ORIGINAL ARTICLE - VASCULAR NEUROSURGERY - ISCHEMIA

Gradual expansion of stent retriever in mechanical thrombectomy for curved middle cerebral artery: structural findings of the stent for predictable recanalization results

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Abstract

Background Trevo Provue stent retriever with visible struts under fluoroscopy may be useful in identifying the optimal position and expansion of the stent during the procedure. This study aimed to demonstrate and analyze changes in the segmental diameter of a radio-opaque stent retriever after deployment according to recanalization results, and its relationship with the angle of the occluded segment of the middle cerebral artery (MCA).

Methods Forty-one patients who underwent mechanical thrombectomy using a Trevo stent retriever were divided into two groups according to Thrombolysis in Cerebral Infarction (TICI) score (TICI 0-2a and TICI 2b/3). The proximal (Pt), middle (Mt), and distal diameter (Dt) of the deployed stent, at three post-deployment waiting times ($t = 0$, 3, and 5 min), were measured, and ratios of Mt to Pt (Mt/Pt) and of Mt to Dt (Mt/Dt) were calculated.

Results TICI 2b/3 was achieved in 31 patients (75.6%) and TICI 0-2a in 10 patients (24.4%). In the TICI 2b/3 group, both changes of Mt/Pt ($P < 0.001$) and Mt/Dt ($P = 0.001$) until 3 min were significant and all Mt/Pt (each $P < 0.01$), M3/D3 ($P = 0.014$), and M5/D5 ($P = 0.012$) were significantly larger than those in the TICI 0-2a group. The angle of the MCA was significantly correlated with Mt/Pt and Mt/Dt ($P < 0.001$).

Conclusion The diameter of the stent retriever after deployment was associated with the recanalization results in mechanical thrombectomy following MCA occlusion.

Keywords Mechanical thrombolysis · Middle cerebral artery thrombosis · Stent · Thrombectomy

Introduction

Endovascular mechanical thrombectomy (MT) is an advanced technique to treat occlusion of the intracranial large vessels and is performed using several endovascular devices including stent retrievers [4, 17, 19]. Recanalization rates have improved with development in techniques [9, 18]. Nevertheless, the failure to recanalize remains the most important problem in acute ischemic stroke and leads to poor prognosis [20]. In several reports, many factors were found to affect recanalization rate of occluded vessels. The characteristics of the thrombus may affect recanalization, e.g., whether the clot contains red or white blood cells, how long the clot segment is, and where it is located within the vessel [1, 7, 15, 27]. Conversely, clot length was shown not to influence successful recanalization, and the location of the thrombus was not useful in predicting recanalization of the middle cerebral artery (MCA) [1, 10]. In addition, the histology of the thrombus is not predictive of the recanalization before or during the procedure. Therefore, consideration has switched from the thrombus to the structure and morphology of the occluded vessels and the stent retriever itself. Many reports have documented that the largely angled MCA may adversely affect wall apposition and full expansion of the deployed stent, due to stent kinking and angulation [20, 21, 28]. The self-expandable aspect of the stent may precipitate integration of the stent struts to the thrombus burden and allow the stent to catch and

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withdrawal more clots. Technically, for sufficient expansion and integration of the stent to the thrombus, previous reports recommend a waiting time of 3–5 min after the stent deployment [4, 22, 23, 25]. In addition, some reports postulated that a "push and fluffing" technique may precipitate the interaction between the stent and clot by facilitating the expansion and apposition of the stent [8, 24]. As such, the Trevo Provue retriever stent (Stryker Neurovascular, Fremont, CA, USA), with visible struts under fluoroscopy, may be useful in identifying the optimal position and expansion of the stent during the procedure. However, few reports have described and analyzed the appearance of the visible stent in practice. Haussen et al. [8] described cell size changes in the stent strut using an in vitro model without an artificial clot. Yi et al. [26] demonstrated less angulation and kinking of larger stents using practical angiography but did not precisely described the status of the visible stent strut. In our initial experiments, the Trevo stent showed gradual self-expansion just after deployment (Fig. 1), but this was uneven and slower than we expected despite occurring just after unsheathing without the "push and fluffing" (Fig. 2). Thereafter, we were curious about changes in stent diameter during expansion in a thrombotic occluded MCA, and stent narrowing in the vessel angles. In this study, we analyzed the changes in segmental diameter of the stent retriever after deployment according to recanalization results, and the relationships with the diameter of the stent and angle of the occluded segment in MCA.

Materials and methods

Populations in study

We enrolled patients who were treated for acute ischemic stroke with unilateral occlusion of the MCA using stent retrievers between 2014 and 2018 in a single institute and identified 77 patients. Among them, 41 patients were retrospectively analyzed and categorized as follows: (1) occlusion that initially occurred only in the M1 segment; (2) MT performed using a Trevo Provue XP stent retriever (or usable older version); (3) well-defined stent strut in digital subtraction angiography (DSA) images; and (4) brain computed tomography (CT) or magnetic resonance image (MRI) performed immediately in pre- and post-procedure. Recanalization results were evaluated by the Thrombolysis in Cerebral Infarction (TICI) score, and a TICI 2b/3 score was considered to indicate successful recanalization. According to the recanalization results, patients were divided into two groups (TICI 0-2a and TICI 2b/3). This retrospective study was approved by the local institutional review board (No. GCIRB2019-031).

