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Predictors of intracranial hemorrhage after mechanical thrombectomy using a stent-retriever for anterior circulation ischemic stroke

A retrospective study

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Abstract

Intracranial hemorrhage (ICH) after mechanical thrombectomy (MT) is a potentially catastrophic complication. We aimed to identify predictors of hemorrhagic complications following MT using a stent-retriever (SR) for acute ischemic stroke (AIS) patients due to large vessel occlusion of anterior circulation. In consecutive AIS patients, the clinical and procedural variables were retrospectively analyzed. ICH was evaluated on computed tomography performed 24 hours following MT and dichotomized into asymptomatic ICH and symptomatic intracranial hemorrhage (SICH) depending on the presence of neurological deterioration. Using univariate and multivariate analyses, the predictors of ICH and SICH were identified. The optimal cutoff value for predicting SICH was determined by receiver operating characteristic (ROC) analysis. Among 135 patients, ICH was detected in 52 (38.5%), and 17 (12.6%) were classified as having SICH. We found that serum glucose level (odds ratio [OR] 1.016, $P = .011$) and number of SR passes (OR 2.607, $P < .001$) were significantly correlated with ICH. Independent predictors of SICH included the baseline Alberta stroke program early computed tomography score (ASPECTS) (OR 0.485, $P = .042$), time from stroke onset to groin puncture (OTP) (OR 1.033, $P = .016$), and number of SR passes (OR 2.342, $P = .038$). In ROC analysis, baseline ASPECTS ≤ 7, OTP > 280 minutes, and SR passes > 3 were the optimal cutoff values for predicting SICH. In conclusion, serum glucose level and SR pass serve as predictors for any form of ICH in large vessel occlusion-induced AIS patients undergoing MT. Moreover, patients with lower ASPECTS, prolonged OTP, and multiple SR passes are more vulnerable to SICH.

Abbreviations: AICH = asymptomatic intracranial hemorrhage, AIS = acute ischemic stroke, ASPECTS = Alberta stroke program early CT score, CT = computed tomography, ECASS = European cooperative acute stroke study, ICH = intracranial hemorrhage, LVO = large vessel occlusion, MT = mechanical thrombectomy, NIHSS = national institutes of health stroke scale, OTP = onset to groin puncture, PT = procedure time, SICH = symptomatic intracranial hemorrhage, SR = stent-retriever.

Keywords: acute ischemic stroke, intracranial hemorrhages, risk factors, stents, thrombectomy

1. Introduction

Currently, mechanical thrombectomy (MT) is the gold standard reperfusion treatment for acute ischemic stroke (AIS) derived from large-vessel occlusion (LVO) of anterior circulation. This is based on its proven efficacy and safety in several randomized trials.[1–3] Moreover, the current treatment guidelines recommend MT using a stent-retriever (SR) as the first line of treatment for LVO of the anterior circulation.[4]

Despite advancements in thrombectomy techniques and devices resulting in a reperfusion rate of > 80% in patients with LVO following MT,[5,6] it remains problematic that intracranial hemorrhage (ICH) is a commonly encountered post-procedural complication occurring in approximately 40% of patients with LVO after MT.[7,8] In particular, symptomatic intracranial hemorrhage (SICH) is such a potentially life-threatening complication as to cause unfavorable outcomes and raises mortality, thus eventually decreasing the risk-benefit ratio of endovascular treatment.[8,9] Therefore, it is mandatory to identify potential predictors of the above-mentioned feared complications, which will be essential for maximizing the efficacy of MT through a stringent risk assessment and reasonable strategies for peri-procedural management.

According to previous studies, there are several clinical or procedural predictors of hemorrhagic complications following MT for LVO-induced AIS patients; these include the national institutes of health stroke scale (NIHSS) score on admission, serum glucose level, systolic blood pressure, Alberta stroke program

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early computed tomography (CT) score (ASPECTS) on admission, delayed MT, duration of the procedure, and multiple passes of SR.[8–14] Still, there is heterogeneity and paucity of consensus concerning various predictors of hemorrhagic complications in patients undergoing MT. Therefore, we conducted this retrospective study to identify independent predictors of hemorrhagic complications (ICH and specifically SICH) in anterior circulation LVO-induced AIS patients undergoing MT using the SR.

