Journal of the Neurological Sciences 403 (2019) 127–132

Contents lists available at ScienceDirect

Journal of the Neurological Sciences

journal homepage: www.elsevier.com/locate/jns

Association between initial NIHSS score and recanalization rate after endovascular thrombectomy

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ARTICLE INFO

Keywords:
Ischemic stroke
Anterior circulation occlusion
Thrombectomy
Recanalization

ABSTRACT

Background: National institutes of Health Stroke Scale (NIHSS) score and the presence of successful recanalization are crucial determinants of clinical outcome in patients with major artery occlusion. However, it is unknown whether successful recanalization rate after endovascular therapy (EVT) depends on NIHSS score.
Methods: From our prospective EVT registry, data on patients with an occlusion at the internal carotid artery or middle cerebral artery were analyzed. Successful recanalization was judged as positive when reperfusion of the thrombolysis in cerebral infarction (TICI) scale ≥2b was observed. Successful recanalization rate was also evaluated based on the NIHSS score subgroups: 0–8, 9–16, 17–24, and > 24. Multivariate regression analysis was used to evaluate the impact of NIHSS score on successful recanalization.
Results: We studied 183 patients (age 76 [68–83], male 110 [60%], NIHSS score 19 [14–24]). One hundred and forty-six (80%) patients had the successful recanalization. Patients achieved the recanalization had lower NIHSS score as 18 (12 − 23), contrary those failed it had higher NIHSS score as 24 (20–27) ($p < .001$). Successful recanalization rate was correlated to the NIHSS score grade; 100% in the NIHSS 0–8 group, 88% in 9–16, 81% in 17–24, and only 60% in > 24 ($p < .001$). Multivariate regression analysis showed NIHSS score was an independent parameter of recanalization (odds ratio 0.905 [95%CI 0.837–0.979], $p = .013$).
Conclusion: NIHSS score may serve as a predictor of successful recanalization. Recanalization is relatively easier in mild stroke than in those with severe stroke.

1. Introduction

Recent advancements in endovascular therapy (EVT) modalities have markedly changed hyperacute stroke management [1]. Rapid and successful recanalization facilitates restoring the beneficial anterograde flow to achieve neurological recovery and favorable outcomes [2]. To date, numerous studies have reported that factors, including onset-to-treatment time, atrial fibrillation, occlusion site, and thrombus signal and length, are associated with successful recanalization after intravenous thrombolysis [3–5]. However, predictive parameters after EVT are not well-established, except the collateral flow on neuroimaging [6–8]. Further improvement in the prediction of EVT recanalization would provide additional information if physicians decide whether EVT should be performed.

The National Institutes of Health Stroke Scale (NIHSS) score is the most widely used semi-quantitative scoring system, which represents the initial neurological deficit as well as clinical outcomes at 3 months of stroke onset [9]. Typically, a baseline NIHSS score of 8 is considered the cut-off score associated with unfavorable outcomes [10]. Because the NIHSS score is related to not only clinical symptoms but also to the penumbra volume [11], we hypothesized that the score obtained before EVT can predict the rate of successful recanalization, thus offering important information before EVT. Therefore, in this study, we investigated whether the recanalization rate after EVT depends on the initial NIHSS score.

2. Methods

2.1. Patients

From our prospective EVT registry, data on 305 consecutive ischemic stroke patients examined between April 2011 and May 2018

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https://doi.org/10.1016/j.jns.2019.06.033
Received 3 February 2019; Received in revised form 12 June 2019; Accepted 28 June 2019
Available online 29 June 2019
0022-510X/

were retrospectively reviewed. In this study, only patients who had occlusion of the internal carotid artery (ICA) or horizontal portion (M1) of the middle cerebral artery (MCA) were analyzed. Thus, patients with occlusion of other arteries, such as the anterior cerebral artery (ACA), distal MCA, basilar artery (BA), posterior cerebral artery (PCA), and vertebral artery (VA), were excluded. Moreover, patients with symptomatic stenosis but without an occlusion were also excluded. The Institutional Review Board of Nippon Medical School approved our prospective stroke registry, and written informed consent was obtained from all patients.