Mechanical Thrombectomy and evaluations

MT was performed in patients within 6 h of symptom onset and neurologic deficit (National Institutes of Health Stroke Scale; NIHSS $\geq$ 8) following acute ischemic stroke with large vessel occlusion (confirmed by brain CT angiography) and ASPECTs (Alberta Stroke Program Early CT score) $\geq$ 6, without intracranial hemorrhage. Recombinant tissue plasminogen activator (t-PA) was administrated intravenously at a maximum dose of 90 mg/kg within 4.5 h of symptom onset. Procedures were performed by two neurointerventionalists and under conscious sedation without respiratory distress by using intravenously administrated dexmedetomidine. An 8 Fr balloon guided catheter [either Merci (Stryker, Kalamazoo, MI, USA) or Optimo (Tokai Medical Products, Aichi, Japan)] was placed in the cervical segment of the targeted internal carotid artery (ICA) after groin preparation and femoral artery puncture. An intermediate catheter using 6 Fr Catalyst (Stryker Neurovascular, Fremont, CA, USA) or 5 Fr Navien (Medtronics, Irvine, CA, USA) was introduced coaxially with a 0.021-in. microcatheter (Trevo Pro 18; Stryker Neurovascular, Fremont, CA, USA) and a 0.014-in. microwire (Transcend 14; Stryker Neurovascular, Fremont, CA, USA). The microcatheter and microwire were passed through the occlusion site, then Trevo Provue XP 4 mm ×
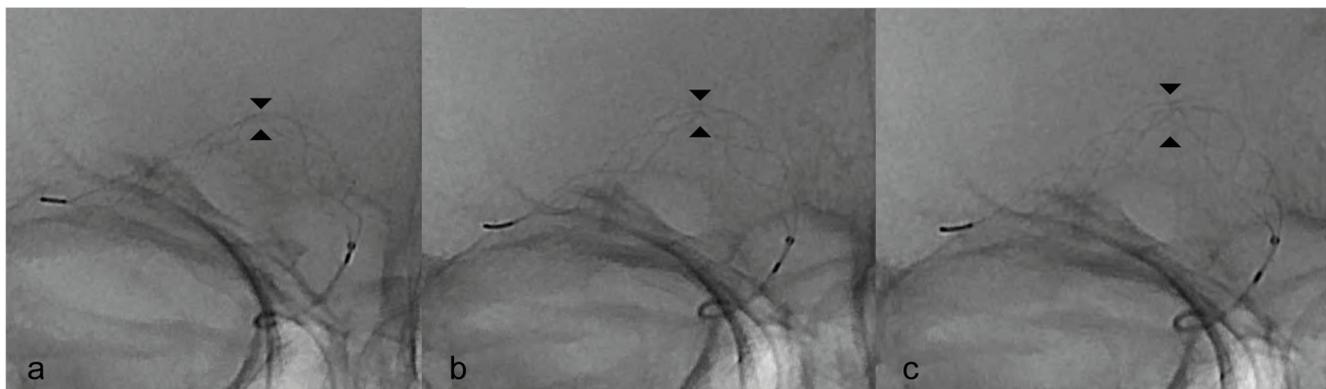

Fig. 1 Digital subtraction angiography (non-subtraction image) shows gradual expansion (between double arrow heads) of a stent retriever (Trevo Provue 4 mm × 20 mm) after deployment. **a** At initial just after deployment of the stent. **b** At 3 min waiting time. **c** At 5 min waiting time

Fig. 2 Magnified microscopic photographs of unsheathing the Trevo XP Provue stent retriever (the ruler is graduated in 0.25 mm). **a** Immediate unsheathing status shows little expansion of the stent. **b** After 3 min the stent expands more, but not fully. **c** The stent fully expands after 5 min
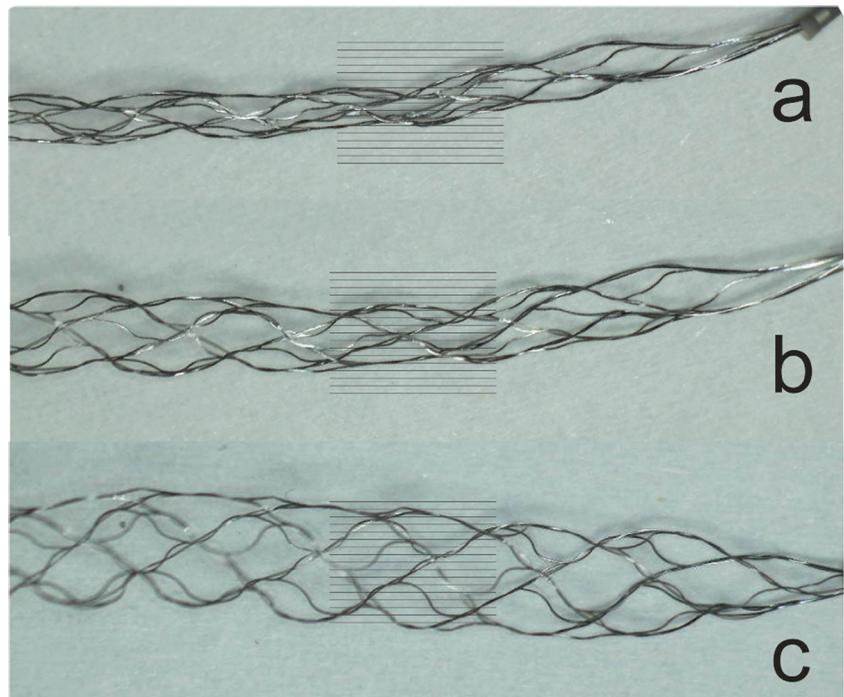
20 mm (Stryker Neurovascular, Fremont, CA, USA) was deployed, and sufficiently covering whole thrombus burden with "push and fluffing" technique in all cases. After 5 min, the stent retriever was fully withdrawn, keeping consistent negative pressure on the balloon guiding catheter and intermediate catheter to achieve aspiration. This process was repeated up to five times in the event of unsuccessful recanalization. Additional stent retrievers were not permitted due to insurance issues. Following stent withdrawal, distal migration of the clot was identified in final angiography. The number of device passages was recorded, and the recanalization time was defined as the time from groin puncture to final recanalization. Immediate post-procedural dual-energy CT was performed to identify the aggravating ischemic area and differentiate between contrast extravasation and intraparenchymal hemorrhage. Clinical assessment using the National Institutes of Health Stroke Scale (NIHSS) was performed initially (upon arrival to the hospital) and after 24 h. The modified Rankin Scale (mRS) was assessed at discharge and after 30 days.