2. Methods

2.1. Study population and clinical data

The ethical committee of our institution gave its approval to the current study (IRB No. 2022AS0146). Given that it was designed retrospectively, the written informed consent was waived. We analyzed the clinical and procedural data of 162 patients with anterior circulation LVO-induced AIS who were treated by MT at our institution from March 2014 to December 2021 according to the national treatment guidelines that were current at the time of treatment.[4,15]

The following were the requirements for eligibility in the current study: AIS caused by intracranial LVO of anterior circulation confirmed on digital subtraction angiography; MT initiated within 6 hours of symptom onset; pre-stroke modified Rankin Scale (mRS) score < 2, admission NIHSS score ≥ 6, and ASPECTS on admission ≥ 6; and MT performed with at least 1 pass of the SR device.

Patients diagnosed with intracranial-extracranial tandem occlusion, treated with direct aspiration alone, and those without subsequent imaging data were excluded. Figure 1 demonstrates the flowchart for including the study population.

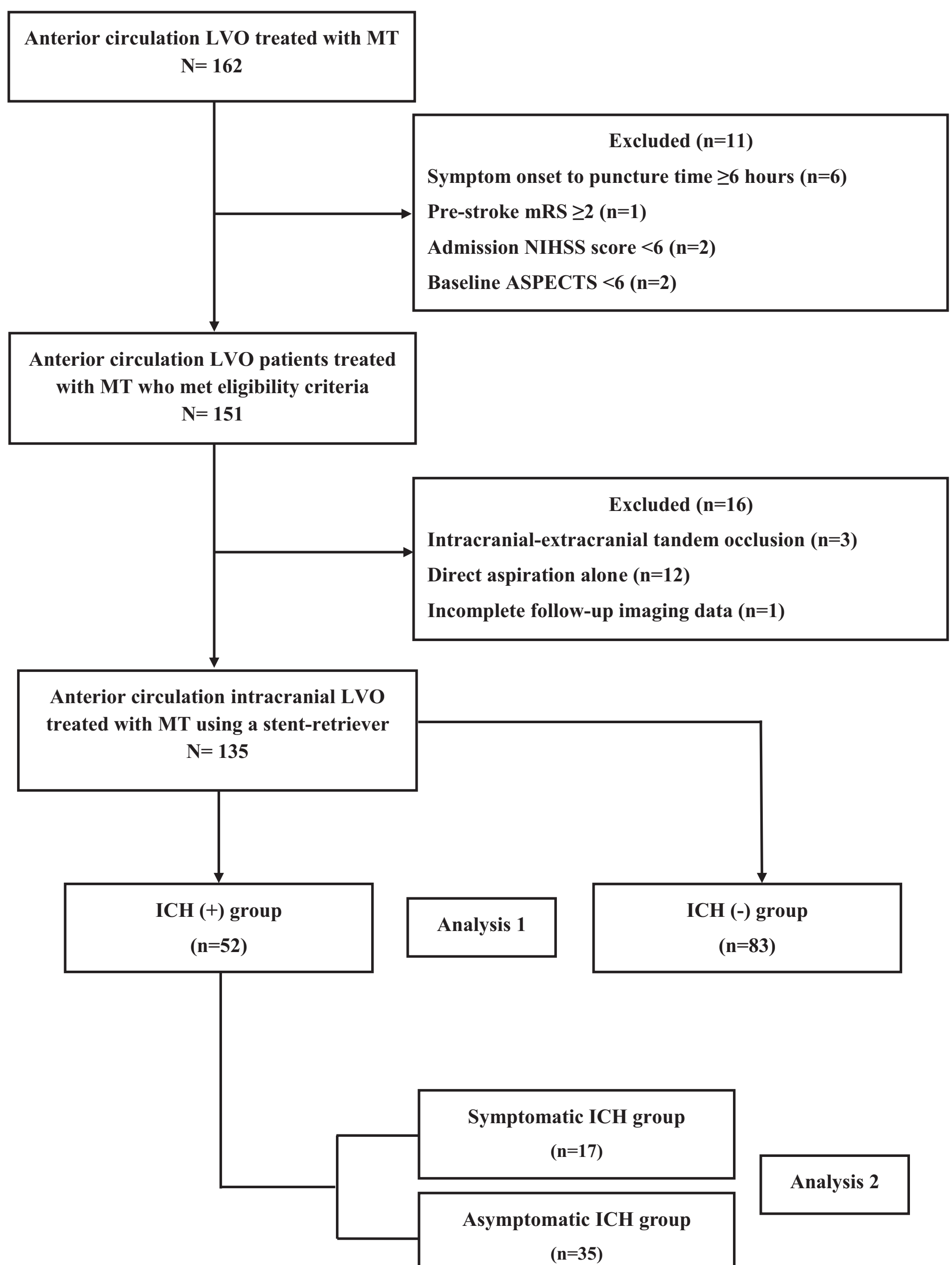

Figure 1. Flowchart of patient inclusion. LVO, large vessel occlusion; MT, mechanical thrombectomy; mRS, modified Rankin Scale; NIHSS, National Institutes of Health Stroke Scale; ASPECTS, Alberta Stroke Program Early CT Score; ICH, intracranial hemorrhage. ASPECTS = Alberta stroke program early CT score.

We collected the following clinical variables from the finally enrolled 135 patients: age, sex, relevant comorbidities, history of antiplatelet and/or anticoagulant agent use, baseline laboratory findings, initial blood pressure in the emergency department, initial stroke severity assessed with the NIHSS score on admission, ASPECTS based on pre-procedural brain CT scan,[16] and stroke subtypes based on the Trial of Org 10172 in Acute Stroke Treatment (TOAST) criteria.[17]

Procedural variables included the site of arterial occlusion, intravenous tissue plasminogen activator pretreatment, time from stroke onset to groin puncture (OTP), procedure time (PT) defined as the time from groin puncture to the first successful recanalization or abortion of the procedure without successful recanalization,[18] procedure details (use of direct aspiration technique, number of SR attempts per procedure), and rescue therapies (implantation of an intracranial stent, intra-arterial glycoprotein IIb/IIIa inhibitor infusion, and/or intra-arterial thrombolysis).

2.2. Endovascular treatment

