awareness. Each item is scored 0-4 points based on impairment severity (some items range 0-2 points), yielding a total score of 0-42 points.

(2) Treatment outcome measure: Recanalization rate (mTICI Grade 2b/3 Proportion) [34]: Postoperative angiography assesses reperfusion. mTICI grade of 2b/3 indicates successful vessel recanalization.

(3) Imaging assessment indicator: Fazekas scale [36] (a visual grading system for assessing white matter lesions in neuroimaging; typically ranges from 0 to 3, with each grade representing a different severity of white matter damage).

(4) Complication indicators: Hemorrhagic transformation [37] (a major complication of AIS requiring early identification via imaging [CT/MRI] and clinical assessment, classified according to ECASS criteria).

(5) Multivariate logistic regression analysis for favorable functional outcomes at 90 days.

Statistical analysis

All statistical analyses were performed using SPSS software (version 25.0; IBM Corp.). Continuous variables were assessed for normality using the Shapiro-Wilk test. Data conforming to a normal distribution are presented as mean ± standard deviation (SD) and were compared between the two independent groups (BT vs. D-MT) using the independent-samples t test (for homogeneity of variance) or Welch's t test (for heterogeneity of variance), as appropriate. Non-normally distributed continuous data are presented as median with interquartile range (IQR) and were compared using the Mann-Whitney U test. Categorical variables are presented as counts and percentages [n (%)] and were compared using the Pearson χ^2 test or Fisher's exact test when expected cell counts were less than 5. For all analyses, a two-tailed P value <0.05 was considered statistically significant. To identify independent predictors of a favorable functional outcome (defined as modified Rankin Scale score of 0-2 at 90 days), variables showing a significant association ($P<0.05$) in univariate analyses were entered into a multivariable binary logistic regression model. Results are presented as adjusted odds ratios (OR) with their corresponding 95% confidence intervals (CI).

Results

Comparison of baseline data for patients

This study included 169 patients (96 in the BT group and 73 in the D-MT group). Comparison of baseline characteristics between the BT Group and the D-MT Group, including age, gender, underlying diseases, smoking history, alcohol consumption history, baseline NIHSS score, etiological classification, and collateral circulation grading, revealed no statistically significant differences ($P>0.05$), indicating comparability between the groups (**Table 1**).

Comparison of core functional prognosis indicators

Table 2 compares the prognostic outcomes between the two patient groups. Results show that the 90-day favorable prognosis rate was 56.25% in the BT group and 46.58% in the D-MT group. Although the BT group had a higher 90-day favorable prognosis rate than the D-MT group, the difference between the two groups was not statistically significant (χ^2= 1.555, $P=0.212$). The 90-day mortality rate in the BT group was 4.17%, and the incidence of moderate to severe disability was 39.58%, both lower than those in the D-MT group (10.96%, 42.47%). The differences between the two groups were not statistically significant ($\chi^2=2.900$, $P=0.089$; $\chi^2=0.143$, $P=0.706$). These results indicate that for patients with anterior circulation stroke, the BT group demonstrated a certain prognostic advantage, while the two treatment regimens showed no significant difference in overall prognosis.

Comparison of neurological function indicators

Table 3 presents the comparison of NIHSS scores between patients receiving the two treatment modalities via the Mann-Whitney U Test, with median values indicating neurological improvement. Results indicate that the 24-hour neurological improvement in the BT group (8) was superior to that in the D-MT group (11), though the difference was not statistically significant ($P=0.244$). The BT group (4) showed better 7-day neurological improvement than the D-MT group (7), but the difference was not statistically significant ($P=0.742$). Results indicate that bridge therapy is beneficial for neurological improvement in patients with anterior circulation stroke, but the difference compared with direct mechanical thrombectomy is not significant ($P>0.05$).

Comparison of treatment effectiveness indicators

Table 4 compares treatment outcomes between patients receiving two therapeutic approaches using chi-square analysis. Results show that the recanalization rate (mTICI grade: 2b/3) in the BT group was 94.79%, while that in the D-MT group was 95.89%. However, no statistically significant difference was observed between the two groups ($\chi^2=0.001$, $P=0.973$). The results indicate that treatment outcomes for patients with anterior circulation stroke are independent of the selected treatment modality.

Image evaluation

Table 5 compares imaging assessment metrics between patients receiving two treatment modalities via chi-square test. Results indicate that the proportion of patients with Fazekas grade 0 in the BT group (19.79%) was higher than that in the D-MT group (12.33%), while the proportion with Fazekas grade 1 in the BT group (45.83%) was lower than that in the D-MT group (65.75%). The proportion of Fazekas grade 2 lesions in the BT group (32.29%) was higher than that in the D-MT group (21.92%), and the proportion of Fazekas grade 3 lesions in the BT group (2.08%) was higher than that in the D-MT group (0%). The differences between the two treatment groups were not statistically significant ($P=0.056$). Additionally, based on

Table 1. Comparison of baseline characteristics

Variable	BT group *n*=96	D-MT group *n*=73	Test	*95% CI*	Effect size	*P* value
Gender						
Male	58	40	Chi-Square Test	-	0.538	0.463
Female	38	33				
Age (years)	64.03±13.97	63.14±12.89	Independent-samples t test	-3.249-5.037	0.426	0.671
Underlying disease						
Hypertension	54	46	Chi-Square Test	-	0.785	0.376
Diabetes	10	15	Chi-Square Test	-	3.377	0.066
Atrial fibrillation	37	35	Chi-Square Test	-	1.500	0.221
History of smoking	13	4	Chi-Square Test	-	2.979	0.084
Drinking history	6	4	Chi-Square Test	-	0.044	0.833
Baseline NIHSS score (M(IQR))	12.5 (9-17)	13.0 (10-17)	Mann-Whitney U Test	-	-0.803	0.422
Etiological Classification						
Aortic Atherosclerosis	55	35	Chi-Square Test	-	1.455	0.228
Cardiac Embolism	41	38				
Collateral Circulation Grading						
Ineffective Collateral Circulation Group (0-1)	75	50	Chi-Square Test	-	1.998	0.158
Effective Collateral Circulation Group (2-4)	21	23				
7-Day Survival	93	70	Chi-Square Test	-	0.021	0.790
7-Day Mortality	3	3				
LDL-C ([M(IQR), mmol/L])	2.83 (2.22-3.20)	2.56 (1.86-3.13)	Mann-Whitney U Test	-	-1.136	0.256
Blood glucose ([M(IQR), mmol/L])	6.70 (5.80-7.78)	6.48 (5.50-8.24)	Mann-Whitney U Test	-	-0.367	0.714
Systolic blood pressure (mmHg)	143.90±23.82	137.23±25.06	Independent-samples t test	-0.807-14.133	1.761	0.080
Diastolic blood pressure (mmHg)	84.50±16.42	80.08±19.01	Independent-samples t test	-0.972-9.808	1.618	0.108