Radiologic measurement

Key images were obtained in the anterior-posterior plane using DSA during the procedure at time 0 (initial), 3, and 5 min into waiting time (t) after first deployment of the stent retriever. A picture archiving and communication system viewer (INFINITT PiViewSTAR, INFINITT Healthcare Co., Seoul, Korea) was used. Methods of measurement used to determine the diameter of the stent and the vessel angles are schematized in Fig. 3. The diameter at each time point ($t = 0$,

3, and 5 min) was measured at the following locations: the most stenotic mid-portion (Mt) of the stent involving thrombus burden, and the widest proximal portion (Pt), and distal portion (Dt) of the stent within the working length. Ratio of Mt to Pt (Mt/Pt) and of Mt to Dt (Mt/Dt) were calculated as percentage (%). We measured two vessel angles as follows: (1) the angle between the terminal segment of the ICA and the first bent M1 segment after the ICA terminus (IC-MCAA), (2) the most bent angle of the occluded M1 segment (MCAA) (Fig. 4). The measurement on the images was performed by two physicians (C. J. Y and C. W. P) who were not involved in the thrombectomy and were blinded from the purpose of this study and any patient information until the measurement finished completely.

Statistical analysis

Nonparametric continuous data (not normally distributed according to the Kolmogorov-Smirnov test) were analyzed using Mann-Whitney U tests and are reported as interquartile range (IQR). Fisher's exact test was used for categorical data comparison between two groups. Parametric data were analyzed using Student's t tests and are reported as mean ± standard deviation (SD). Repeated measures ANOVA (analysis of variance) was used for comparison between the changes in stent diameter over time. Pearson correlation analysis was used for identifying relationships between measured values. P values < 0.05 (two-tailed) were considered significant. Statistical analyses were performed using SPSS version 23 (IBM, Armonk, NY, USA).

Fig. 3 Schematized measurement guideline image. **a** Two imaginary outlines (dot lines) connecting the peak point on the convex portion of the stent strands. **b** Within the outlines and working zone of the stent, stenotic mid-portion (Mt), widest proximal (Pt), and distal portion (Dt) diameters of the stent. A single asterisk denotes an angle between the internal carotid artery (ICA) and middle cerebral artery (MCA, M1). Double asterisks denote an angle of the MCA curve
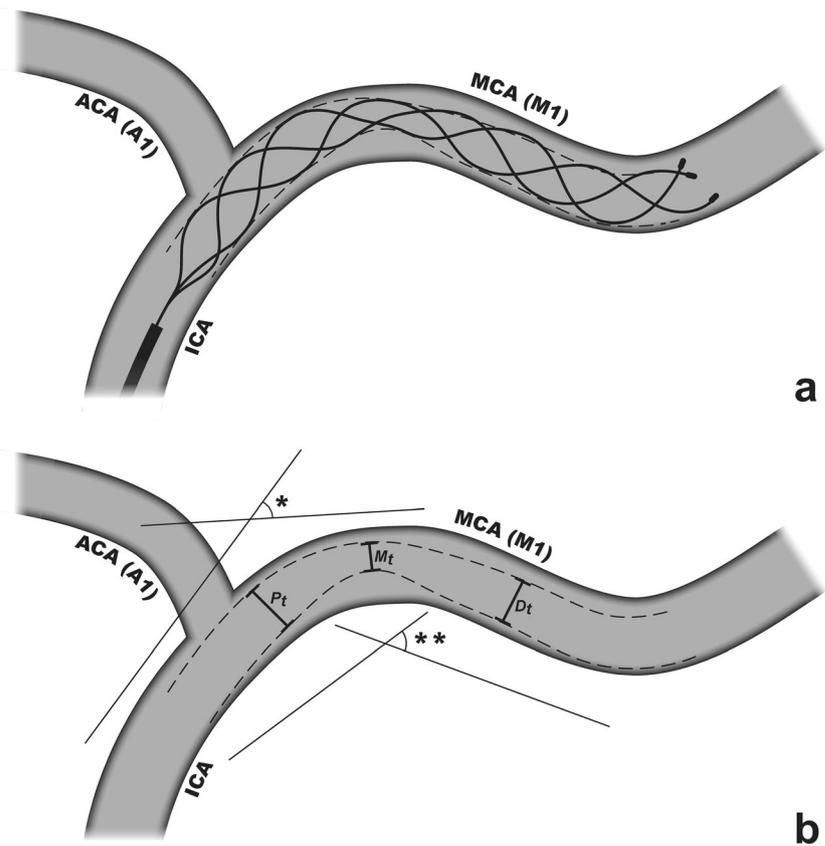
Results

Baseline patient characteristics and status following MT are presented in Table 1. TICI 2b/3 was achieved in 31 patients (75.6%) and TICI 0-2a in ten patients (24.4%). There was no significant difference between the groups in pre- and intra-/post-thrombectomy status.