Intravenous tissue plasminogen activator was given to eligible patients (within 4.5 hours of stroke onset) prior to the procedure in accordance with the national guidelines.[4,15] Then they were transferred to an angiographic suite for emergent thrombectomy. All endovascular procedures were conducted using a biplane neuro-angiography system (Allura Clarity FD20/15; Philips Healthcare, Best, The Netherlands) under conscious sedation by experienced neuro-interventionists.

All enrolled patients underwent MT using second-generation stent-like thrombectomy devices, such as Solitaire (Medtronic Neurovascular, Irvine, CA) or Trevo (Stryker Neurovascular, Fremont, CA), concurrently with 8F balloon-guiding catheter to modulate the carotid antegrade flow by temporary inflation, which reduces embolic burden in a new territory. Some patients underwent thrombectomy using both SR and large-bore aspiration catheter (SOFIA 6F; Micro Vention-Terumo, Tustin, CA). The aspiration catheter was used to perform the previously reported direct contact aspiration.[19] With the aspiration catheter placed in the region adjacent to the occlusion site, direct aspiration was carried out with a 50 mL syringe. If the initial direct aspiration was unsuccessful, the thrombectomy strategy was switched to using SR devices. If MT was unsuccessful to the last, adjunctive rescue therapy was administered. The attending neuro-interventionist made the decision on thrombectomy devices and adjunctive rescue therapies.

Angiographic result of MT was assessed based on the grade of recanalization according to the modified Thrombolysis in Cerebral Infarction (mTICI) scoring system, for which successful recanalization was defined as mTICI score of 2b or 3 on the final cerebral angiography, as previously described.[20]

2.3. Intracerebral hemorrhage assessment

Post-procedural follow-up conventional brain CT scan was taken 24 hours following MT or earlier in the occurrence of sudden neurological deterioration, which suggests hemorrhagic complications.[11,14] Subsequent CT scans were obtained at various time points 3 to 7 days after MT considering the patient's clinical status. Post-procedural ICH was defined according to the European cooperative acute stroke study (ECASS) criteria,[21] and dichotomized into SICH and asymptomatic intracranial hemorrhage (AICH). SICH was determined by assessing the correlation between clinical worsening and radiologic findings (any ICH on CT scan associated with the neurological deterioration that increased NIHSS score by more than 4 points within 24 hours or caused death).[22] AICH was defined as any newly reported ICH without additional neurological deterioration. Representative images of AICH and SICH are shown in Figure 2. Two neuro-interventionists and 1 neuro-radiologist blinded to the clinical details independently assessed all radiologic data. The final judgments were made by consensus.