Note: BT, bridging therapy; D-MT, direct mechanical thrombectomy; NIHSS, National Institutes of Health Stroke Scale; IQR, interquartile range; CI, confidence interval; LDL-C, low-density lipoprotein cholesterol.

Table 2. Comparison of core indicators for functional prognosis

Variable	BT group *n*=96	D-MT group *n*=73	Test	Effect size	*P* value
favorable functional outcomes (0-2 points)	54 (56.25)	34 (46.58)	Chi-Square Test	1.555	0.212
poor outcome (3-6 points)	42 (43.75)	39 (53.42)			
90-day mortality rate (6 points)	4 (4.17)	8 (10.96)	Chi-Square Test	2.900	0.089
90-day rate of severe disability (3-5 points)	38 (39.58)	31 (42.47)	Chi-Square Test	0.143	0.706

Note: BT, bridging therapy; D-MT, direct mechanical thrombectomy.

Table 3. Comparison of neurological function indicators

Variables	BT group *n*=96	D-MT group *n*=73	Test	*Z*	*P*
Preoperative NIHSS	12.5 (9-17)	13.0 (10-17)	Mann-Whitney U Test	-0.803	0.422
NIHSS at 24 hours post-surgery	8 (4-15)	11 (4.5-16)	Mann-Whitney U Test	-1.166	0.244
NIHSS at 7 days post-surgery	4 (2-14)	7 (1-12.5)	Mann-Whitney U Test	-0.330	0.742

Note: BT, bridging therapy; D-MT, direct mechanical thrombectomy; NIHSS, National Institutes of Health Stroke Scale.

Table 4. Comparison of vascular recanalization rates

Variable	BT group *n*=96	D-MT group *n*=73	Test	Effect size	*P* value
Vessel patency rate	91 (94.79)	70 (95.89)	Chi-Square Test	0.001	0.973
Vessel non-patency rate	5 (5.21)	3 (4.11)			

Note: BT, bridging therapy; D-MT, direct mechanical thrombectomy.

Table 5. Comparison of Fazekas grading between BT group and D-MT group

Variable	BT group *n*=96	D-MT group *n*=73	Test	Effect size	*P* value
0	19 (19.79)	9 (12.33)	Chi-Square Test	7.542	0.056
1	44 (45.83)	48 (65.75)			
2	31 (32.29)	16 (21.92)			
3	2 (2.08)	0 (0)			

Note: BT, bridging therapy; D-MT, direct mechanical thrombectomy.

Fazekas grading, cerebral small vessel disease severity was categorized as mild (0-1 points) or moderate-severe (2-3 points) (**Table 6**). Post-treatment, the BT group showed a lower proportion of mild disease (65.62%) compared to the D-MT group (78.08%). while the BT group showed a 34.38% moderate-to-severe rate post-treatment, higher than the D-MT group's 21.92%. Nevertheless, this disparity lacked statistical significance (with a *P*-value of 0.077). This finding shows that direct mechanical thrombectomy brings about superior imaging results for patients suffering from pre-circulatory stroke. Still, the difference between these two methods does not have statistical significance.

Comparison of complication rates

Table 7 compares hemorrhagic conversion rates and baseline wake-up stroke proportions between the two treatment modalities using chi-square analysis. The BT group exhibited a hemorrhagic conversion rate of 37.50% and a wake-up stroke proportion of 54.17%; the D-MT group had rates of 36.99% and 53.42%, respectively. The differences were not statistically significant for either comparison (*P*=0.945 for hemorrhagic conversion; *P*=0.924 for wake-up stroke proportion). This indicates that the incidence of hemorrhagic conversion is not directly related to the treatment method, and the two groups were comparable in terms of baseline wake-up stroke proportion.

Multivariate logistic regression analysis for 90-day favorable functional outcomes

Based on 90-day mRS scores, 169 patients with anterior circulation stroke were divided

Table 6. BT group and D-MT impact assessment

Variable	BT group *n*=96	D-MT group *n*=73	Test	Effect size	*P* value
Mild (Grade 0-1)	63 (65.62)	57 (78.08)	Chi-Square Test	3.126	0.077
Moderate to severe (Grade 2-3)	33 (34.38)	16 (21.92)			

Note: BT, bridging therapy; D-MT, direct mechanical thrombectomy.

Table 7. Comparison of hemorrhagic conversion and baseline wake-up stroke proportion

Variable	BT group *n*=96	D-MT group *n*=73	Test	Effect size	*P* value
Hemorrhagic Conversion	36 (37.50)	27 (36.99)	Chi-Square Test	0.005	0.945
Post-Awakening Stroke Rate	52 (54.17)	39 (53.42)	Chi-Square Test	0.009	0.924

Note: BT, bridging therapy; D-MT, direct mechanical thrombectomy. The variable 'Post-awakening stroke rate' represents the proportion of patients with wake-up stroke (unknown onset time) at baseline, not a post-procedural complication.

into a favorable prognosis group (n=88) and an unfavorable outcome group (n=81). **Table 8** presents univariate analysis results showing statistically significant differences between the groups in age, sex, baseline NIHSS score, history of hypertension, history of atrial fibrillation, smoking history, blood pressure (systolic and diastolic), blood glucose, collateral circulation classification, and TOAST classification (all $P<0.05$). **Table 9** presents the results of multivariate logistic regression analysis incorporating statistically significant variables from univariate analysis. The results indicate that smoking history (OR=0.238, 95% CI: 0.057-0.988, $P=0.048$), baseline NIHSS score (OR=1.120, 95% CI: 1.041-1.205, $P=0.002$), and collateral circulation classification (OR=0.408, 95% CI: 0.175-0.948, $P=0.037$) were independent predictors of poor functional outcome in anterior circulation stroke patients.