In the TICI 2b/3 group, median number of device passages was 1 (interquartile range, IQR 1–3) and recanalization time was 44.5 ± 24.9 min. The TICI 2b/3 group revealed three scores (IQR 3–5) in mRS at discharge and two scores (IQR 3–5) after 30 days. In the TICI 0-2a group, median number of device passages was 2 (IQR 3–5) and recanalization time was 73.5 ± 31.2 min. The TICI 0-2a group revealed four scores (IQR 3–6) in mRS at discharge and three scores (IQR 4–5) after 30 days.

The data showing measurements of the stent is provided in Table 2. Proximal and mid-portion diameters of the stent showed significant differences between two groups in all waiting time (0, 3, and 5 min; $P < 0.05$), while distal portion diameter did not.

One patient (3.2%) in the TICI 2b/3 group suffered symptomatic hemorrhage after MT, underwent surgical evacuation but died in postoperative period. Three patients (30%) in the TICI 0-2a group underwent decompressive craniectomy due to aggravating brain edema. Among them, one died due to intractable brain swelling. There was no procedure-related complications or hemorrhagic events associated with further relevant clinical deterioration.

The Mt/Pt and the Mt/Dt became significantly larger at 3 min than at 0 min in the TICI 2b/3 group. The Mt/Pt in all times (each $P = 0.004$, $P < 0.001$, and $P < 0.001$) and the Mt/Dt at 3 and 5 min (each $P = 0.014$ and $P = 0.012$) were significantly larger in the TICI 2b/3 group than in the TICI 0-2a group. There were no significant changes in the Mt/Pt and the Mt/Dt of the TICI 0-2a group (Fig. 5).

There were no significant differences in the ICMCAA ($P = 0.410$) and the MCAA ($P = 0.084$) between two groups. The MCAA was negatively correlated with the Mt/Pt and the Mt/Dt (each $r = -0.539$, -0.546, and -0.563 of Mt/Pt; each $r = -0.546$, -0.579, and -0.564 of Mt/Dt; $P < 0.001$) (Fig. 6). The ICMCAA had no significant correlation with the Mt/Pt (each $P = 0.454$, 0.292, and 0.268) and the Mt/Dt (each $P = 0.326$, 0.264, and 0.244).

Discussion

The results of this study revealed that the change of the stent diameter ratios until 3 min after deployment is relevant to
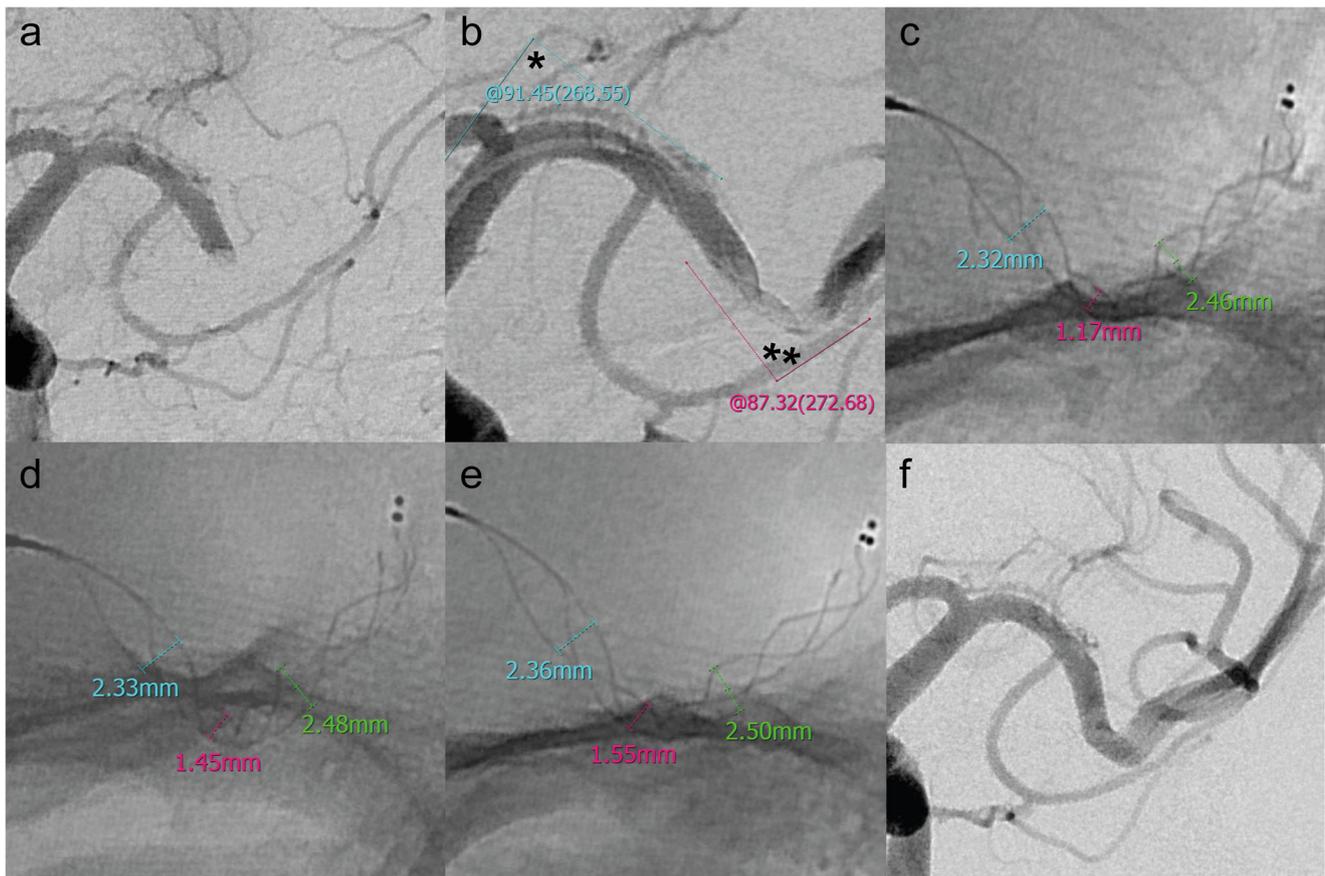
Fig. 4 Digital subtraction angiography shows practical measurement of stent diameter in 65-year old female patient with acute ischemic stroke. Initial angiography shows total occlusion of left middle cerebral artery (**a**). After stent deployment, internal cerebral artery terminus—proximal M1 segment angle (asterisk) and the most bent angle of the occluded M1 segment (double asterisks)—are measured (**b**). Diameter in proximal, mid-, and distal portion of stent are measured at 0, 3, and 5 min waiting time (**c–e**). Final angiography shows fully recanalization (**f**)