2.4. Statistical Analysis

The Student's *t* test was used to evaluate continuous variables that were presented as either mean with standard deviation or median with interquartile range. Categorical variables, expressed as the numbers of patients with percentages, were analyzed using Pearson's chi-squared test. According to the presence of ICH, patients were categorized into 2 groups, and univariate analyses were conducted to compare the 2 groups (ICH vs no ICH). In addition, patient characteristics in the

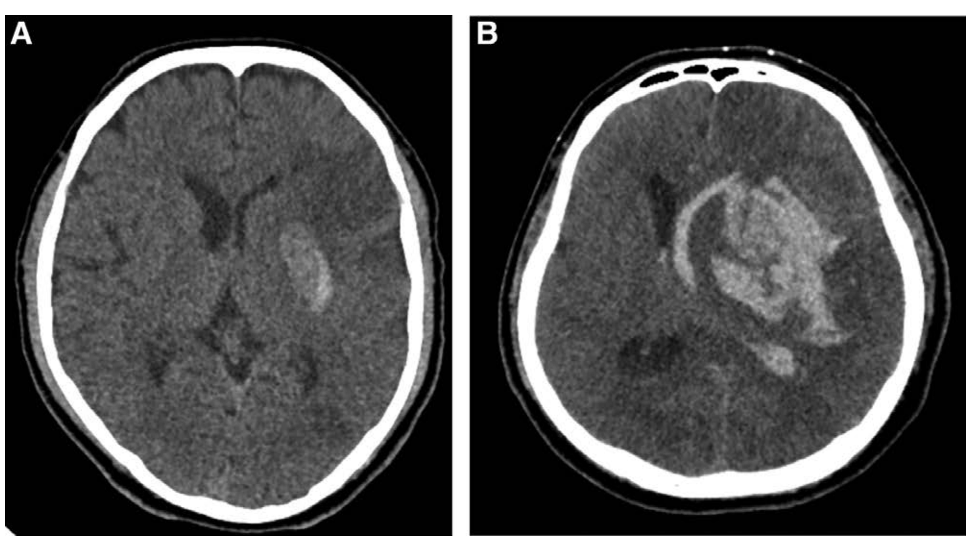

Figure 2. Representative images of (A) asymptomatic intracranial hemorrhage (ICH) and (B) symptomatic ICH on axial computed tomography (CT) scans. (A) CT scan demonstrating ICH of left putamen without additional neurological deterioration, classified hemorrhagic infarction type 2 according to ECASS criteria. (B) CT scan showing ICH of left basal ganglia with intraventricular hemorrhage and mass effect causing a midline shift to the right (ECASS criteria parenchymal hematoma type 2), leading to clinical deterioration. ECASS, European Cooperative Acute Stroke Study.

Table 1

Demographic, clinical and procedural variables of all patients.

	All patients (n = 135)
Male	66 (48.9)
Age (yr)	69.6 ± 12.0
Hypertension	75 (55.6)
Diabetes mellitus	32 (23.7)
Atrial fibrillation	55 (40.7)
Dyslipidemia	42 (31.1)
Coronary heart disease	32 (23.7)
Previous stroke	20 (14.8)
Antiplatelet medication	45 (33.3)
Anticoagulant medication	26 (19.3)
Initial SBP (mm Hg)	151.9 ± 22.1
Initial DBP (mm Hg)	89.5 ± 15.2
Platelet count (10^9/L)	244.0 ± 86.9
INR	1.12 ± 0.20
Serum glucose (mg/dL)	136.0 ± 32.9
Admission NIHSS score	17 (14–20)
Baseline ASPECTS	8 (7-9)
Cause of stroke	
Large-artery atherosclerosis	36 (26.7)
Cardioembolic	88 (65.2)
Other or unknown	11 (8.1)
Occlusion site	
Intracranial ICA	40 (29.6)
MCA - M1	78 (57.8)
MCA - M2	17 (12.6)
Pretreatment of IV tPA	90 (66.7)
Onset to groin puncture (min)	275 (235–300)
Procedure time (min)	65 (45–87.5)
Direct aspiration	38 (28.1)
Number of stent-retriever passes	2.59 ± 1.16
1	22 (16.3)
2	51 (37.8)
3	33 (24.4)
4	21 (15.6)
>5	8 (5.9)
Rescue therapies	
Intracranial stenting	32 (23.7)
IA glycoprotein IIb/IIIa inhibitor	8 (5.9)
IA thrombolysis	14 (10.4)
Successful recanalization	107 (79.3)