Discussion

LVO is characterized by sudden onset, rapid progression, and poor prognosis. EVT, as the core treatment for anterior circulation LVO, has been demonstrated in multiple studies to significantly improve patient outcomes [38, 39]. Currently, two primary strategies exist in clinical practice: BT and D-MT [19, 22]. Bridge therapy involves administering intravenous rt-PA for thrombolysis followed by mechanical thrombectomy. Its theoretical basis is that thrombolytic agents pre-dissolve part of the thrombus, thus enhancing thrombectomy efficiency. Direct mechanical thrombectomy, however, omits intravenous thrombolysis and proceeds directly to endovascular thrombectomy, aiming to shorten recanalization time. It is particularly suitable for patients with contraindications to thrombolysis or those with prolonged onset time [40]. However, the relative merits of these two treatment strategies remain controversial [19]. Some studies suggest bridging therapy improves recanalization rates, reduces the number of thrombectomy attempts, and thereby enhances functional outcomes [38]. On the contrary, other studies suggest that intravenous thrombolysis might elevate the risk of hemorrhagic transformation [41, 42]. And for patients within a more limited therapeutic time window, delayed thrombectomy could counteract its advantages [43]. Furthermore, with the evolution of thrombectomy devices (e.g., combined use of stenting and aspiration devices) and technological advancements [44], the efficacy of direct mechanical thrombectomy may now approach or even surpass that of bridging therapy. Therefore, systematically comparing the clinical outcomes, procedural safety, and complication risks of these two strategies in anterior circulation strokes is crucial for optimizing treatment decisions.

The findings of this study show that at 90 days, the proportion of favorable functional outcomes was higher in the BT group (56.25%) than that in the D-MT group (46.58%). Meanwhile, the mortality rate (4.17%) and the rates of moderate-to-severe disability (39.58%) in the BT group were lower compared with those in the D-MT group (10.96%, 42.47%). However, none of these differences were statistically significant ($P>0.05$). These results are in line with the conclusions drawn by Zhang et al. [45].

Table 8. Comparison of baseline characteristics between the good prognostic function and poor prognostic function

Variable	favorable functional outcomes *n*=88	poor outcome *n*=81	Test	*95% CI*	Effect size	*P* value
Gender						
Male	60 (68.18)	38 (46.91)	Chi-Square Test	-	7.831	0.005
Female	28 (31.82)	43 (53.09)				
Age (years)	59.94±14.97	67.67±10.32	Independent-samples t test	-11.605 - -3.842	-3.931	0.000
Underlying disease						
Hypertension	44 (50.00)	56 (69.14)	Chi-Square Test	-	6.393	0.011
Diabetes	13 (14.77)	12 (14.1)	Chi-Square Test	-	0.000	0.994
Atrial fibrillation	25 (28.41)	47 (58.02)	Chi-Square Test	-	15.128	0.000
History of smoking	14 (15.91)	3 (3.70)	Chi-Square Test	-	6.945	0.008
Drinking history	8 (9.09)	2 (2.47)	Chi-Square Test	-	3.322	0.068
Baseline NIHSS score (M(IQR))	11.00 (8.25-14.00)	15.00 (12.00-18.50)	Mann-Whitney U Test	-	-4.654	0.000
Etiological Classification						
Aortic Atherosclerosis	58 (65.91)	32 (39.51)	Chi-Square Test	-	11.811	0.011
Cardiac Embolism	30 (34.09)	49 (60.49)				
Collateral Circulation Grading						
Ineffective Collateral Circulation Group (0-1)	57 (64.77)	68 (83.95)	Chi-Square Test	-	8.056	0.005
Effective Collateral Circulation Group (2-4)	31 (35.23)	13 (16.05)				
LDL-C ([M(IQR), mmol/L])	2.74 (2.14-3.21)	2.57 (1.85-3.16)	Mann-Whitney U Test	-	-0.831	0.406
Blood glucose ([M(IQR), mmol/L])	6.3 (5.48-7.78)	6.80 (5.90-8.20)	Mann-Whitney U Test	-	-2.105	0.035
Systolic blood pressure (mmHg)	137.14±22.77	145.23±25.77	Independent-samples t test	-15.470 - -0.726	-2.169	0.032
Diastolic blood pressure (mmHg)	79.93±16.10	85.48±18.90	Independent-samples t test	-10.869 - -0.230	-2.060	0.041
Treatment methods						
BT	54 (61.36)	42 (51.85)	Chi-Square Test	-	1.555	0.212
D-MT	34 (38.64)	39 (48.15)				
Vascular recanalization rate	87 (98.86)	74 (91.36)	Chi-Square Test	-	3.736	0.053
Post-awakening stroke rate	42 (47.73)	49 (60.49)	Chi-Square Test	-	2.766	0.096

Note: NIHSS, National Institutes of Health Stroke Scale; mRS, modified Rankin Scale; IQR, interquartile range; CI, confidence interval; LDL-C, low-density lipoprotein cholesterol; BT, bridging therapy; D-MT, direct mechanical thrombectomy.

Table 9. Logistic regression analysis of poor prognosis in patients with anterior circulation stroke

Factor	*B*	*SE*	*Wald*	*OR*	*95% CI*	*P* value
Gender	0.374	0.390	0.920	1.453	0.677-3.119	0.338
Age	0.017	0.018	0.930	1.018	0.982-1.054	0.335
Hypertension	0.397	0.417	0.909	1.488	0.657-3.366	0.340
Atrial fibrillation	0.558	0.917	0.371	1.748	0.290-10.553	0.543
History of smoking	-1.437	0.727	3.905	0.238	0.057-0.988	0.048
Baseline NIHSS score	0.113	0.037	9.259	1.120	1.041-1.205	0.002
Systolic Blood Pressure	0.002	0.011	0.049	1.002	0.982-1.024	0.825
Diastolic Blood Pressure	0.009	0.014	0.403	1.009	0.982-1.036	0.526
Blood Glucose	0.034	0.066	0.262	1.035	0.908-1.178	0.608
Collateral Circulation Grading	-0.897	0.430	4.341	0.408	0.175-0.948	0.037
Etiological Classification	-0.235	0.891	0.070	0.790	0.138-4.528	0.792

Note: OR, odds ratio; CI, confidence interval; B, regression coefficient; SE, standard error; NIHSS, National Institutes of Health Stroke Scale.

