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Weight status influences the effect of hyperglycemia at admission on clinical outcomes after endovascular thrombectomy

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Abstract:

BACKGROUND: Insulin resistance is more prevalent in the overweight population, which can affect their glucose metabolism. This study explores whether weight status influences the relationship between admission hyperglycemia and outcomes after thrombectomy.

METHODS: Four hundred and fifty-two patients with acute anterior circulation ischemic stroke undergoing thrombectomy were retrospectively analyzed. Hyperglycemia at admission was described as venous blood glucose ≥7.8 mmol/L and overweight as body mass index ≥24 kg/m^2. The outcomes included the rates of functional independence (90-day modified Rankin Scale 0–2), symptomatic intracranial hemorrhage within 24 h after thrombectomy, and mortality at 90 days.

RESULTS: Overall, hyperglycemia at admission decreased the likelihood of functional independence (adjusted odds ratio [OR] 0.50, 95% confidence interval [CI] 0.30–0.83, $P = 0.008$). Weight status modified the efficacy of admission hyperglycemia on functional independence ($P = 0.022$ for interaction). Hyperglycemia at admission was negatively associated with functional independence among overweight patients (adjusted OR 0.30, 95% CI 0.15–0.60, $P = 0.001$) but not among normal-weight patients (adjusted OR 1.13, 95% CI 0.48–2.70, $P = 0.776$). Weight status did not influence the efficacy of hyperglycemia at admission on mortality ($P = 0.201$ for interaction) or symptomatic intracerebral hemorrhage ($P = 0.105$ for interaction).

CONCLUSIONS: Weight status influenced the effect of hyperglycemia at admission on functional independence after thrombectomy. Hyperglycemia at admission was related to functional independence among overweight patients but not among normal-weight patients. Our findings suggest tight control of glucose may be needed for overweight patients in the thrombectomy setting.

Keywords:

Endovascular thrombectomy, hyperglycemia, outcome, stroke, weight status

Introduction

Hyperglycemia is frequently observed in the acute phase of stroke.[1] This phenomenon can be caused by diabetes mellitus and/or acute stress responses.[2] Hyperglycemia at admission has been linked to poor clinical outcomes after endovascular thrombectomy,[3,4] which could be mediated by multiple mechanisms, such as intracellular acidosis in ischemic tissues, altered blood–brain barrier permeability, exacerbated inflammation, and increased reperfusion injury.[2,4]

Being overweight is a nonnegligible risk factor for ischemic stroke, and its prevalence has increased worldwide in recent decades.[5] Body mass index (BMI) has been extensively used to classify weight status.[6] Overweight patients have a higher incidence of insulin

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resistance,[7] which can affect their metabolism of glucose,[8] and thus, might influence the efficacy of hyperglycemia among patients receiving thrombectomy. More than half of patients receiving thrombectomy were reported to be overweight,[9-11] It is clinically meaningful to elucidate the impact of weight status on the effect of hyperglycemia at admission in the thrombectomy setting, which might shed light on the potential utility of postthrombectomy blood glucose management.[12] This study explores whether weight status influences the efficacy of hyperglycemia at admission in patients treated by endovascular thrombectomy.

Methods

Ethics statements

The local ethics committee approved the study (approval number: 2019-004–11). Each patient gave written informed consent at admission for nonpersonal information use in clinical investigations, and reinformed consent was waived for this retrospective analysis.

Research participants

We retrospectively enrolled patients undergoing thrombectomy within 24 h after onset for acute ischemic stroke due to anterior circulation large artery occlusion at one comprehensive stroke center between May 2019 and April 2023. Patients were included if they met all the following criteria: (1) not <18 years of age, (2) anterior circulation occlusion (middle cerebral artery [M1/M2] and/or intracranial internal carotid artery), (3) modified Rankin Scale (mRS) ≤2 before onset, (4) BMI ≥18.5 kg/m^2, and (5) available information on blood glucose at admission and clinical prognosis at 90 days evaluated with mRS score. All participants were treated following the current guideline.[13]

Data collection

Demographic variables included age, gender, height, weight, pretreatment mRS score, and smoking history. Comorbidities consisted of prior ischemic stroke, diabetes, hypertension, and atrial fibrillation. Clinical variables were admission blood pressure, baseline National Institutes of Health Stroke Scale (NIHSS) score, pretreatment venous blood glucose level, alteplase treatment, onset to puncture time, onset to reperfusion time, anesthesia type, number of passes, and stroke mechanism defined by the Trial of Org 10172 in Acute Stroke Treatment classification (TOAST).[14] Imaging variables were pretreatment Alberta Stroke Program Early CT Score, pretreatment occlusion location, collateral status, and posttreatment reperfusion status.