Data are presented as mean ± standard deviations or numbers (%), or median (interquartile range). ASPECTS = alberta stroke program early CT score, DBP = diastolic blood pressure, ICH = intracranial hemorrhage, IA = intra-arterial, ICA = internal carotid artery, INR = international normalized ratio, SBP = systolic blood pressure, MCA = middle cerebral artery, NIHSS = national institutes of health stroke scale, IV tPA = intravenous tissue plasminogen activator.

SICH and AICH groups were compared. Consequently, multivariate logistic regression analysis was conducted for variables with a *P* value of < .10 in univariate analysis to identify predictors of ICH and SICH, respectively. Adjusted odds ratios (ORs) and 95% confidence intervals (CIs) were calculated. The optimal cutoff value for predicting SICH was determined using receiver operating characteristic (ROC) analysis. The cutoff value was established using the highest sum of the Youden index measures of sensitivity and specificity. All statistical analyses were conducted using SPSS 23.0 software (IBM Corp., Armonk, NY), and statistics were determined significant at *P* < .05.

3. Results

In the current study, 135 eligible patients were enrolled (Fig. 1). Among the entire cohort, any form of ICH was detected in 52 (38.5%) patients, and 17 (12.6%) patients were classified as having SICH according to the ECASS criteria. Table 1 demonstrates all patient's demographic, clinical, and procedural variables.

3.1. Predictors of ICH

In the univariate analysis, serum glucose, admission NIHSS score, baseline ASPECTS, PT, and the number of SR passes correlated with ICH occurrence (*P* < .1). Serum glucose level (OR 1.016, 95% CI 1.004–1.029, *P* = .011) and number of SR passes (OR 2.607, 95% CI 1.742–3.902, *P* < .001) were found to be independent predictive variables of ICH in multivariate logistic regression (Table 2).

3.2. Predictors of SICH

Univariate and multivariate analyses were conducted to compare SICH and AICH groups (Table 3). The SICH group showed lower ASPECTS, prolonged OTP, longer PT, and a higher number of passes of SR than the AICH group. In the multivariate analysis, baseline ASPECTS (OR 0.485, 95% CI 0.242–0.973, *P* = .042), OTP (OR 1.033, 95% CI 1.006–1.061, *P* = .016), and number of SR passes (OR 2.342, 95% CI 1.049–5.229, *P* = .038) were found to be independent predictors of SICH.

The ROC analysis revealed that the optimal cutoff values for SICH prediction were baseline ASPECTS ≤ 7, OTP > 280 minutes, and number of SR passes > 3. The results of subsequent multivariate analysis of the above 3 independent SICH predictors' cutoff points are shown in Table 4.

4. Discussion

ICH following reperfusion treatment for AIS was not an uncommon post-procedural complication. We found that this occurred at a rate of 38.5% in our series. This is consistent with previously published studies showing that it was estimated at approximately 40%.[7,8,13] Moreover, SICH is a severe complication of MT, occurring at a rate of 12.6% (17/135) in our study. This is also in agreement with previously published literatures.[8,13] This retrospective study identified several potential predictors of ICH and SICH following MT using the SR in anterior circulation LVO-induced AIS patients. Hyperglycemia and multiple passes of SR were independent predictors of any form of ICH. Moreover, patients with lower ASPECTS on admission, prolonged OTP, and multiple passes of SR were more vulnerable to SICH.