Collectively, these studies suggest that in eligible anterior circulation LVO patients, BT and D-MT demonstrate comparable overall efficacy, allowing clinicians to flexibly select treatment strategies based on individual patient circumstances. Notably, the potential advantage observed in the BT group in this study may be related to the synergistic effect of rt-PA. The theoretical basis of BT lies in rt-PA's ability to pre-dissolve partial thrombus, thereby reducing thrombus burden and decreasing the number of thrombectomy attempts and procedural duration [46, 47]. Although this study did not directly count thrombectomy attempts, the BT group demonstrated superior median NIHSS scores at 24 hours (8 points) and 7 days (4 points) compared to the D-MT group (11 points and 7 points, respectively), indirectly supporting this mechanism. Furthermore, rt-PA may improve collateral circulation perfusion and mitigate damage to the ischemic penumbra, thereby creating more favorable conditions for subsequent mechanical thrombectomy [47]. However, this advantage did not translate into statistically significant differences, potentially due to factors such as limited sample size, patient variability, and timing of the treatment.

The D-MT group demonstrated a certain advantage in imaging assessment of cerebral small vessel disease, with a higher proportion of mild cerebral small vessel disease (Fazekas grade 0-1) at 78.08% compared to the BT group (65.62%). This finding has not been systematically reported in previous studies and is speculated to be related to the potential effects of rt-PA on cerebral microvessels. As a fibrinolytic agent, rt-PA may increase blood-brain barrier permeability through pathways such as activating matrix metalloproteinases, thereby exacerbating microvascular injury [48]. In contrast, D-MT omits the intravenous thrombolysis step, potentially reducing interference with cerebral microvessels and offering particular advantages for patients with concomitant cerebral microvascular disease. However, this difference also failed to reach statistical significance (*P*=0.077) and requires further validation in larger-scale studies.

Vascular recanalization is the primary goal of EVT. Researches reveal that the recanalization rates (assessed via the modified thrombolytic ischemic classification of cerebral infarction, mTICI 2b/3) in the BT group and the D-MT group were 94.79% and 95.89% respectively. There was no statistically significant difference between these two groups (*P*=0.973). This demonstrates that both strategies can achieve highly effective recanalization. This outcome is closely linked to the iterative development and technological advancements of thrombectomy devices. With the widespread adoption of third-generation stent retrievers (e.g., Solitaire FR, Trevo XP) and aspiration thrombectomy systems (e.g., Penumbra), the recanalization efficacy of D-MT has significantly improved. Some studies report recanalization rates exceeding 90%, consistent with the findings of this study [49, 50]. However, the "timeliness" of recanalization may impact prognosis more than the "recanalization rate". By omitting intravenous thrombolysis, D-MT significantly shortens the "time to recanalization" (TTR) [51]. Although this study did not directly compare TTR, the temporal advantage of D-MT may have offset the thrombolytic effect of BT, resulting in comparable overall efficacy between the two strategies. The temporal advantage of D-MT is particularly pronounced in patients with prolonged onset times, those beyond the thrombolysis time window, or those with contraindications to thrombolysis. This explains why D-MT is widely applied in real-world practice for populations such as post-awakening stroke patients (approximately 54% in this study) [52].

Safety is a crucial factor in clinical decision-making. This study showed that there was no significant difference in the rate of hemorrhagic transformation (37.50% vs. 36.99%) or the post-awakening stroke rate (54.17% vs. 53.42%) between the BT group and the D-MT group (*P*>0.05), which implies that both strategies have comparable safety profiles [53].

Multivariate logistic regression analysis showed that smoking history, baseline NIHSS score, and collateral circulation grading were independent predictors of poor outcomes in patients with anterior circulation LVO. This finding provides important targets for individualized prognostic assessment and treatment decision-making. A history of smoking was positively associated with favorable prognosis (OR=0.238, *P*=0.048), a result seemingly counterintuitive to conventional wisdom and potentially attributable to sample bias. The proportion of smokers in this study was low (13.54% in the BT group, 5.48% in the D-MT group), and univariate analysis showed a higher prevalence of smoking history in the favorable outcome group (15.91%) compared to the poor outcome group (3.70%) (*P*=0.008). One possible explanation is that smokers tend to be younger (mean age 59.94 years in the favorable outcome group vs. 67.67 years in the poor outcome group), possessing better vascular reserve and greater tolerance to ischemic injury. However, this conclusion should be interpreted cautiously, as long-term smoking remains a well-established risk factor for stroke [54], and our findings may only reflect the specificity of short-term prognosis. Baseline NIHSS score was a strong predictor of poor outcomes (OR=1.120, *P*=0.002), consistent with multiple studies [55]. Higher baseline NIHSS scores indicate more severe neurological deficits, potentially larger ischemic penumbra, and poorer prognosis. This suggests that clinicians should carefully consider patients' baseline neurological status when selecting treatment strategies: for patients with lower baseline NIHSS scores (e.g., <10), BT may offer greater benefits through thrombolysis and collateral circulation improvement; whereas for high-score patients, rapid recanalization via D-MT may be more critical. Collateral circulation grading showed a positive correlation with favorable prognosis (OR=0.408, *P*=0.037), indicating that patients with well-developed collateral circulation are more likely to achieve favorable outcomes. As a compensatory mechanism for cerebral blood flow, collateral circulation can delay the progression of the ischemic penumbra to irreversible infarction, buying time for vascular recanalization [56]. In this study, the 90-day favorable functional outcome rate (35.23%) was significantly higher in the effective collateral circulation group (grades 2-4) compared to the ineffective group (grades 0-1) (64.77%) (*P*=0.005), further confirming collateral circulation's importance. This suggests that treatment decisions should incorporate imaging-assessed collateral circulation status: patients with well-developed collateral circulation may tolerate delayed reperfusion better and may be candidates for BT to enhance reperfusion efficiency; conversely, patients with poor collateral circulation should prioritize D-MT to shorten TTR.