The following information was obtained from all patients: age, sex, past medical history, premorbid modified Rankin scale (mRS) score, initial NIHSS score on admission, intervals of the onset-to-door time, onset-to-puncture time, puncture-to-first pass time, puncture-to-recanalization time, and onset-to-recanalization time, methods of EVT, number of passes, site of occlusion, administration of intravenous thrombolysis, degree of ischemic core, presence of reperfusion, symptomatic intracerebral hemorrhage (sICH), and stroke etiology. Vascular risk factors were identified as follows: 1) hypertension, use of antihypertensive agents, systolic blood pressure ≥ 140 mmHg, or diastolic blood pressure ≥ 90 mmHg at hospital discharge; 2) diabetes mellitus, use of hypoglycemics, random glucose level ≥ 200 mg/dL, or glycosylated hemoglobin > 6.4% on admission; and 3) hyperlipidemia, use of antihyperlipidemic agents, or serum cholesterol level > 220 mg/dL. sICH was defined parenchymal hematoma type 2 with a decrement of NIHSS score ≥ 4. Upon discharge, stroke etiology was determined using the Trial of ORG 10172 in Acute Stroke Treatment criteria: 1) large-artery atherosclerosis, 2) cardioembolism, or 3) other or undetermined etiology of stroke [12]. At 3 months of stroke onset, clinical outcomes were assessed and a favorable clinical outcome was defined as an mRS of ≤ 2.

2.2. Imaging

Our current imaging protocols before EVT are as follows. Typically, immediate magnetic resonance imaging (MRI) on a 1.5-T scanner (ECHELON_OVAL, Hitachi Medical Corporation) is routinely used as the first-line tool to examine patients with suspected stroke. We do not perform computed tomography (CT) as a routine examination. Therefore, most cases of major arterial occlusion were diagnosed using MR angiography (MRA). DWI was performed using the following parameters: repetition time (TR), 6000 ms; echo time (TE), 65 ms; b values, 0 and 1000 s/mm^2; field of view, 240 mm; acquisition matrix, 128 × 128; and slice thickness, 4.5 mm with a 2.5-mm gap. Time-of-flight MRA covered the circle of Willis with TR, 23 ms; TE, 6.9 ms; flip angle, 20°; field of view, 200 mm; acquisition matrix, 352 × 224; and section thickness, 1.2 mm. For patients having a contraindication to MRI, CT and CT angiography are used. For patients transferred from other facilities and already diagnosed as having major arterial lesions, we typically skip imaging before EVT, and these patients are directly transferred to the digital subtraction angiography room. In patients examined with DWI, the degree of ischemic core was semi-calculated suing DWI-Alberta Stroke Programme Early CT Score (DWI-ASPECTS) before EVT [13].

2.3. EVT procedures

In our hospital, EVT was generally performed based on the guideline of each era. However, EVT was also conducted for patients suspected as having a mismatch between clinical symptoms and imaging findings, beyond the guidelines, such as late time window, low NIHSS score, distal occlusion, and significant ischemic changes on imaging. With respect to the methods of EVT for anterior circulation stroke, both aspiration techniques and stent retrievers are available. After a 9-Fr sheath was portioned via the transfemoral approach, we introduced a 9-Fr Optimo balloon-guiding catheter (Tokai Medical, Aichi, Japan) to the cervical portion of the ICA. When we used the aspiration technique, we introduced a Penumbra system, such as the ACE 68, 5MAX ACE, or 4MAX, (Penumbra, Inc., Alameda, CA, USA) to the surface of the clot. To introduce the Penumbra system easily to the clot surface, we inflated the balloon of the guiding catheter to increase stability and used a coaxial catheter, such as the 3MAX, PX slim microcatheter (Penumbra, Inc.), Marksman (Medtronic, Irvine, California, USA), or Trevo Pro (Stryker, Kalamazoo, Michigan, USA) as well as a 0.014-inch microguidewire. Even when we selected stent retrievers, we preferred continuous aspiration from a coaxial configuration via the penumbra system, mainly as a reported manner [14]. Moreover, Trevo ProVue Retriever (Stryker), Solitaire Revascularization Device (Medtronic), and Revive Self Expanding (Codman Neuro/DePuy Synthes, Johnson and. Johnson, USA) were used. From 2011 to 2012, Merci device (Concentric Medical, Inc., Mountain View, CA, USA) was used.