Pretreatment blood glucose level ≥7.8 mmol/L was considered hyperglycemia.[4] BMI (weight [kg]/height [m^2]) was stratified into ≥24 kg/m^2 (overweight) and <24 kg/m^2 (normal-weight) according to the Chinese criteria.[15] Pretreatment collaterals were graded by the American Society of Interventional and Therapeutic Neuroradiology/Society of Interventional Radiology guidelines and were considered being poor (grade 0–2) and good (grade 3–4).[16] The modified Thrombolysis in Cerebral Infarction score (mTICI) was adopted to assess reperfusion status[17] and was stratified into mTICI 0–2a (failed reperfusion) and mTICI 2b–3 (successful reperfusion).

Clinical outcomes

The primary outcome measure was functional independence (90-day mRS 0–2). The secondary endpoints were symptomatic intracranial hemorrhage (SICH) within 24 h after treatment, defined as hemorrhage with an increase of the NIHSS score at less than four points[18] and mortality at 90 days.

Statistical analysis

The categorical variables were shown by numbers (percentages) and quantitative variables by median (interquartile range) or mean ± standard deviation depending on their distributions. The Chi-square or Fisher's test for the categorical variables, *t*-test for the normal variables, and nonparametric tests for the nonnormal variables were adopted for univariate comparisons between groups.

We assessed the effects of hyperglycemia at admission on clinical outcomes using multivariable binary logistic regression models, which were adjusted for age, history of diabetes, pretreatment NIHSS score, alteplase treatment, occlusion location, and collateral status. These confounders were selected based on basing on backwards selection and potential predictors of hyperglycemia/outcomes. All variables with $P < 0.05$ in univariate analyses were first included to the models, and those with $P \geq 0.05$ in backward elimination were excluded. Multiplicative interaction analyses were then carried out to elucidate the impact of weight status on the associations of hyperglycemia at admission and clinical outcomes. Adjusted odds ratios (OR) for multivariable analyses were reported with 95% confidence intervals (CIs). Statistical significance was considered a two-tailed $P < 0.05$. The Stata software version 17 (StataCorp LLC) was adopted for the above analyses.

Clinical trial registry

This work is a retrospective analytical study. No clinical trials were involved.

Results

Baseline characteristics

During the study period, 452 were enrolled from

696 patients receiving thrombectomy for the current study. The median BMI was 24.5 (23.3–26.4) kg/m^2, and the median glucose level was 7.3 (6.4–9.3) mmol/L. One hundred and seventy-one patients were normal-weight, among whom 57 had hyperglycemia with a median glucose level of 10.2 (8.5–12.4) mmol/L. Of the 281 overweight patients, 121 had hyperglycemia with a median glucose level of 10.0 (8.6–12.5) mmol/L [Figure 1]. Overweight patients were prone to have hyperglycemia (43.1% vs. 33.3%; P = 0.040) and were less likely to have good collaterals (24.2% vs. 35.7%; P = 0.009) compared with normal-weight patients [Table S1]. When comparing normal-weight patients, those with hyperglycemia had more diabetes (38.6% vs. 8.8%; P < 0.001), more glucose-lowering treatments (6.1% vs. 24.6%; P = 0.001), less atrial fibrillation (33.3% vs. 50.0%; P = 0.039), and higher pretreatment NIHSS score (18 vs. 16; P = 0.028). Overweight patients with hyperglycemia had more diabetes (44.6% vs. 7.5%; P < 0.001), more glucose-lowering treatments (5.6% vs. 29.8%; P < 0.001), and greater systolic blood pressure (158.1 vs. 149.5 mmHg; P = 0.015) compared with those without hyperglycemia. The other characteristics in both normal-weight and overweight groups were balanced [Table 1].