successful recanalization (TICI 2b/3) in acute ischemic stroke due to occlusion of the MCA. In addition, the ratio of the stent diameters at all times was inversely affected by the angle of MCA with thrombotic occlusion.

The primary goal of MT using a stent retriever is elimination of the thrombus and restoration of blood flow as quickly as possible. As such, many reports have postulated that the interaction between the stent retriever and the thrombus is a crucial factor for recanalization, and they have demonstrated the effort required for sufficient expansion and vessel approximation of the stent retriever [3, 16, 24]. Optimal stent strut interaction with the clot may be influenced by reasonable expansion and integration of the stent into the thrombus burden [8, 24]. We achieved deployment of the stent retriever in all cases by performing the "push and fluffing" technique documented by Haussen et al. [8]. Thereafter, we found that the whole portion of the stent did not expand simultaneously and evenly after unsheathing in practical cases, it showed relatively more expansion in proximal and distal portion of the stent while less in mid-portion. The discrepancy of the segmental expansion suggests that the stent's embedding of the thrombus

may be longer than expansion of other portions of the stent. In addition, passive expansion of the deployed stent during waiting time was continued by residual radial force, especially in the occluded segment of the MCA. The expansion of the stent was the most significant at 3 min after deployment in the TICI 2b/3 group. This suggests that initial expansion rate of stent deployment may play a more important role in precipitating integration into the thrombus within the first 3 min. This result could support the standardized 3-min deployment time even if practical retrieval at 3 min waiting time was unachieved. However, we also found that stent expansion continued to a lesser degree from 3 to 5 min. The stent diameter would continue to increase until that it reaches an ideal diameter against the thrombus and vessel wall. Our study showed that the diameter of the stent at 5 min reached nearly 70% of the proximal or distal diameter in the TICI 2b/3 group, while that of the TICI 0-2a group only reached nearly 50%. Therefore, the integration time of the stent strut into the thrombus could be greater than 5 min. Several studies have reported that 3–5 min of waiting time after stent deployment were provided for more stent-clot interaction [4, 22, 23, 25]. Our

Table 1 Baseline characteristics and intra/post-thrombectomy status of total 41 patients and subgroups divided according to successful recanalization and comparison between the subgroups

	Total $N = 41$	TICI 0-2a $N = 10$ (24.4%)	TICI 2b/3 $N = 31$ (75.6%)	P value
Pre-thrombectomy status				
Age (year, IQR)	70.0 (54.5–77.0)	71.0 (62.0–77.5)	65.0 (52.0–77.0)	0.430
Sex (female)	17 (41.5%)	6 (60.0%)	11 (35.5%)	0.270
Smoking	13 (31.7%)	1 (10.0%)	12 (38.7%)	0.129
Alcohol	12 (29.3%)	1 (10.0%)	11 (35.5%)	0.231
Hypertension	25 (61.0%)	6 (60.0%)	19 (61.3%)	1.000
Diabetes mellitus	5 (12.2%)	1 (10.0%)	4 (12.9%)	1.000
Total Cholesterol[a] (mg/dl)	154.9 ± 37.5	157.1 ± 40.71	154.2 ± 37.1	0.750
LDL[a] (mg/dl)	93.9 ± 31.6	95.4 ± 33.9	93.4 ± 31.4	0.820
Atrial fibrillation	18 (43.9%)	4 (40.0%)	14 (45.2%)	1.000
Stroke history	2 (4.9%)	0	2 (6.5%)	0.442
BMI[a]	23.9 ± 3.1	24.3 ± 3.0	23.8 ± 3.1	0.544
IV t-PA	26 (63.4%)	8 (80.0%)	18 (58.1%)	0.277
ASPECTs (IQR)	10 (9–10)	10 (10–10)	9 (8–10)	0.548
Initial NIHSS (IQR)	18 (14.8–23)	17 (15–22)	20 (13–23)	0.448
Intra-/post-thrombectomy status				
ICA-MCA angle (°)[a]	52.8 ± 21.0	62.4 ± 29.9	49.7 ± 16.6	0.410
MCA angle (°)[a]	55.7 ± 24.7	70.9 ± 34.1	50.8 ± 19.1	0.084
Distal migration of clot	4 (9.8%)	1 (10.0%)	3 (9.7%)	1.000
Extravasation of contrast	16 (39.0%)	3 (30.0%)	13 (41.9%)	0.712
Parenchymal hemorrhage	4 (9.8%)	2 (20.0%)	2 (6.5%)	0.245
Post NIHSS[b] (IQR)	13 (7–23)	14 (9–18)	12 (5–23)	0.106