Balloon angioplasty using Gateway balloon (Stryker) was performed when the physicians judged it to be appropriated. The balloon diameter was 2/3 to 3/4 normal vessel diameter. After positioning the balloon at the lesion, the balloon was inflated slowly up to a general nominal pressure and maintained for 120 s. Aspirin (200 mg) and clopidogrel (300 mg) were administered using a nasal tube before the angioplasty. Permanent stent deploy was avoided as much as possible. In addition, intra-arterial thrombolysis using urokinase and intracranial and cervical ICA stenting were performed when needed.

2.4. Assessment of recanalization

At the end of EVT, arterial reperfusion was documented and recanalization was scored by the thrombolysis in cerebral infarction (TICI) grade: grade 0, no perfusion; grade 1, penetration, but no distal branch filling; 2a, perfusion with incomplete (< 50%) distal branch filling; 2b, perfusion with incomplete ($\geq$50%) distal branch filling; 2c, near complete perfusion except for slow flow; and 3, complete perfusion with filling of all distal branches [15]. TICI scale $\geq$2b was considered to indicate successful recanalization.

2.5. Statistical analysis

First, all patients were classified into the successful recanalization and no successful recanalization groups. Clinical characteristics and radiological findings were compared between both groups. Multivariate logistic regression analysis was performed to identify independent factors associated with successful recanalization. To evaluate the detailed association of the NIHSS score with successful recanalization, we classified the NIHSS score into the following subgroups: NIHSS 0–8, 9–16, 17–24, and > 24. Finally, we investigated the association of favorable outcomes with successful recanalization, according to each NIHSS score subgroup. Mann-Whitney *U* test and Kuraskal Wallis were used to analyze the differences in continuous variables, whereas Fisher's exact test and Pearson's chi-square test were performed to analyze the differences in categorical variables. Moreover, multivariate analysis was performed for variables with $p < .1$ identified using univariate analysis. The relative risks of successful recanalization were expressed as odds ratios (OR) with 95% confidence intervals (CIs). Data are presented as median values (interquartile ranges [IQR]) or frequencies (%). All statistical analyses were performed using IBM SPSS Statistics for Windows version 22 (SPSS Japan, Inc., Tokyo, Japan). The results were considered significant at $p < .05$.

3. Results

Among the 305 patients in this study 3 patients had ACA occlusion, 61 had distal MCA occlusion, 32 had BA occlusion, 5 had PCA occlusion, and 5 had VA occlusion. Among the remaining 199 patients, 16 had stenotic lesions. Thus, data on 183 patients (median age, 76 [IQR, 68–83] years; 110 [60%] men) with ICA or M1 occlusion were analyzed

Table 1
Clinical and radiological backgrounds between successful recanalization and no successful recanalization groups.