The findings of this study are largely consistent with those of most RCTs. In this study, the recanalization rates in both groups were very close (BT group: 94.79%, D-MT group: 95.89%), which is similar to the results reported by Ramazanoglu et al. [57]. Compared with the DIRECT-MT trial, the proportion of patients achieving a favorable functional outcome at 90 days was higher in the BT group (56.25% vs. 46.0%), possibly due to differences in patient characteristics. The median baseline NIHSS score in this study (12.5-13 points) was lower than that in the D-MT trial (17 points), and the proportion of effective collateral circulation (26.04%) was higher. These factors may have contributed to improved outcomes. Additionally, as a single-center study, this research allowed for more standardized treatment protocols and postoperative management, which may have positively influenced the results.

Research limitations

Treatment selection was determined by a multidisciplinary team based on patient conditions rather than random assignment, potentially affecting the objectivity of the results. Although the sample size met statistical requirements, it remains insufficient for statistical power regarding rare complications (e.g., symptomatic intracranial hemorrhage). Follow-up duration was limited to 90 days, lacking long-term prognostic data (e.g., 1-year survival rate, reocclusion rate). Procedural metrics such as thrombectomy attempts and procedure duration were not detailed, preventing in-depth analysis of operational efficiency differences between the two strategies. The absence of subgroup analyses (e.g., based on time-to-treatment windows or thrombus characteristics) may have obscured true differences between the two approaches in specific patient populations.

Conclusion

In summary, bridging therapy and direct mechanical thrombectomy demonstrate comparable overall efficacy and safety in patients with anterior circulation large vessel occlusion stroke. However, each approach holds distinct advantages in specific patient populations. Clinical treatment decisions should be guided by individual patient characteristics, including time-to-treatment, baseline neurological status, and collateral circulation status, rather than relying solely on the relative merits of treatment modalities. Smoking history, baseline NIHSS score, and collateral circulation grading serve as independent prognostic factors and should be incorporated into clinical assessment systems to inform individualized treatment and prognosis evaluation.

Disclosure of conflict of interest

None.

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References

[1] Thamizhoviya G. Exosome-based liquid biopsy for real-time diagnosis and assessment in acute stroke and its subtypes. Advances in Modern Biomedicine 2025; 1: 21-32.

[2] Hao G, Shi Z, Zhang B, Dong Y and Liang G. Global burden of ischemic stroke in middle-aged workforce population, 1990-2021: systematic analysis of the global burden of disease study 2021. Neuroepidemiology 2025: 1-18.

[3] Sun T, Chen S, Wu K, Sun M, Zhang X and You C. Trends in incidence and mortality of stroke in china from 1990 to 2019. Front Neurol 2021; 12: 759221.

[4] Saini V, Guada L and Yavagal DR. Global epidemiology of stroke and access to acute ischemic stroke interventions. Neurology 2021; 97 Suppl 2: S6-S16.

[5] Shi Z, Guo S, Zheng S, Min JY and Geng Y. Number of stent retriever passes associated with clinical outcome after mechanical thrombectomy in acute ischemic stroke. J Stroke Cerebrovasc Dis 2020; 29: 105199.

[6] Gao F, Tong X, Jia B, Wei M, Pan Y, Yang M, Sun D, Nguyen TN, Ren Z, Demiraj F, Yao X, Xu C, Yuan G, Wan Y, Tang J, Wang J, Jiang Y, Wang C, Luo X, Yang H, Shen R, Wu Z, Yuan Z, Wan D, Hu W, Liu Y, Jing P, Wei L, Zheng T, Wu Y, Yang X, Sun Y, Wen C, Chang M, Yin B, Li D, Duan J, Sun D, Guo Z, Xu G, Wang G, Wang L, Wang Y, Jia W, Ma G, Huo X, Mo D, Ma N, Liu L, Zhao X, Wang Y, Fiehler J, Wang Y and Miao Z. Bailout intracranial angioplasty or stenting following thrombectomy for acute large vessel occlusion in China (ANGEL-REBOOT): a multicentre, open-label, blinded-endpoint, randomised controlled trial. Lancet Neurol 2024; 23: 797-806.

[7] Goyal M, Hill MD, Saver JL and Fisher M. Challenges and opportunities of endovascular stroke therapy. Ann Neurol 2016; 79: 11-17.

[8] Blanc R, Escalard S, Baharvadhat H, Desilles JP, Boisseau W, Fahed R, Redjem H, Ciccio G, Smajda S, Maier B, Delvoye F, Hebert S, Mazighi M and Piotin M. Recent advances in devices for mechanical thrombectomy. Expert Rev Med Devices 2020; 17: 697-706.

[9] Goyal M, Demchuk AM, Menon BK, Eesa M, Rempel JL, Thornton J, Roy D, Jovin TG, Willinsky RA, Sapkota BL, Dowlatshahi D, Frei DF, Kamal NR, Montanera WJ, Poppe AY, Ryckborst KJ, Silver FL, Shuaib A, Tampieri D, Williams D, Bang OY, Baxter BW, Burns PA, Choe H, Heo JH, Holmstedt CA, Jankowitz B, Kelly M, Linares G, Mandzia JL, Shankar J, Sohn SI, Swartz RH, Barber PA, Coutts SB, Smith EE, Morrish WF, Weill A, Subramaniam S, Mitha AP, Wong JH, Lowerison MW, Sajobi TT and Hill MD; ESCAPE Trial Investigators. Randomized assessment of rapid endovascular treatment of ischemic stroke. N Engl J Med 2015; 372: 1019-1030.

[10] Campbell BC, Mitchell PJ, Kleinig TJ, Dewey HM, Churilov L, Yassi N, Yan B, Dowling RJ, Parsons MW, Oxley TJ, Wu TY, Brooks M, Simpson MA, Miteff F, Levi CR, Krause M, Harrington TJ, Faulder KC, Steinfort BS, Priglinger M, Ang T, Scroop R, Barber PA, McGuinness B, Wijeratne T, Phan TG, Chong W, Chandra RV, Bladin CF, Badve M, Rice H, de Villiers L, Ma H, Desmond PM, Donnan GA and Davis SM; EXTEND-IA Investigators. Endovascular therapy for ischemic stroke with perfusion-imaging selection. N Engl J Med 2015; 372: 1009-1018.