Our results showed that the higher serum glucose level on admission was a predictor of SICH following MT in patients with LVO-induced AIS. This concurs with previously published studies.[9,10,12] Hyperglycemia may cause blood-brain barrier disruption, cytotoxic edema, and exacerbation of the thrombo-inflammatory response. Therefore, hyperglycemic patients in AIS undergoing MT may be susceptible to hemorrhagic complications.[23–25] However, a recent study showed that glycosylated hemoglobin (HbA1c) is a more reliable predictive factor of hemorrhagic complications than serum glucose value on admission.[26] This suggests that long-term vascular injury derived from chronically uncontrolled blood glucose was more precisely reflected in HbA1c rather than hyperglycemia on admission, which possibly arose from acute stress response after AIS.[27] However, it is limited for global use because HbA1c is not measured as a routine laboratory parameter in all patients with stroke. This warrants further large-scale prospective trials because it is unclear which parameters are more accurate predictors of the possibility of hemorrhagic complications in AIS patients.

Contrary to the results of the current study, according to a previous retrospective study conducted on 329 patients, the number of SR passes was found to be insignificant for hemorrhagic transformation.[28] However, this should be regarded with caution; the number of passes per procedure in the above study was almost 3 or less (96.7%), and more than 3 passes were too sparse (3.3%). The number of SR passes and an increased risk of SICH are positively correlated, according to several previous

Table 2

Results of univariate analysis and multivariate logistic regression for predictors of ICH.

	ICH (+) (n = 52)	ICH (-) (n = 83)	*P* value (univariate)	Odds ratio (95% CI)	*P* value (multivariate)
Male	24 (46.2)	42 (50.6)	.618		
Age (yr)	71.0 ± 10.4	68.7 ± 12.9	.282		
Hypertension	29 (55.8)	46 (55.4)	.969		
Diabetes mellitus	16 (30.8)	16 (19.3)	.144		
Atrial fibrillation	25 (48.1)	30 (36.1)	.177		
Dyslipidemia	19 (36.5)	23 (27.7)	.294		
Coronary heart disease	13 (25.0)	19 (22.9)	.781		
Previous stroke	10 (19.2)	10 (12.0)	.278		
Antiplatelet medication	14 (26.9)	31 (37.3)	.206		
Anticoagulant medication	11 (21.2)	15 (18.1)	.661		
Initial SBP (mm Hg)	154.8 ± 21.1	150.2 ± 22.6	.243		
Initial DBP (mm Hg)	90.1 ± 14.9	89.1 ± 15.5	.703		
Platelet count (10^9/L)	239.1 ± 90.7	247.1 ± 84.8	.601		
INR	1.10 ± 0.30	1.05 ± 0.22	.316		
Serum glucose (mg/dL)	146.3 ± 26.1	129.6 ± 35.1	.002	1.016 (1.004–1.029)	.011*
Admission NIHSS score	18 (15–21)	16 (13–19)	.071	1.003 (0.912–1.103)	.949
Baseline ASPECTS	7.75 ± 1.25	8.37 ± 1.13	.003	0.808 (0.548–1.192)	.283
Cause of stroke					
Large-artery atherosclerosis	14 (26.9)	22 (26.5)	.958		
Cardioembolic	33 (63.5)	55 (66.3)	.742		
Other or unknown	5 (9.6)	6 (7.2)	.625		
Occlusion site					
Intracranial ICA	15 (28.8)	25 (30.1)	.623		
MCA - M1	31 (59.6)	47 (56.6)	.735		
MCA - M2	6 (11.5)	11 (13.3)	.772		
Pretreatment of IV tPA	35 (67.3)	55 (66.3)	.901		
Onset to groin puncture (min)	275 (235–291)	280 (225–300)	.885		
Procedure time (min)	80 (70–100)	55 (40–75)	<.001	1.015 (0.993–1.038)	.179
Direct aspiration	15 (28.8)	23 (27.7)	.888		
Number of stent-retriever passes	3.25 ± 1.19	2.17 ± 0.92	<.001	2.607 (1.742–3.902)	<.001*
Rescue therapies					
Intracranial stenting	11 (21.2)	21 (25.3)	.585		
IA glycoprotein IIb/IIIa inhibitor	3 (5.8)	5 (6.0)	.952		
IA thrombolysis	5 (9.6)	9 (10.8)	.821		
Successful recanalization	39 (75.0)	68 (81.9)	.338		