Variables	Successful recanalization group	No successful recanalization group	p
	N = 146	N = 37	
Age	76 (68–83)	78 (67–84)	0.737
Male	88 (60)	22 (60)	1.000
NIHSS score	18 (12–23)	24 (20–27)	< 0.001
Premorbid modified Rankin Scale score 0–2	131 (90)	32 (87)	0.561
Onset to door, minute	135 (53–236)	79 (60–259)	0.313
Onset to puncture, minute	206 (142–316)	198 (127–333)	0.884
Puncture to first-pass, minute	25 (17–40)	38 (20–60)	0.050
Puncture to recanalization, minute	39 (23–64)	–	–
Onset to recanalization, minute	277 (194–431)	–	–
Intravenous thrombolysis	49 (34)	9 (24)	0.327
DWI-ASPECTS	7 (5–8)	6 (4–8)	0.157
Site of occlusion			
Internal carotid artery	59 (40)	18 (49)	0.456
Horizontal portion of middle cerebral artery	87 (60)	19 (51)	–
Vascular risk factors			
Hypertension	99 (68)	26 (70)	0.845
Diabetes mellitus	32 (22)	10 (27)	0.516
Dyslipidemia	61 (42)	11 (30)	0.194
Atrial fibrillation	76 (52)	22 (60)	0.464
1st endovascular thrombectomy modalities			
Merci	8 (6)	9 (24)	0.002
Penumbra	111 (76)	23 (62)	0.099
Solitaire	8 (6)	2 (5)	1.000
Trevo	10 (7)	3 (8)	0.728
Revive	1 (1)	0 (0)	1.000
Angioplasty	7 (5)	0 (0)	0.348
Intra-arterial thrombolysis	1 (1)	0 (0)	1.000
Number of passes	2 (1–3)	3 (2–4)	< 0.001
Rescue stent			
Intracranial artery	2 (1)	0 (0)	1.000
Cervical carotid artery	6 (4)	0 (0)	0.603
Stroke classification			
Cardioembolic stroke	116 (63)	25 (68)	0.482
Large artery atherosclerosis	37 (20)	5 (14)	–
Other determined	3 (2)	0 (0)	–
Unknown	20 (14)	7 (19)	–

Data are no. of patients (%) and median (interquartile range) for discontinuous variables. NIHSS indicates, National Institutes of Health Stroke Scale; and DWI-ASPECTS, Diffusion-weighted image-Alberta Stroke Program Early CT Score.

in this study. The median NIHSS score was 19 (14–24), and the onset-to-door time was 113 (55–240) minutes. ICA occlusion was seen in 77 (43%) patients, and atrial fibrillation was observed in 98 (54%) patients. Intravenous thrombolysis was initiated in 58 (32%) patients.

After undergoing EVT, 146 (80%) patients achieved a TICI ≥2b recanalization, while 37 (20%) did not. Patients in the successful recanalization group had lower NIHSS score than those in the no successful recanalization group (18 [12–23] vs. 24 [20–27], $p < .001$). The puncture-to-first pass time tended to be shorter in the successful recanalization group than in the no successful recanalization group (25 [17–40] vs. 38 [20–60] minutes, $p = .050$). Number of passes was 2 (1–3) in the successful recanalization group and 3 (2–4) in the no successful recanalization group ($p < .001$). With respect to the EVT modalities, the use of the Merci retriever was infrequent in the successful recanalization group (6% vs. 24%, $p = .002$). All other relevant information has been presented in Table 1. When multivariate regression analysis was performed, the NIHSS score (OR: 0.905 [95% CI 0.837–0.979], $p = .013$) and puncture-to-first pass (OR: 0.978 [95% CI 0.964–0.993], $p = .004$), and the number of passes (OR: 0.667 [95% CI 0.491–0.907], $p = .010$) were the independent parameters of successful recanalization, after adjustment for age, sex, atrial fibrillation, intravenous thrombolysis, DWI-ASPECTS, ICA occlusion, and Merci retriever use (Table 2).

Table 2
Multivariate logistic regression analysis for successful recanalization.

	Odds ratio	95% Confidential interval	p
NIHSS score, per 1-point	0.905	0.837–0.979	0.013
Age, per 1-year	1.011	0.964–1.060	0.641
Male	0.584	0.189–1.801	0.349
Atrial fibrillation	0.888	0.311–2.537	0.824
Intravenous thrombolysis	1.090	0.378–3.143	0.874
DWI-ASPECTS, per 1-point	1.036	0.833–1.289	0.750
Internal carotid artery occlusion	1.893	0.676–5.299	0.224
Number of passes	0.667	0.491–0.907	0.010
Puncture to first-pass, per 1-minute	0.978	0.964–0.993	0.004
Merci retriever	0.780	0.117–5.195	0.797

NIHSS indicates, National Institutes of Health Stroke Scale; and DWI-ASPECTS, Diffusion-weighted image-Alberta Stroke Program Early CT Score.