ASPECTs Alberta Stroke Program Early CT score, *BMI* body mass index, *ICA* internal carotid artery, *IQR* interquartile range, *NIHSS* National Institutes of Health Stroke Scale, *MCA* middle cerebral artery, *TICI* thrombolysis in cerebral infarction

[a] Mean ± standard deviation

[b] Within 24 h after the thrombectomy

results may be in line with this; however, these suggest that waiting beyond 5 min may adversely delay the recanalization time because of tapering off the expansion gap.

The results of our study showed that the larger the angle of the MCA, the smaller the ratio of the stent diameter although there was no significant relationship between MCA angle and the recanalization results. Schwaiger et al. [20] suggested that a strongly curved MCA (M1) may diminish full expansion of the stent and hence reduced interaction force on the thrombus. Our data support this hypothesis by showing a negative correlation between the MCAA and the stent diameter ratios (M*t*/P*t* and M*t*/D*t*). As such, the angle of the curved MCA may be considered as a predictable factor influencing recanalization. Yi et al. [26] suggested that a larger diameter (6 mm) stent retriever may improve vessel wall apposition and attenuate kinking and angulation of the stent, leading to improved recanalization. However, in our experience, a larger diameter stent retriever has only been used in the case of ICA occlusion. Therefore, the effectiveness of a larger diameter stent is unknown in this study.

The M*0*/P*0* showed significant difference between the two groups while the M*0*/D*0* did not, and this discrepancy could have some explanations. First, geographically, the distal portion (D*0*) of the stent may be usually located in one of divisions of M2 segment and might have necessarily smaller diameter than the proximal portion (P*0*), and the restricted expansion of the stent may be similar in two groups. Second, the histological characteristics of an un-retrievable thrombus include more white blood cells, and hard and fibrin-rich solid materials, resulting in more tension in the stent restricting or blocking arterial flow [3, 13, 14]. In our study, any other baseline factors were not significantly different between the two groups. Therefore, we hypothesize that the proximal portion of the stent was more affected by pushing pressure than the distal portion, and the mid portion of the stent might be less integrated into the solid clot. As such, the solid clot may play a role as a leverage on transitional zone between proximal and mid-portion of the stent. The proximal stent segment might be further expanded due to more pushing force, and the discrepancy of P*0* and M*0* would also become larger

Table 2 Radiologic measuring results of two groups according to times

	TICI 0-2a ($n = 10$)	TICI 2b/3 ($n = 31$)	P value
P0	3.35 mm ± 0.33 mm	3.04 mm ± 0.46 mm	0.028*
P3	3.45 mm ± 0.24 mm	3.11 mm ± 0.45 mm	0.031*
P5	3.51 mm ± 0.33 mm	3.14 mm ± 0.43 mm	0.021*
M0	1.79 mm ± 0.29 mm	2.12 mm ± 0.48 mm	0.046*
M3	1.84 mm ± 0.28 mm	2.38 mm ± 0.47 mm	0.002*
M5	1.87 mm ± 0.28 mm	2.45 mm ± 0.49 mm	0.001*
D0	2.70 mm ± 0.46 mm	2.88 mm ± 0.43 mm	0.262
D3	2.75 mm ± 0.52 mm	2.96 mm ± 0.41 mm	0.201
D5	2.72 mm ± 0.52 mm	3.00 mm ± 0.43 mm	0.092

All statistical scale results were recorded as mean ± standard deviation

TICI thrombolysis in cerebral infarction, *Dt* distal widest diameter within working length of the stent at ($t = 0$, 3, and 5 min waiting time), *Mt* most stenotic diameter of mid-stent involving thrombus burden at ($t = 0$, 3, and 5 min waiting time), *Pt* proximal widest diameter within working length of the stent at ($t = 0$, 3, and 5 min waiting time)

*$P < 0.05$

(Fig. 7). This hypothesis may apply only to the immediate period just after stent deployment.

The rate of successful recanalization (TICI 2b/3) in our study was 75.6%, comparable to results published in recent large randomized studies reporting recanalization rates of 56–88%, with comparable occlusion sites and various stent retrievers [2, 5, 6, 11, 19]. Nonetheless, our rate of successful recanalization was lower than the average reported by other studies specifically using the Trevo stent retriever (88–90%)

[12, 17]. Here, we included only cases of MCA (M1) occlusion and radiologically measurable stent strut images (regardless of recanalization score), resulting in the exclusion of 36 patients. If included, a total of 65 of 77 patients (84.4%) would have had successful recanalization (TICI 2b/3).