Associations between hyperglycemia at admission and clinical outcomes

After adjustment for the potential confounders, hyperglycemia at admission decreased the likelihood of functional dependence (28.7% vs. 44.5%; adjusted OR 0.50, 95% CI 0.30–0.83, P = 0.003) [Figure 2]. The association of admission hyperglycemia and functional independence was influenced by weight status (P for interaction = 0.022). Hyperglycemia at admission was negatively related to functional independence among overweight patients (24.8% vs. 47.5%; adjusted OR 0.30, 95% CI 0.15–0.60, P = 0.001) but not among normal-weight patients (36.8% vs. 40.4%; adjusted OR 1.13, 95% CI 0.48–2.70, P = 0.776) [Figures 2 and 3].

Hyperglycemia at admission was not related to the rates of 24 h SICH, whether patients were normal-weight (adjusted OR 0.19, 95% CI 0.02–2.01, P = 0.168) or overweight (adjusted OR 1.59, 95% CI 0.60–4.20, P = 0.352). The relationship between hyperglycemia at admission and mortality was not significant in normal-weight patients (adjusted OR 1.05, 95% CI 0.46–2.42, P = 0.911) but was significant in overweight patients (adjusted OR 2.14, 95% CI 1.12–4.09, P = 0.021). Interactions between weight status and hyperglycemia at admission on SICH (P = 0.105) or mortality (P = 0.201) were not significant [Figure 2].

Discussion

This study showed that hyperglycemia at admission was negatively related with functional independence among overweight patients but not among normal-weight patients, revealing that weight status influenced the efficacy of hyperglycemia at admission among patients receiving thrombectomy for acute ischemic stroke due to anterior circulation large artery occlusion.

We first confirmed the results obtained in previous observations that hyperglycemia at admission was related to functional independence after endovascular therapy.[3,4] Furthermore, we revealed that the association was only observed in overweight patients and not in normal-weight patients. Although excessive glucose may initially function to repair ischemic brain issue by providing the metabolic fuel,[19] it has been demonstrated to exacerbate brain injury of cerebral ischemia.[1] Moreover, the duration of hyperglycemia could also play a vital role in its deteriorating effect on postischemic neurons.[1] Having persistent hyperglycemia, i.e., lasting from admission to 24–48 h after the onset, was related to poor functional outcomes compared to just having hyperglycemia at admission in patients receiving reperfusion therapy.[20-22] Overweight patients have high prevalence of insulin resistance,[7,23] which was

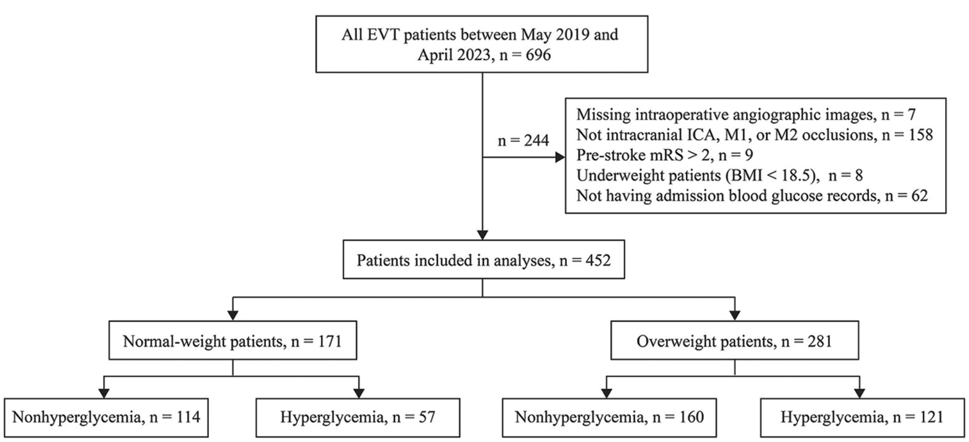

Figure 1: Flowchart illustrating the study inclusion/exclusion and grouping process. EVT: endovascular thrombectomy, ICA: internal carotid artery, M1, M2: the first or second segment of middle cerebral artery, mRS: modified Rankin Scale, BMI: body mass index