Next, we classified all patients into four categories based on the NIHSS score and calculated the successful recanalization rates among the categories. The results revealed the successful recanalization rates was significantly correspond to the NIHSS score subcategories. Indeed, successful recanalization was observed in all 21 (100%) patients with the NIHSS 0–8 category, 38 (88%) of 43 patients in the NIHSS 9–16 category, 60 (81%) of 74 patients in the NIHSS 17–24 category, and 27 (60%) of 45 in the NIHSS score > 24 category (Fig. 1). Table 3 shows the clinical and radiological findings based on the NIHSS score subcategories. The puncture-to-first pass time, puncture-to-recanalization time, and the number of passes were similar among the four categories ($p = .277$, 0.337, and 0.262, respectively). The onset-to-puncture and onset-to-recanalization times were longer in the milder stroke subgroup than in the severe stroke subgroup ($p = .024$ and 0.051, respectively). Intravenous thrombolysis was infrequent ($p = .008$) and DWI-ASPEWCTS was lower ($p = .001$) in the severe stroke subgroup. Atrial fibrillation was frequent, and thus, cardioembolic stroke was frequent in the severe subgroup ($p = .004$ and 0.006, respectively).

Finally, the impact of successful recanalization on clinical outcomes among the NIHSS subcategories was evaluated. Among the 183 examined patients, 163 had premorbid mRS 0–2, and 10 patients were

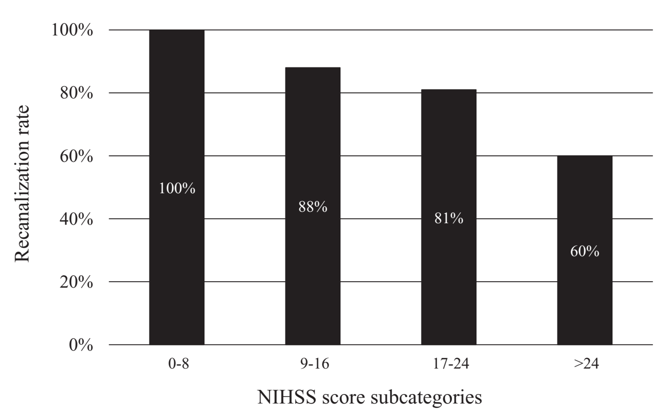

Fig. 1. Successful recanalization rates based on the National Institutes of Health Stroke Scale (NIHSS) score categories.

Table 3
Clinical and radiological backgrounds based on National Institutes of Health Stroke Scale (NIHSS) subgroups.