[11] Bala F, Bricout N, Nouri N, Cordonnier C, Henon H and Casolla B. Safety and outcomes of endovascular treatment in patients with very severe acute ischemic stroke. J Neurol 2021; 269: 2493-2502.

[12] Yeo LL, Chen VHE, Leow AS, Meyer L, Fiehler J, Tu TM, Tham CH, Sia CH, Jamous A, Behme D, Kastrup A, Papanagiotou P, Styczen H, Forsting M, Lee TH, Chu CL, Fischer S, Maus V, Abdullayev N, Kabbasch C, Mönch S, Maegerlein C, Arnberg F, Andersson T, Holmin S, Teoh HL, Paliwal P, Ahmad A, Gopinathan A, Yang C, Seet RC, Chan BP, Sharma VK and Tan BY. Outcomes in young adults with acute ischemic stroke undergoing endovascular thrombectomy: a real-world multicenter experience. Eur J Neurol 2021; 28: 2736-2744.

[13] Yang JS, Zhu ZF, Zhang JY, Zhang HP, Liu DH, Han BJ and Zhang L. Clinical analysis of intravenous thrombolysis therapy in acute cerebral infarction with low-dose of Rt-Pa. J Brain Nerv Dis 2013.

[14] Wang R, Zeng J, Wang F, Zhuang X, Chen X and Miao J. Risk factors of hemorrhagic transformation after intravenous thrombolysis with rt-PA in acute cerebral infarction. QJM 2018; 112: 323-326.

[15] Zheng TH, Hao JJ, Zhou XY, Gao J, Zhu XP, Zhang HJ and Wang SS. Analysis of related factors of early intracranial hemorrhage after intravenous Rt-Pa thrombolysis in advance-aged patients with cerebral infarction. Zhongguo Naoxueguanbing Zazhi 2012.

[16] Groot AE, de Bruin H, Nguyen TTM, Kappelhof M, de Beer F, Visser MC, Zwetsloot CP, Halkes PHA, de Kruijk J, van der Meulen WDM, van der Ree TC, Kwa VIH, van Schaik SM, Hani L, van den Berg R, Sprengers MES, Roosendaal SD, Emmer BJ, Nederkoorn PJ, Majoie CBLM, Roos YBWEM and Coutinho JM. Presentation outside office hours does not negatively influence treatment times for reperfusion therapy for acute ischemic stroke. J Neurol 2021; 268: 133-139.

[17] Chen PM, Lehmann B, Meyer BC, Rapp K, Hemmen T, Modir R, Agrawal K, Hailey L, Mortin M and Meyer DM. Timing of symptomatic intracerebral hemorrhage after rt-PA treatment in ischemic stroke. Neurol Clin Pract 2019; 9: 304-308.

[18] Mori M, Naganuma M, Okada Y, Hasegawa Y, Shiokawa Y, Nakagawara J, Furui E, Kimura K, Yamagami H, Kario K, Okuda S, Koga M, Minematsu K and Toyoda K. Early neurological deterioration within 24 hours after intravenous rt-PA therapy for stroke patients: the stroke acute management with urgent risk factor assessment and improvement rt-PA registry. Cerebrovasc Dis 2012; 34: 140-146.

[19] Xiong Y, Pan Y, Nogueira RG, Ren Z, Jovin TG and Wang Y. Treating acute large vessel occlusion stroke: to bridge or not to bridge? Stroke Vasc Neurol 2021; 6: 324-327.

[20] Mehta AM, Desai SM and Jadhav AP. Mechanical thrombectomy for acute ischemic stroke: current state and future directions. Curr Treat Options Neurol 2024; 26: 297-318.

[21] Nguyen HA, Vu DL, Nguyen QA, Mai DT, Tran AT, Le HK, Nguyen TT, Nguyen TT, Tran C, Dao VP and Pierot L. Predictive factors for clinical outcome after direct mechanical thrombectomy for anterior circulation large vessel occlusion within 4.5 h. Front Neurol 2022; 13: 895182.

[22] Sarraj A, Grotta J, Albers GW, Hassan AE, Blackburn S, Day A, Sitton C, Abraham M, Cai C, Dannenbaum M, Pujara D, Hicks W, Budzik R, Vora N, Arora A, Alenzi B, Tekle WG, Kamal H, Mir O, Barreto AD, Lansberg M, Gupta R, Martin-Schild S, Savitz S and Tsivgoulis G; SELECT Investigators. Clinical and neuroimaging outcomes of direct thrombectomy vs bridging therapy in large vessel occlusion. Neurology 2021; 96: e2839-e2853.

[23] Yang P, Treurniet KM, Zhang L, Zhang Y, Li Z, Xing P, Zhang Y, Zhang P, Wang H, Hong B, Dippel DW, Roos YB, Majoie CB, Deng B and Liu J; DIRECT-MT investigators. Direct intra-arterial thrombectomy in order to revascularize AIS patients with large vessel occlusion efficiently in Chinese tertiary hospitals: a multicenter randomized clinical trial (DIRECT-MT)-protocol. Int J Stroke 2019; 15: 689-698.

[24] Cao J, Xing P, Zhu X, Chen R, Shao H, Xuan J, Jiang T, Yang P, Zhang Y, Li Z, Chen W, Li T, Wang S, Lou M, Peng Y and Liu J. Mild and moderate cardioembolic stroke patients may benefit more from direct mechanical thrombectomy than bridging therapy: a subgroup analysis of a randomized clinical trial (DIRECT-MT). Front Neurol 2022; 13: 1013819.

[25] Sarioglu O, Sarioglu FC, Capar AE, Sokmez DFB, Topkaya P and Belet U. The role of CT texture analysis in predicting the clinical outcomes of acute ischemic stroke patients undergoing mechanical thrombectomy. Eur Radiol 2021; 31: 6105-6115.