Data are presented as mean ± standard deviations or numbers (%), or median (interquartile range).
ASPECTS = alberta stroke program early CT score, DBP = diastolic blood pressure, IA = intra-arterial, ICA = internal carotid artery, ICH = intracranial hemorrhage, INR = international normalized ratio, IV tPA = intravenous tissue plasminogen activator, MCA = middle cerebral artery, NIHSS = national institutes of health stroke scale, SBP = systolic blood pressure.
*Statistical significance.

studies.[10,13,14] In more detail, a recent multi-center study revealed that more than 3 attempts of SR was an independent predictor of SICH.[8] Several mechanisms support the correlation between hemorrhagic transformation and multiple attempts of SR. First, multiple passes of SR may cause an endothelial injury to the arterial wall after each trial through an additional mechanical stretch during thrombus retrieval, which could lead to hemorrhagic transformation.[29] In particular, the use of SR may injure the endothelium by generating a sustained radial force to the vessel wall to trap the thrombus clot.[30] Second, multiple attempts to remove the clot cause blood-brain barrier disruption, and its severity is associated with aggravation of hemorrhagic transformation.[31]

As we know the importance of time on clinical outcomes in AIS, recent studies on the association between various time metrics and hemorrhagic complications have been conducted. The association of PT with post-procedural hemorrhagic complications has been described previously, with prolonged PT increasing the risk of SICH.[11,18] However, we failed to reproduce these results in the multivariate analysis, whereas OTP remained a significant predictor for SICH. This may be because, in addition to the SR passes, multifactorial variables were involved in the composition of overall PT, such as proficiency in attending neuro-interventionists, complicated vessel anatomy, and procedure details (direct aspiration, and rescue therapies). In summary, multiple thrombectomy maneuvers may increase PT, but the number of passes does not necessarily equal the PT; therefore, we speculate that it cannot be used as a surrogate marker for SICH.

Several studies have postulated the impact of OTP as a predictor of SICH, which is consistent with our results. According to a retrospective study conducted on 632 patients, OTP of more than 270 min was a significant predictor for SICH.[8] Similar results have been demonstrated in a previous study: prolonged OTP significantly increases the risk of parenchymal hematoma.[32] These results may be attributed to the enhanced susceptibility of ischemic brain tissue to reperfusion injury. Consequently, after arriving at the emergency department, a fast transfer to the angiography suite for eligible patients is the key to reducing hemorrhagic events after MT. A more recent multi-center analysis discovered that a longer interval between onset and admission was significantly correlated with hemorrhagic complications classified as parenchymal hematoma type 2 according to the ECASS criteria. Moreover, it was the time metric with the most significant impact.[33] Therefore, further studies based on subdivided time metrics are warranted to clarify novel time-related variables to help predict hemorrhagic complications.

This study did not identify a higher baseline NIHSS score as a predictor of hemorrhagic complications, unlike previous reports.[9,10] This might imply that in addition to reflecting the ischemic core, the NIHSS score also represents the reversible penumbra, in contrast to ASPECTS. In previous studies, lower ASPECTS had a significant correlation with a risk of SICH, in line with our results.[12,14,34] Notably, 2 validated predictive

Table 3

Results of univariate analysis and multivariate logistic regression for predictors of SICH.