Variables	NIHSS score subcategories				p
	0–8	9–16	17–24	> 24	
	N = 21	N = 43	N = 74	N = 45	
Age	72 (65–80)	75 (71–83)	76 (67–81)	79 (69–85)	0.148
Male	15 (71)	33 (77)	43 (58)	19 (42)	0.007
NIHSS score	5 (3–6)	13 (10–15)	21 (18–22)	27 (26–31)	< 0.001
Premorbid modified Rankin Scale score 0–2	21 (100)	40 (93)	66 (89)	36 (80)	0.070
Onset to door, minute	190 (86–352)	135 (53–279)	131 (56–245)	74 (53–147)	0.024
Onset to puncture, minute	301 (154–507)	232 (155–385)	215 (136–316)	168 (136–239)	0.057
Puncture to first-passs, minute	38 (21–49)	26 (16–44)	25 (15–44)	32 (18–49)	0.277
Puncture to recanalization, minute	39 (23–50)	60 (25–97)	46 (24–66)	50 (28–83)	0.337
Onset to recanalization, minute	405 (245–648)	290 (251–469)	275 (199–375)	255 (180–331)	0.051
Intravenous thrombolysis	5 (24)	16 (37)	31 (42)	6 (13)	0.008
DWI-ASPECTS	8 (7–9)	7 (6–9)	7 (4–8)	6 (4–7)	0.001
Site of occlusion					
Internal carotid artery	4 (19)	20 (46)	29 (39)	24 (53)	0.057
Horizontal portion of middle cerebral artery	17 (81)	23 (54)	45 (61)	21 (47)	0.057
Vascular risk factors					
Hypertension	14 (67)	24 (56)	51 (69)	36 (80)	0.113
Diabetes mellitus	3 (14)	12 (28)	20 (27)	7 (16)	0.311
Dyslipidemia	10 (48)	16 (37)	29 (39)	17 (38)	0.866
Atrial fibrillation	6 (29)	20 (47)	39 (53)	33 (73)	0.004
1st endovascular thrombectomy modalities					
Merci	0 (0)	3 (7)	3 (4)	11 (24)	0.001
Penumbra	13 (62)	31 (72)	62 (84)	28 (63)	0.039
Solitaire	1 (5)	3 (7)	4 (5)	2 (4)	0.960
Trevo	2 (10)	2 (5)	5 (7)	4 (9)	0.847
Revive	0 (0)	1 (2)	0 (0)	0 (0)	0.351
Angioplasty	4 (18)	3 (7)	0 (0)	0 (0)	< 0.001
Intra-arterial thrombolysis	1 (5)	0 (0)	0 (0)	0 (0)	0.051
Number of passes	1 (1–2)	2 (1–3)	2 (1–3)	2 (1–3)	0.262
Rescue stent					
Intracranial artery	1 (1)	1 (1)	0 (0)	0 (0)	0.209
Cervical carotid artery	1 (5)	3 (7)	2 (3)	0 (0)	0.308
Symptomatic intracerebral hemorrhage	0 (0)	4 (9)	4 (5)	2 (4)	0.470
Stroke classification					
Cardioembolic stroke	9 (43)	20 (47)	49 (66)	38 (84)	0.006
Large artery atherosclerosis	7 (33)	15 (35)	13 (18)	2 (4)	–
Other determined	1 (5)	0 (0)	2 (3)	0 (0)	–
Unknown	4 (19)	8 (19)	10 (14)	5 (11)	–

Data are no. of patients (%) and median (interquartile range) for discontinuous variables. DWI-ASPECTS indicates Diffusion-weighted image-Alberta Stroke Program Early CT Score.

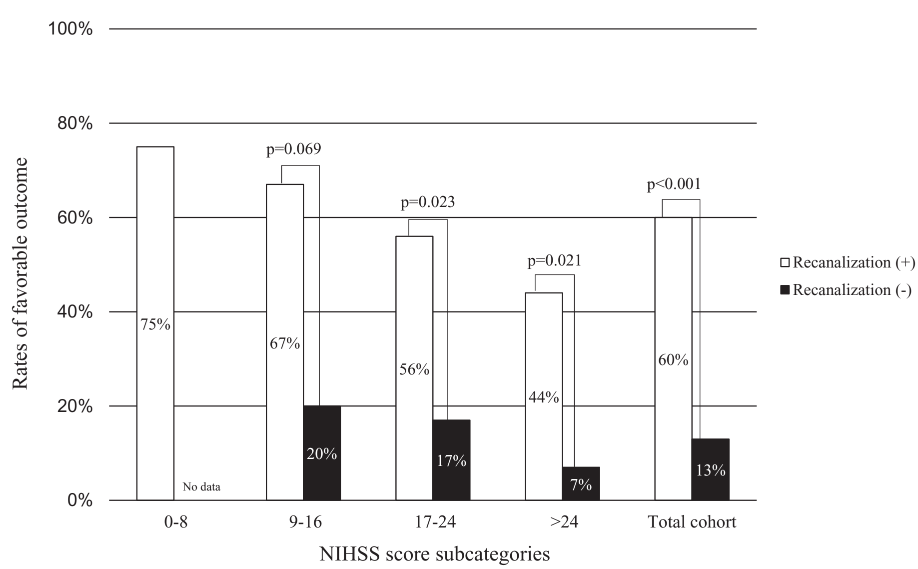

Fig. 2. Association of favorable outcome rates with successful recanalization based on the National Institutes of Health Stroke Scale (NIHSS) score categories.