Limitations

In the present study, there is no data of practical stent retrieval at 0- or 3-min waiting time for clinical efficacy because of an inherent retrospective design and our traditional 5-min waiting policy in mechanical thrombectomy using a stent retriever. The authors learned the need of further prospective study having a comparison with shorter waiting time based on the result of this study. Although this study has the small sample size, baseline characteristics of the two groups were relatively well-balanced with no significant differences, although there was a discrepancy in the number of cases between the two groups. In measurement process, our original image viewer and measurement system have not had the special function of isolation-accessing image; therefore, the physicians in charge of measuring the diameter of the stent retriever might be able to see the entire angiographic images during the measurement process. The situation may have a little bias bring more positive measurement to the final values. However, the measurement was achieved in the situation of unreleased purposes of this study; therefore, we assure that the situation was not much of factor affecting the
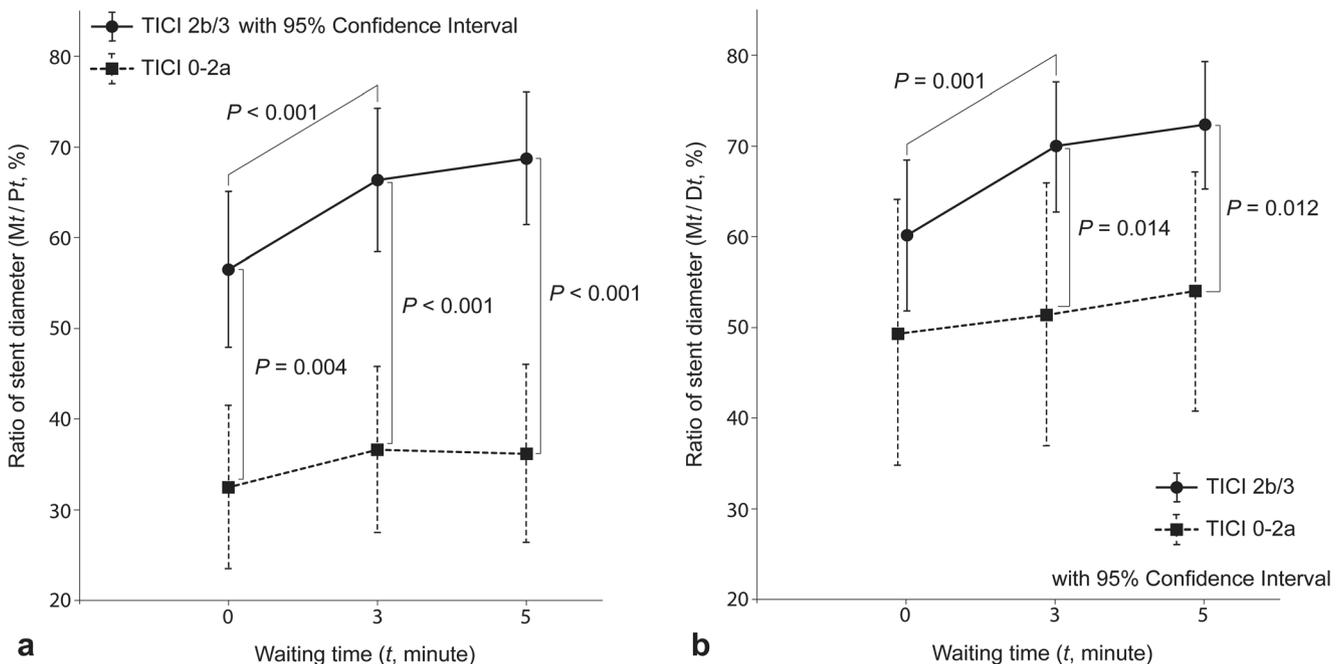

Fig. 5 The repeated measures ANOVA graphs of two groups (TICI 2b/3 and TICI 0-2a). **a** Change of ratio of mid-portion to proximal portion diameter of the stent (M*t*/P*t*) at three post-deployment waiting times (*t*). **b** Change of ratio of mid-portion to distal portion diameter of the stent (M*t*/D*t*) at three post-deployment waiting times (*t*)

Fig. 6 Simple scatter dot plots for linear correlation graphs of the middle cerebral artery (MCA, M1) angle and stent diameter ratios (t = waiting time as 0, 3, and 5 min; Mt/Pt = ratio of mid-portion to proximal portion diameter of the stent; Mt/Dt = ratio of mid-portion to distal portion diameter of the stent)
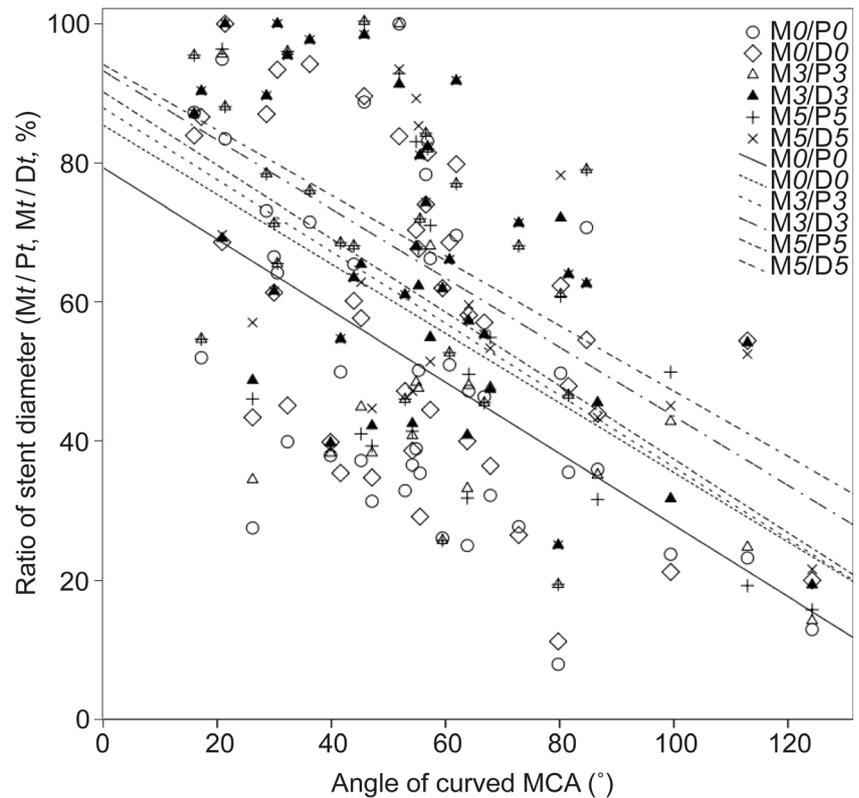
measurement. In addition, more exact measurement is necessarily required to use original image on the original viewer system.