Table 1: Baseline information and outcomes according to categorized body mass index and admission hyperglycemia

Variables	Normal-weight patients (*n*=171)			Overweight patients (*n*=281)		
	Nonhyperglycemia (*n*=114), *n* (%)	Hyperglycemia (*n*=57), *n* (%)	*P*	Nonhyperglycemia (*n*=160), *n* (%)	Hyperglycemia (*n*=121), *n* (%)	*P*
Age (years), median (IQR)	71 (64–79)	68 (62–76)	0.357	70 (62–78)	71 (65–77)	0.539
Female sex	50 (43.9)	27 (47.4)	0.863	58 (36.3)	47 (38.8)	0.547
BMI (kg/m^2), median (IQR)	22.8 (21.5–23.4)	23.0 (22.1–23.9)	0.007	26.0 (24.5–27.7)	26.1 (24.5–27.8)	0.421
Prestroke mRS ≥1	6 (5.3)	9 (15.8)	0.022	9 (5.6)	9 (7.4)	0.539
Medical history						
Hypertension	58 (50.9)	35 (61.4)	0.193	92 (57.5)	83 (68.6)	0.057
Diabetes mellitus	10 (8.8)	22 (38.6)	<0.001	12 (7.5)	54 (44.6)	<0.001
Glucose-lowering treatments	7 (6.1)	14 (24.6)	0.001	9 (5.6)	36 (29.8)	<0.001
Ischemic stroke	11 (9.6)	8 (14.0)	0.390	16 (10.0)	14 (11.6)	0.673
Atrial fibrillation	57 (50.0)	19 (33.3)	0.039	79 (49.4)	52 (43.0)	0.287
Smoking	49 (43.0)	22 (38.6)	0.583	70 (43.8)	46 (38.0)	0.334
Current stroke event						
SBP (mmHg), mean±SD	146.8±27.1	149.8±30.7	0.526	149.5±26.4	158.1±32.5	0.015
DBP (mmHg), mean±SD	83.2±16.0	84.2±18.4	0.713	84.6±16.3	87.8±17.9	0.121
NIHSS score, median (IQR)	16 (12–20)	18 (14–22)	0.028	17 (12–22)	16 (14–21)	0.901
ASPECTS, median (IQR)	8 (7–10)	9 (7–9)	0.444	8 (7–10)	8 (7–9)	0.173
Glucose (mmol/L), median (IQR)	6.5 (5.5–7.2)	10.2 (8.5–12.4)	<0.001	6.6 (6.2–7.0)	10.0 (8.6–12.5)	<0.001
Intravenous thrombolysis	46 (40.4)	29 (50.9)	0.191	66 (41.3)	61 (50.4)	0.126
Occlusion site						
M1	58 (50.8)	21 (36.9)	0.219	90 (56.2)	56 (46.3)	0.059
M2	10 (8.8)	6 (10.5)		23 (14.4)	13 (10.7)	
ICA	46 (40.4)	30 (52.6)		47 (29.4)	52 (43.0)	
Anesthesia						
General anesthesia	6 (5.3)	6 (10.5)	0.283	0	4 (3.3)	0.067
Local anesthesia	72 (63.2)	30 (52.7)		105 (65.6)	78 (64.5)	
Conscious sedation	36 (31.5)	21 (36.8)		55 (34.4)	39 (32.2)	
Good collaterals	42 (36.8)	19 (33.3)	0.652	41 (25.6)	27 (22.3)	0.521
OPT (min), median (IQR)	280 (195–394)	250 (155–390)	0.290	275 (188–395)	255 (191–380)	0.558
ORT (min), median (IQR)	347 (260–427)	315 (230–460)	0.439	332 (240–453)	323 (260–440)	0.972
Device-pass number, median (IQR)	1 (1–2)	1 (1–2)	0.317	1 (1–2)	1 (1–2)	0.596
Successful reperfusion	107 (93.9)	54 (94.7)	0.818	149 (93.1)	113 (93.4)	0.931
Stroke subtype						
Cardioembolism	65 (57.0)	27 (47.4)	0.274	84 (52.5)	61 (50.4)	0.930
Large-artery atherosclerosis	47 (41.2)	27 (47.4)		69 (43.1)	54 (44.6)	
Others	2 (1.8)	3 (5.2)		7 (4.4)	6 (5.0)	