lost to the 3-month follow-up. Among the remaining 153 patients, 77 (50%) showed favorable outcomes. Basically, NIHSS score was clearly associated with favorable outcome at 3 months. Indeed, patients with favorable outcome had a lower NIHSS score compared to those without it (17 [9–22] vs. 21 [15–25], p = .001). Furthermore, the rates of favorable outcomes well correlated to the NIHSS score subcategories; 15 (75%) of the 20 patients with NIHSS score 0–8, 23 (61%) of 38 with NIHSS score 9–16, 30 (48%) of 62 with NIHSS score 17–24, and 9 (27%) of 33 with NIHSS score > 24. The role of successful recanalization on favorable outcomes seemed consistent among the NIHSS score subcategories. When successful recanalization was achieved, favorable clinical outcomes were seen in 15 (75%) of 20 patients with NIHSS score 0–8, 22 (67%) of 33 with NIHSS score 9–16, 28 (56%) of 50 with NIHSS score 17–24, and 8 (44%) of 18 with NIHSS score > 24. In contrast, when successful recanalization was not achieved, favorable outcomes were seen in only 1 (20%) of 5 patients with NIHSS score 9–16, 2 (17%) of 12 with NIHSS score 17–24, and 1 (7%) of 15 with NIHSS score > 24 (Fig. 2).

4. Discussion

Our study revealed the association between the NIHSS score and recanalization rate after EVT in acute stroke patients with ICA and M1 occlusion. We also demonstrated the importance of successful recanalization for achieving favorable outcomes.

In the present study, multivariate regression analysis showed the independency of the NIHSS score in predicting successful recanalization. An advantage of the NIHSS score is that it can be easily and immediately calculated at bedside without any additional examination. In addition, we showed that the severity of stroke well correlated to the rate of recanalization. Indeed, the successful recanalization rate was 100% in patients with NIHSS score 0–8, which gradually decreased with an increase in the score (88%, 81%, and 60% in the remaining groups), which enabled quantitatively estimating the possibility of sufficient recanalization rate. Thus, it may be reasonable to use the NIHSS score not only to evaluate the neurological severity but also to predict the rate of recanalization after EVT.

In our cohort, a mild NIHSS score was related to high DWI-ASPECTS, infrequent atrial fibrillation, and large-artery atherosclerosis, while a high NIHSS score was associated with short onset-to-door time, atrial fibrillation, and cardioembolic stroke. After adjusting these parameters including the DWI-ASPECTS, NIHSS score was associated with the successful recanalization. We think the NIHSS score signifies two essential parameters related to the successful recanalization: thrombus size, and collateral status. First, a high NIHSS score is basically associated with large ischemia often due to large artery occlusion [16], which is organized by the large thrombus. A large thrombus also tends to obstruct the perforator, such as the anterior choroidal artery and lateral strait artery, compared to a small thrombus. It is reasonable that the removal of the larger thrombus is more difficult. Next, significant differences were reported in the NIHSS score between the good and reduced collateral flow [17]. In patients treated with intra-arterial thrombolysis, a good collateral status may result in enhanced major reperfusion [18]. Similarly, among patients undergoing EVT, a higher recanalization rate was reported among those who showed a good collateral flow even using the Merci device [19]. A study involving patients enrolled in a large trial also reported the collateral flow as a pivotal factor in revascularization [20]. A retrograde robust collateral flow may prevent thrombus augmentation and might be important for the dissolution of the fragmented proximal thrombus by entering the thrombus interspace. In addition, cerebral blood vessel damage occurs early and in a progressive manner during ischemia [21]. Therefore, collateral flow represented by the NIHSS score plays a significant role in achieving successful recanalization.