Another limitation is that only the Trevo stent retriever measuring 4 mm × 20 mm was included in our study. The type and length of stent were determined by two neurointerventionalists' preferences and prior experience. In our experience, the 4 mm × 20 mm Trevo stent retriever was easier to handle and more feasible for use in MT compared to other stents. In addition, it was not known whether use of longer or larger diameter stents is feasible and safe,

due to lack of published data. Use of a larger stent retriever could be investigated following publication of more data, and increased experience and expertise in these instruments could be acquired.

The fact that the Trevo stent has unique radio-opaque strands and struts made it suitable for measuring the diameter at each waiting time. Further studies are needed to address other experimental models or radio-opaque stent retrievers. Especially, a comparison study in regard of stent expansion speed would be required between Trevo and other stent retrievers to avoid the need to wait.
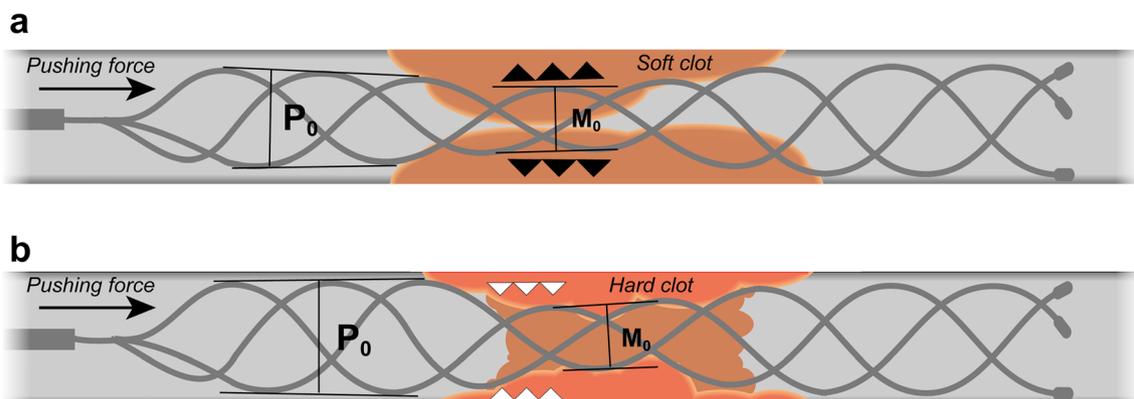

Fig. 7 Schematic of the initial expansion of the widest proximal portion (P0) and stenotic mid-portion (M0) of deployed stent. **a** The stent strut likely invades and integrates into soft clots (black arrow heads) in the

successful recanalization group. **b** The stent strut is unlikely to integrate into hard clots (white arrow heads) in the poor recanalization group

Conclusion

Investigation of post-deployed stent diameter may predict successful recanalization following MT for thrombotic occlusion of the MCA and reduce the number of retrieval attempts. Further, prospective study is needed regarding shortening the waiting time of the deployed stent retriever.

Compliance with ethical standards

All procedures performed in this study were in accordance with the ethical standards of the institute and with the 1964 Helsinki Declaration and its later amendments. Formal consent was not required for the collection of this data.

Informed consent For this type of study, formal consent is not required.

Conflict of interest The authors declare that they have no conflict of interest.

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Comments

The authors describe the progressive enlargement of the Trevo stent within a delay of 5 min when placed in the middle cerebral artery during mechanical thrombectomy. The Trevo has the unique advantage of being visible along its entire course, allowing to see the level of wall apposition. According to Choi et al., this is an important prognostic factor in the ability of the stentretriever to extract the clot. This finding has the following consequences:

– Clinical studies and not only experimental studies as achieved up to now need to be done in order to determine whether waiting for several minutes after placement of a stent retriever is needed to achieve a better recanalization but also better clinical outcome as this waiting time has negative consequences in relation to delay of restoral of normal brain perfusion

– All stent retrievers that will be released in the future should be visible in order to assess the level of expansion of the stent retriever

– There is no satisfactory reliable way to compare stent retrievers up to now. The first pass rate seems to be a possible way. The time for complete expansion, as evaluated in this study, may be another way to achieve a comparative analysis among stent retrievers

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