mRS: Modified Rankin Scale, SBP: Systolic blood pressure, DBP: Diastolic blood pressure, NIHSS: National Institutes of Health Stroke Scale, ASPECTS: Alberta Stroke Program Early CT Score, SD: Standard deviation, IQR: Interquartile range, BMI: Body mass index, ICA: Internal carotid artery, OPT: Onset to groin puncture time, ORT: Onset to reperfusion time, M1 and M2: The first and second segment of middle cerebral artery

described as a phenomenon of impaired biologic insulin response.[8] This could result in an impaired ability to dispose glucose,[8] which may induce a more enduring increase in blood glucose levels, and thus, a more hyperglycemic brain injury. Meanwhile, overweight has been associated with chronic low-grade inflammation,[5] which may worsen hyperglycemia's impact on the ischemic brain through exacerbating the inflammatory cascade. Therefore, the detrimental efficacy of hyperglycemia would be more prominent in overweight patients.

Currently, the potential role of glucose-lowering treatment in improving clinical outcomes remains unclear in the acute phase of ischemic stroke.[3] The Stroke Hyperglycemia Insulin Network Effort trial showed comparable clinical prognosis between standard and intensive glucose management among patients with acute ischemic stroke, 13% of whom received thrombectomy.[24] Our results may offer insight for glucose management in the thrombectomy setting. Considering the significant interaction between having hyperglycemia at admission and being overweight on functional independence, glucose-lowering treatments could have different effects in overweight versus normal-weight patients. Intensive glucose control might have more beneficial effects in overweight patients than in normal-weight patients. Confirming this with future studies is warranted.

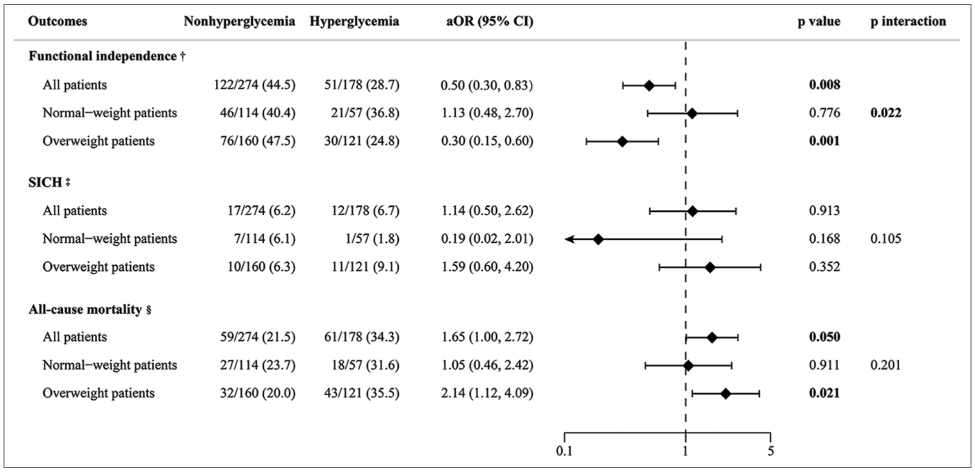

Figure 2: The effect of hyperglycemia at admission on clinical outcomes in the whole patient population and according to categorized body mass index. †Adjustment for age, history of diabetes, pretreatment NIHSS score, alteplase treatment, occlusion location, and collateral status, ‡Adjustment for baseline NIHSS score and history of diabetes, §Adjustment for history of diabetes, smoking status, baseline NIHSS score, occlusion site, and reperfusion status. SICH: symptomatic intracranial hemorrhage, NIHSS: National Institutes of Health Stroke Scale