It has been generally thought that NIHSS score is not associated with the rate of successful recanalization. For example, Seker F. et al. found no association between NIHSS score and successful recanalization [22]. On the other hand, in a paper by Wang DT., there was a significant baseline imbalance between the groups with and without successful recanalization on baseline NIHSS score [23]. A tendency of initial NIHSS score to predict successful recanalization was also shown in a paper by Sung et al. [24]. We think the number of EVT procedures may have a key to explain the conflicting findings regarding the relationship between the NIHSS score and successful recanalization. Indeed, we found a similar finding to a paper by Seker F. et al. that the number of passes was another negative independent factor of successful recanalization. However, the number of passes in our study was less as 3 (2–4) in patient without successful recanalization than their study as 5 (3–7) [22]. In other words, there is a possibility that our decision to abort was slightly earlier compared to their report. If we had attempt more EVT passes, the result might be different. Further study including the number of passes are needed to elucidate our study finding.

Sufficient recanalization was associated with favorable outcomes in each NIHSS subcategory in our study. Although recent progress in EVT modalities has markedly changed acute stroke management, an unresolved question is whether EVT can be beneficial for patients with a low NIHSS score and major artery occlusion [25,26]. It is presumed that patients with a low NIHSS score have good collateral status, and thus, the shrinkage of the penumbra and growth of the core seem infrequent. Indeed, in a subset patient, clinical ischemic penumbra was reported to be relatively stable [27]. In contrast, collateral flow is sometimes dynamic, and collateral failure is associated with infarct groups [28]. Actually, Miteff F et al. reported that although patients with a good collateral status who underwent endovascular thrombectomy achieved favorable outcomes, among those with a good collateral status but no recanalization, only 38% had good outcomes [29]. Pfaff et al. have shown the safety of EVT for patients with an NIHSS score of ≤8, with reasonable rates of good outcomes even in longer time windows [30]. In our cohort, all patients with an NIHSS score of ≤8 achieved sufficient recanalization without sICH even in a late time window. Therefore, we consider that more aggressive and faster EVT may result in better clinical outcomes, regardless of the NIHSS score and the clinical background of patients having ICA and M1 occlusion.

The puncture-to-1st pass time was related to the sufficient recanalization rate. This finding is partially in concordance with the findings of previous reports. A meta-analysis showed that earlier treatment was associated with favorable outcomes and the benefit disappeared after 7.3 h [2]. The adjusted OR for a 30-minute time increment was 1.21 for mortality, 0.79 for favorable outcomes, 0.78 for excellent outcomes, and 1.21 for ICH [31]. However, it has been unclear whether time is associated with the recanalization rate. Anatomical structure is one of the factors related to puncture to the puncture-to-first pass time, including the characteristics of the femoral artery, aortic arch, and intracranial internal artery. Significant tortuosity delays catheter guiding. Another factor is the tandem arterial occlusion and stenosis. Patients who have an additional arterial lesion before the targeted artery responsible for the infarct need much time than those who have a single arterial lesion. Other factors may be clinical symptoms, such as the agitated state and hemispatial neglect, which disrupt to keep in bed without movement. For these patients with complex lesions and clinical characteristics, sometimes, an optimal device may not be available, and occasionally, the risk of distal embolism may increase, which may interfere with sufficient recanalization.

The study has several limitations. First, this study was a retrospective analysis of data obtained from a single stroke center. The recanalization rate might be effected by the skill and thought of the operator. Second, our data set consisted of not only patients with a stent retriever, but also those with an aspiration device as well as those treated with a former-generation device such as the Merci device. These different modalities might have had some effects on our results. We have to continue our study using another date set, containing only patients treated using recent EVT devices. Recent progress in EVT devices may rescue the larger thrombus compared to older devices. Third, although previous studies have established the association of the NIHSS score with collateral flow, we did not assess the collateral status. There have been several grading systems for collateral flow based on the different modalities [32,33]. Because immediate recanalization is essential, delaying EVT is not recommended to evaluate the collateral flow with digital subtraction angiography, such as flow from contralateral ICA and posterior circulation in patients with ICA and M1 occlusion. One technique to achieve a balance between rapid EVT procedure and collateral assessment in clinical settings might be to use CT angiography. A large, prospective study is needed to confirm our study findings.

In conclusion, the NIHSS score may serve as a predictor of successful recanalization. Recanalization is relatively easier in mild stroke patients than in those with severe stroke.

Declaration of Competing Interest

The authors have no conflicts of interest or funding sources to disclose.

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