	SICH (n = 17)	AICH (n = 35)	*P* value (univariate)	Odds ratio (95% CI)	*P* value (multivariate)
Male	7 (41.2)	17 (48.6)	.624		
Age (yr)	71.7 ± 8.0	70.6 ± 11.5	.731		
Hypertension	9 (52.9)	20 (57.1)	.780		
Diabetes mellitus	5 (29.4)	11 (31.4)	.885		
Atrial fibrillation	6 (35.3)	19 (54.3)	.206		
Dyslipidemia	6 (35.3)	13 (37.1)	.899		
Coronary heart disease	3 (17.6)	10 (28.6)	.403		
Previous stroke	3 (17.6)	7 (20.0)	.844		
Antiplatelet medication	5 (29.4)	9 (25.7)	.783		
Anticoagulant medication	5 (29.4)	6 (17.1)	.319		
Initial SBP (mm Hg)	155.8 ± 22.2	154.3 ± 20.8	.812		
Initial DBP (mm Hg)	89.5 ± 14.3	90.4 ± 15.3	.845		
Platelet count (10^9/L)	250.2 ± 96.1	233.7 ± 88.9	.542		
INR	1.12 ± 0.33	1.09 ± 0.28	.721		
Serum glucose (mg/dL)	154.1 ± 19.7	142.5 ± 28.3	.138		
Admission NIHSS score	18 (17–21)	18 (15–20.5)	.450		
Baseline ASPECTS	7.00 ± 1.06	8.11 ± 1.18	.002	0.485 (0.242–0.973)	.042*
Cause of stroke			.638		
Large-artery atherosclerosis	5 (29.4)	9 (25.7)	.783		
Cardioembolic	9 (52.9)	24 (68.6)	.281		
Other or unknown	3 (17.6)	2 (5.7)	.260		
Occlusion site			.425		
Intracranial ICA	4 (23.5)	11 (31.4)	.403		
MCA - M1	11 (64.7)	20 (57.1)	.610		
MCA - M2	2 (11.8)	4 (11.4)	.972		
Pretreatment of IV tPA	12 (70.6)	23 (65.7)	.732		
Onset to groin puncture	290 (285–300)	260 (220–285)	<.001	1.033 (1.006–1.061)	.016*
Procedure time	100 (75–105)	75 (57.5–92.5)	.034	1.022 (0.992–1.054)	.156
Direct aspiration	6 (35.3)	9 (25.7)	.484		
Number of stent-retriever passes	4 ± 1.23	2.89 ± 0.99	.001	2.342 (1.049–5.229)	.038*
Rescue therapies			.885		
Intracranial stenting	4 (23.5)	7 (20.0)	.775		
IA glycoprotein IIb/IIIa inhibitor	1 (5.9)	2 (5.7)	.981		
IA thrombolysis	1 (5.9)	4 (11.4)	.534		
Successful recanalization	12 (70.6)	27 (77.1)	.617		

Data are presented as mean ± standard deviations or numbers (%), or median (interquartile range).
AICH = asymptomatic intracranial hemorrhage, ASPECTS = alberta stroke program early CT score, DBP = diastolic blood pressure, IA = intra-arterial, ICA = internal carotid artery, INR = international normalized ratio, IV tPA = intravenous tissue plasminogen activator, MCA = middle cerebral artery, NIHSS = national institutes of health stroke scale, SBP = systolic blood pressure, SICH = symptomatic intracranial hemorrhage.
*Statistical significance.

Table 4

Results of multivariate analysis for cutoff values of independent predictors of SICH.

	Odds ratio (95% CI)	*P* value
Baseline ASPECTS ≤ 7	5.380 (1.236–23.416)	0.025*
Onset to groin puncture > 280 min	9.380 (2.046–42.999)	0.004*
Number of stent-retriever passes > 3	5.697 (1.104–29.398)	0.038*

ASPECTS = alberta stroke program early CT score, SICH = symptomatic intracranial hemorrhage.
*Statistical significance.

models for SICH (TAG score and The ASIAN Score) contained ASPECTS as a significant variable.[14,34] Patients with large-sized infarct core may be vulnerable to SICH, which indirectly suggests an enormous stroke burden and vulnerability to reperfusion injury after endovascular procedures. Our results indicate that MT should be performed in a timely manner to prevent the occurrence of SICH, which decreases the risk-benefit ratio of MT.

Our results cannot be generalized; several limitations of this study are as follows: First, we included a relatively small series of retrospectively enrolled patients with SICH. This may have confounded the results of multivariate analyses, underestimating the impact of other variables. Second, we failed to evaluate potentially relevant parameters such as biological markers, collateral status, and time-related variability in blood pressure during and after the procedure, which may contribute to the development of hemorrhagic complications. Nevertheless, our findings can be useful in predicting ICH and SICH in AIS patients undergoing MT in a real-world clinical setting.

5. Conclusions

This study identified several significant predictors of ICH and SICH in LVO-induced AIS patients treated with MT using the

SR. Serum glucose level and the number of SR passes were predictors of any form of ICH. Specifically, patients with lower ASPECTS on admission (≤7), prolonged OTP (>280 minutes), and multiple passes of SR (>3) are more vulnerable to SICH. Our study suggests that timely MT is important in preventing SICH. In addition, when more than 3 passes of SR is necessary for recanalization, neuro-interventionists should be aware of the possibility of post-procedural hemorrhagic complications.

Author contributions

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Project administration: Jong-Il Choi.
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Software: In-Hyoung Lee.
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