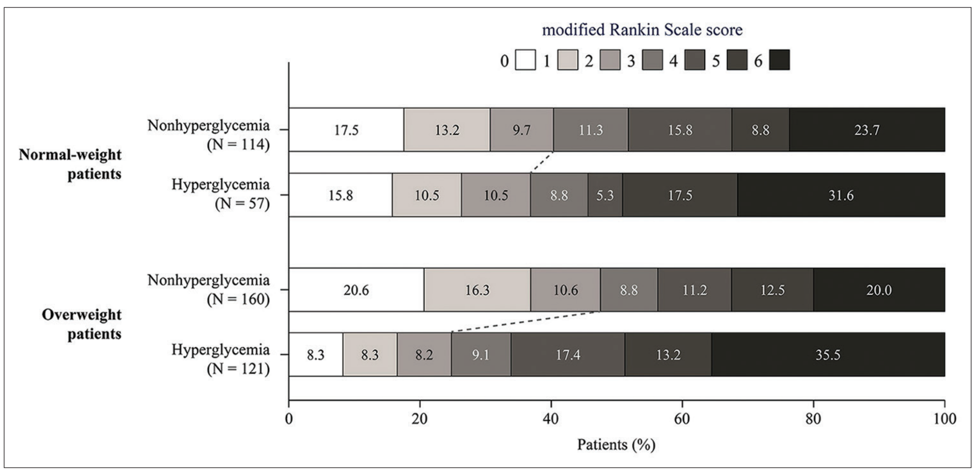

Figure 3: Distribution of modified Rankin Scale scores at 90 days after stroke according to categorized body mass index and blood glucose level at admission. Hyperglycemia at admission was associated with worse outcomes in overweight patients but not in normal-weight patients

Several limitations of the current study are worth mentioning. First, our research was a single-center, observational study, which could unavoidably pose selection bias. Nevertheless, the obtained results might be pathophysiologically plausible. Second, BMI has a low accuracy in evaluating excessive weight, while waist circumference or waist-to-hip ratio has been considered to be more precise. Nevertheless, BMI is still the most practical option in clinical routine.[5] Third, as the study only included Chinese patients, we adopted the Chinese criteria (BMI $\geq$24 kg/m^2) to designate patients as overweight,[15] which might limit the interpretations of our results. However, the proportion of overweight patients (61.4%) was comparable to the proportions (57.0%–70.5%) reported in prior studies,[9-11] which consisted of Western populations receiving thrombectomy and adopted the WHO criteria (BMI $\geq$25 kg/m^2). Studies with other races using the WHO criteria are required to confirm our findings. Fourth, as all observational studies, this study is susceptible to unmeasured confounding, such as the last mealtime to blood glucose test and the glycemia-lowering therapy after admission. Finally, we can only suggest a hypothesis of our findings. Future research is needed to confirm the mechanisms behind our findings by further testing insulin resistance and inflammatory biomarkers.

Conclusions

Weight status influenced the association of hyperglycemia at admission and functional independence among patients receiving endovascular thrombectomy. Hyperglycemia at admission was related to poorer outcomes among overweight patients but not among normal-weight patients. Our findings suggest tight control of glucose may be needed among overweight patients in the thrombectomy setting.

Author contributions

1. Conceptualization: DL, SL; 2. Data acquisition: X-SZ, Z-JC, M-HZ, T-PF; 3. Analysis and interpretation of data: all authors; 4. Visualization: TT, X-SZ, Z-JC; 5. Writing-original draft: TT; 6. Writing-review and editing: all authors; 7. Funding acquisition: DL, SL; 8. Final approval of manuscript: all authors.

Ethical policy and institutional review board statement

The study was conducted according to the principles outlined in the Declaration of Helsinki and was approved by the Ethics Committee of Dalian Municipal Central Hospital (approval number: 2019–004–11, dated on February 15th, 2019).

Data availability statement

The datasets generated during and/or analyzed during the current study are available from the corresponding author on reasonable request.

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Conflicts of interest

There are no conflicts of interest.