[26] Krajíčková D, Krajina A, Šteiner I, Vyšata O, Herzig R, Lojík M, Chovanec V, Raupach J, Renc O, Waishaupt J, Vítková E, Dulíček P, Čabelková P and Vališ M. Fibrin clot architecture in acute ischemic stroke treated with mechanical thrombectomy with stent-retrievers-cohort Study. Circ J 2018; 82: 866-873.

[27] Wu X, Ge Y, Chen S, Yan Z, Wang Z, Zhang W, Chen Z, Xue T and Wang Z. Thrombectomy with or without thrombolysis in patients with acute ischemic stroke: a systematic review and meta-analysis. J Neurol 2022; 269: 1809-1816.

[28] Heldner MR, Chaloulos-Iakovidis P, Panos L, Volbers B, Kaesmacher J, Dobrocky T, Mordasini P, El-Koussy M, Gralla J, Arnold M, Fischer U, Mattle HP and Jung S. Outcome of patients with large vessel occlusion in the anterior circulation and low NIHSS score. J Neurol 2020; 267: 1651-1662.

[29] D'Anna L, Foschi M, Russo M, Dolkar T, Vittay O, Dixon L, Bentley P, Brown Z, Hall C, Halse O, Jamil S, Jenkins H, Kalladka D, Kwan J, Malik A, Patel M, Rane N, Roi D, Singh A, Venter M, Lobotesis K and Banerjee S. Endovascular thrombectomy with or without intravenous thrombolysis for anterior circulation large vessel occlusion in the imperial college london thrombectomy registry. J Clin Med 2023; 12: 1150.

[30] Wen B, Zhang G, Zhan C, Chen C and Yi H. The 2024 revision of the Declaration of Helsinki: a modern ethical framework for medical research. Postgrad Med J 2025; 101: 371-382.

[31] Kim N, Fischer AH, Dyring-Andersen B, Rosner B and Okoye GA. Research techniques made simple: choosing appropriate statistical methods for clinical research. J Invest Dermatol 2017; 137: e173-e178.

[32] Cohen J. Statistical power analysis for the behavioral sciences. 2nd ed. Hillsdale, NJ: Lawrence Erlbaum Associates; 1988.

[33] Rigual R, Fuentes B and Díez-Tejedor E. Management of acute ischemic stroke. Med Clin (Barc) 2023; 161: 485-492.

[34] Siow I, Tan BYQ, Lee KS, Ong N, Toh E, Gopinathan A, Yang C, Bhogal P, Lam E, Spooner O, Meyer L, Fiehler J, Papanagiotou P, Kastrup A, Alexandrou M, Zubel S, Wu Q, Mpotsaris A, Maus V, Anderson T, Gontu V, Arnberg F, Lee TH, Chan BPL, Seet RCS, Teoh HL, Sharma VK and Yeo LLL. Bridging thrombolysis versus direct mechanical thrombectomy in stroke due to basilar artery occlusion. J Stroke 2022; 24: 128-137.

[35] Kwah LK and Diong J. National institutes of health stroke scale (NIHSS). J Physiother 2014; 60: 61.

[36] Jeon ET, Kim SM and Jung JM. Automated rating of Fazekas scale in fluid-attenuated inversion recovery MRI for ischemic stroke or transient ischemic attack using machine learning. Sci Rep 2025; 15: 32219.

[37] Ande SR, Grynspan J, Aviv RI and Shankar JJS. Imaging for predicting hemorrhagic transformation of acute ischemic stroke-a narrative review. Can Assoc Radiol J 2022; 73: 194-202.

[38] Saver JL, Goyal M, Bonafe A, Diener HC, Levy EI, Pereira VM, Albers GW, Cognard C, Cohen DJ, Hacke W, Jansen O, Jovin TG, Mattle HP, Nogueira RG, Siddiqui AH, Yavagal DR, Baxter BW, Devlin TG, Lopes DK, Reddy VK, du Mesnil de Rochemont R, Singer OC and Jahan R; SWIFT PRIME Investigators. Stent-retriever thrombectomy after intravenous t-PA vs. t-PA alone in stroke. N Engl J Med 2015; 372: 2285-2295.

[39] Ismail MAM, Gamal-eldin MM and Ibrahim AM. Mechanical thrombectomy by stent retrievers for treating acute ischemic stroke due to large vessel occlusion. QJM: An International Journal of Medicine 2023; 116.

[40] Park H, Baek JH and Kim BM. Endovascular treatment of acute stroke due to intracranial atherosclerotic stenosis-related large vessel occlusion. Front Neurol 2019; 10: 308.

[41] Agbonon R, Forestier G, Bricout N, Benhassen W, Turc G, Bretzner M, Pasi M, benzakoun J, Seners P, Derraz I, Legrand L, Trystram D, Rodriguez-Regent C, Charidimou A, Rost NS, Bracard S, Cordonnier C, Eker OF, Oppenheim C, Naggara O, Henon H and Boulouis G. Cerebral microbleeds and risk of symptomatic hemorrhagic transformation following mechanical thrombectomy for large vessel ischemic stroke. J Neurol 2024; 271: 2631-2638.

[42] van Landeghem N, Ziegenfuß C, Demircioglu A, Dammann P, Jabbarli R, Haubold J, Forsting M, Wanke I, Köhrmann M, Frank B, Deuschl C and Li Y. Impact of post-thrombectomy isolated subarachnoid hemorrhage on neurological outcomes in patients with anterior ischemic stroke - a retrospective single-center observational study. Neuroradiology 2024; 66: 1737-1745.

[43] Demeestere J, Qureshi MM, Vandewalle L, Wouters A, Strbian D, Nogueira RG, Nagel S, Yamagami H, Puetz V, Abdalkader M, Haussen DC, Mohammaden MH, Möhlenbruch MA, Olivé-Gadea M, Winzer S, Ribo M, Michel P, Marto JP, Tanaka K, Yoshimura S, Martinez-Majander N, Caparros F, Henon H, Tomppo L, Dusart A, Bellante F, Ramos JN, Jesser J, Sheth SA, Ortega-Gutiérrez S, Siegler JE, Nannoni S, Kaesmacher J, Dobrocky T, Salazar-Marioni S, Farooqui M, Virtanen P, Ventura R, Zaidi SF, Castonguay AC, Uchida K, Puri AS, Sakai N, Toyoda K, Farzin B, Masoud HE, Klein P, Bui J,

Rizzo F, Kaiser DPO, Desfontaines P, Strambo D, Cordonnier C, Lin E, Ringleb PA, Roy D, Zaidat OO, Fischer U, Raymond J, Lemmens R and Nguyen TN. Outcomes of bridging intravenous thrombolysis versus endovascular therapy alone in late-window acute ischemic stroke. Stroke 2024; 55: 1767-1775.

[44] Lauer D, Sulženko J, Malíková H, Štětkářová I and Widimský P. Advances in endovascular thrombectomy for the treatment of acute ischemic stroke. Expert Rev Neurother 2025; 25: 675-687.

[45] Zhang J, Chen S, Shi S, Zhang Y, Kong D, Xie Y, Deng X, Tang J, Luo J and Liang Z. Direct endovascular treatment versus bridging therapy in patients with acute ischemic stroke eligible for intravenous thrombolysis: systematic review and meta-analysis. J Neurointerv Surg 2022; 14: 321-325.

[46] Rossi R, Molina S, Mereuta OM, Douglas A, Fitzgerald S, Tierney C, Pandit A, Brennan P, Power S, O'Hare A, Gilvarry M, McCarthy R, Magoufis G, Tsivgoulis G, Nagy A, Vadász Á, Jood K, Redfors P, Nordanstig A, Ceder E, Dunker D, Carlqvist J, Psychogios K, Szikora I, Tatlisumak T, Rentzos A, Thornton J and Doyle KM. Does prior administration of rtPA influence acute ischemic stroke clot composition? Findings from the analysis of clots retrieved with mechanical thrombectomy from the RESTORE registry. J Neurol 2021; 269: 1913-1920.

[47] Swamy N, Barazangi N, Kim W, Chen C, Ke M, Wong C, Gao B, Choe J, Yee A, Spokoyny I, Bedenk A, Fernandez J, Patel S, Grovsenor D, Telischak N, English J and Tong D. Abstract WP329: time dependent recanalization and outcomes in transferred stroke patients with large vessel occlusion (LVO) after IV rt-PA. Stroke 2019; 50.

[48] Wang W, Wang P, Liang Z, Qin Z, Su R, Yin Q, Wang B, Chen J, Zhang Y, Wei X, Huang L, Zhang S and Qi S. Exosome-like nanovesicles derived from Momordica charantia ameliorate delayed t-PA thrombolysis-induced hemorrhagic transformation by inhibiting the ONOO-/HMGB1/MMP-9 pathway. J Funct Foods 2024; 114: 106086.

[49] Kolahchi Z, Rahimian N, Momtazmanesh S, Hamidianjahromi A, Shahjouei S and Mowla A. Direct mechanical thrombectomy versus prior bridging intravenous thrombolysis in acute ischemic stroke: a systematic review and meta-analysis. Life (Basel) 2023; 13: 185.

[50] Cousin P, Scopelliti G, le Berre A, Benzakoun J, Bricout N, Legrand L, Turc G, Cordonnier C, Oppenheim C, Naggara O, Henon H and Ben Hassen W. Intravenous thrombolysis improves recanalization results irrespective of the mechanical thrombectomy technique in acute ischemic stroke. Int J Stroke 2025; 20: 883-890.

[51] Yang P, Zhang Y, Zhang L, Zhang Y, Treurniet KM, Chen W, Peng Y, Han H, Wang J, Wang S, Yin C, Liu S, Wang P, Fang Q, Shi H, Yang J, Wen C, Li C, Jiang C, Sun J, Yue X, Lou M, Zhang M, Shu H, Sun D, Liang H, Li T, Guo F, Ke K, Yuan H, Wang G, Yang W, Shi H, Li T, Li Z, Xing P, Zhang P, Zhou Y, Wang H, Xu Y, Huang Q, Wu T, Zhao R, Li Q, Fang Y, Wang L, Lu J, Li Y, Fu J, Zhong X, Wang Y, Wang L, Goyal M, Dippel DWJ, Hong B, Deng B, Roos YBWEM, Majoie CBLM and Liu J; DIRECT-MT Investigators. Endovascular thrombectomy with or without intravenous alteplase in acute stroke. N Engl J Med 2020; 382: 1981-1993.

[52] Deng Q, Zhang L, Liu Y, Zhou F, Yuan Z, Wang X, Gao J, Yang P, Zhang Y, Xing P, Li Z, Hong B, Han H, Shi H, Shi H and Liu J; DIRECT-MT Investigators. Effect of time window on endovascular thrombectomy with or without intravenous thrombolysis in acute ischemic stroke: results from DIRECT-MT. Cerebrovasc Dis 2024; 53: 176-183.

[53] Wiśniewski A. Safety and efficacy of intravenous thrombolytic treatment in wake-up stroke: experiences from a single center. Brain Behav 2021; 11.

[54] Cai Y, Gu Y, Wang Y, Wang P, Zhang L, Liu C, Chu J, Li H, Lu Z, Zhou Y and Liu H. A clinical prediction model for patients with acute large vessel occlusion due to underlying intracranial atherosclerotic stenosis. Clin Neuroradiol 2022; 33: 519-528.

[55] Takamiya S, Oura D, Ihara R, Niiya Y, Furukawa K, Gekka M, Nakazaki A and Fujimura M. The time threshold to reperfusion for DWI reversal in acute ischemic stroke depends on pre-interventional ADC value. Neuroradiology 2024; 66: 2205-2213.

[56] Ohba H, Ohbayashi N, Fukuda H, Yahara K, Nabika S, Suto Y, Tokuda N, Yoshida K, Nakaoka M and Sakamoto S. Predictors of reperfusion and 90-day functional outcome after mechanical thrombectomy for large vessel occlusion strokes. J Stroke Cerebrovasc Dis 2021; 30: 105687.

[57] Ramazanoglu L, Kocak M, Aslan IK, Onal Y, Velioglu M and Gozke E. Thrombectomy with or without bridging thrombolysis for anterior circulation stroke. Neurol India 2023; 71: 248-254.