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Table S1: Baseline characteristics and outcomes of all patients and according to categorized body mass index

Variables	All patients (BMI ≥18.5 kg/m², n=452), n (%)	Normal-weight patients (BMI 18.5–24 kg/m², n=171), n (%)	Overweight patients (BMI ≥24 kg/m², n=281), n (%)	P
Age (years), median (IQR)	70 (63–77)	70 (63–78)	70 (63–77)	0.573
Female sex	182 (40.3)	77 (45.0)	105 (37.4)	0.273
BMI (kg/m²), median (IQR)	24.5 (23.3–26.4)	22.9 (21.8–23.4)	26 (24.5–27.7)	<0.001
Prestroke mRS ≥1	33 (7.3)	15 (8.8)	18 (6.4)	0.348
Medical history				
Hypertension	268 (59.3)	93 (54.4)	175 (62.3)	0.098
Diabetes mellitus	98 (21.7)	32 (18.7)	66 (23.5)	0.232
Glucose-lowering treatments	66 (14.6)	21 (12.3)	45 (16.0)	0.276
Ischemic stroke/TIA	49 (10.8)	19 (11.1)	30 (10.7)	0.885
Atrial fibrillation	207 (45.8)	76 (44.4)	131 (46.6)	0.653
Smoking	187 (41.4)	71 (41.5)	116 (41.3)	0.960
Current stroke event				
SBP (mmHg), mean±SD	151.2±29.1	147.8±28.3	153.2±29.4	0.056
DBP (mmHg), mean±SD	85.0±17.0	83.5±16.8	86.0±17.1	0.136
Baseline NIHSS score, median (IQR)	17 (13–21)	16 (13–21)	17 (13–21)	0.792
ASPECTS, median (IQR)	8 (7–9)	9 (7–10)	8 (7–9)	0.177
Glucose (mmol/L), median (IQR)	7.3 (6.4–9.3)	7.2 (6.3–9)	7.4 (6.5–9.4)	0.071
Hyperglycemia (≥7.8 mmol/L)	178 (39.4)	57 (33.3)	121 (43.1)	0.040
Intravenous thrombolysis	202 (44.7)	75 (43.9)	127 (45.2)	0.782
Occlusion site				
M1	225 (49.8)	79 (46.2)	146 (52.0)	0.126
M2	52 (11.5)	16 (9.4)	36 (12.8)	
ICA	175 (38.7)	76 (44.4)	99 (35.2)	
Anesthesia				
General anesthesia	16 (3.5)	12 (7.1)	4 (1.4)	0.007
Local anesthesia	285 (63.1)	102 (59.6)	183 (65.1)	
Conscious sedation	151 (33.4)	57 (33.3)	94 (33.5)	
Good collaterals	129 (28.5)	61 (35.7)	68 (24.2)	0.009
OPT (min), median (IQR)	274 (185–390)	275 (185–394)	270 (190–385)	0.716
ORT (min), median (IQR)	330 (245–445)	331 (245–450)	325 (245–445)	0.656
Device-pass number, median (IQR)	1 (1–2)	1 (1–2)	1 (1–2)	0.827
Successful reperfusion	423 (93.6)	161 (94.2)	262 (93.2)	0.701
Stroke subtype				
Cardioembolism	237 (52.4)	92 (53.8)	145 (51.6)	0.645
Large-artery atherosclerosis	197 (43.6)	74 (43.3)	123 (43.8)	
Others	18 (4.0)	5 (2.9)	13 (4.6)	
Outcomes				
Functional independence (mRS 0–2)	173 (38.3)	67 (39.2)	106 (37.7)	0.757
SICH	29 (6.4)	8 (4.7)	21 (7.5)	0.240
All-cause mortality	120 (26.5)	45 (26.3)	75 (26.7)	0.930

BMI: Body mass index, IQR: Interquartile range, TIA: Transient ischemic attack, SBP: Systolic blood pressure, SD: Standard deviation, DBP: Diastolic blood pressure, NIHSS: National Institutes of Health Stroke Scale, ASPECTS: Alberta Stroke Program Early CT Score, M1 and M2: The first and second segment of middle cerebral artery, ICA: Internal carotid artery, OPT: Onset to groin puncture time, ORT: Onset to reperfusion time, SICH: Symptomatic intracranial hemorrhage, mRS: Modified Rankin Scale