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Original Article

Results of Mechanical Thrombectomy in Patients Aged ≥80 Years

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Objective: The effectiveness of mechanical thrombectomy (MT) for anterior circulation large vessel occlusion (LVO) is controversial in elderly patients. The aim of this study was to evaluate the efficacy of MT in octogenarians.

Methods: One hundred and sixty-five patients who underwent MT for anterior circulation LVO between May 2014 and August 2019 at our institution were evaluated. Patients were divided into two groups, the elderly group (≥80 years) and non-elderly group (<80 years), and we compared the effective recanalization rate (Thrombolysis in Cerebral Infarction 2b-3), good outcome rate (modified Rankin Scale 0–2 at 90 days), time from groin puncture to recanalization (P to R), symptomatic intracranial hemorrhage (sICH), and mortality rate between them retrospectively. Eligible patients for MT were judged using the Japanese stroke guidelines, and the selection criteria were more carefully applied to elderly patients.

Results: MT was performed on 48 elderly patients (29.1%) and 117 non-elderly patients (70.9%). On the other hand, 10 elderly patients (19.6%) and 5 non-elderly patients (5.4%) did not undergo MT even though they met the inclusion criteria. There were significantly fewer male patients and smokers in the elderly group, but other baseline and clinical characteristics were not significantly different between the groups. Effective recanalization (elderly 93.8% vs non-elderly 91.5%), good outcome (45.8% vs 60.7%), P to R (33.5 minutes vs 33.5 minutes), sICH (2.1% vs 4.3%), and mortality (8.3% vs 2.6%) were not significantly different between the two groups.

Conclusion: When recanalization was achieved by strict preoperative evaluation of clinical conditions and imaging, MT may be safe and effective even for octogenarians or older patients.

Keywords ▶ acute ischemic stroke, mechanical thrombectomy, large vessel occlusion, elderly patients

Introduction

Several randomized controlled trials demonstrated the efficacy of mechanical thrombectomy (MT) for acute ischemic stroke related to anterior circulation system major cerebral artery occlusion. A sub-analysis with respect to age in a meta-analysis conducted by HERMES Collaborators revealed the efficacy of MT in patients aged ≥80 years.[1] Therefore, the upper age limit is not established in the guidelines for the management of stroke in the United States[2] or Japan.[3] On the other hand, in clinical practice, elderly patients often have a poor outcome despite effective recanalization achieved within a short time. Even when the extent of cerebral infarction on imaging is narrow, the reduction of physical strength or deterioration of a concomitant disease may affect rehabilitation, leading to the absence of recovery from neurological symptoms. Elderly specific problems may markedly influence the outcome. We retrospectively examined the efficacy and safety of MT by comparing the results of this procedure between patients with anterior circulation major cerebral artery occlusion aged ≥80 years and those aged <80 years (non-elderly patients) at our hospital.

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Materials and Methods

Materials

Of 184 patients with acute ischemic stroke who underwent MT for occlusion of the internal carotid artery (ICA) to proximal

(M1–M2) middle cerebral artery between May 2014 and August 2019, the subjects were 165, excluding 19 with a modified Rankin Scale (mRS) score of ≥3 before onset. In reference to the recommendation grade A items described in the guidelines for the adequate use of MT devices in Japan,[3] our criteria for indicating MT were: 1) interval from onset or final healthy-state confirmation ≤24 hours, 2) patients for whom intravenous thrombolysis with tissue plasminogen activator (tPA) cannot be indicated or non-responders with no amelioration of neurological symptoms, 3) mRS score before onset 0–2, 4) preoperative National Institutes of Health Stroke Scale (NIHSS) score ≥6, and 5) diffusion-weighted image (DWI)-Alberta Stroke Program Early CT Score (ASPECTS): ≥6. On the other hand, the upper age limit was not established. Among non-elderly patients, patients with a low ASPECTS or mild-status patients who did not meet the above indication criteria were individually reviewed, and MT was performed after informed consent when its benefit was considered to be great. On the other hand, we complied with the indication criteria more strictly for elderly patients. Independence at home before onset and an interval of ≤4.5 hours from onset until the start of treatment were regarded as standards. When the interval exceeded 4.5 hours, patients with a DWI-ASPECTS of ≥7 and small ischemic core volume were selected for treatment.

Procedures of MT

In all patients, treatment was started via the transfemoral approach and a 9 Fr balloon guiding catheter was guided into the affected-side cervical ICA. When the transfemoral approach was difficult, it was switched to the right brachial artery-mediated approach. For MT, a Penumbra aspiration catheter (Medicos Hirata, Osaka, Japan) and a Penumbra MAX pump (Medicos Hirata) were used. A direct aspiration first-pass technique (ADAPT)[4] was selected as a first-choice procedure, and a large-diameter catheter that was considered to be satisfactory for guiding by surgeons was adopted in accordance with the site of occlusion. When a thrombus aspiration catheter did not reach the site of occlusion or when ADAPT did not lead to effective recanalization, MT was performed using a combination technique with different stent retrievers (Solitaire; Medtronic, Minneapolis, MN, USA), Trevo XP (Stryker, Kalamazoo, MI, USA).[5,6]

Evaluation items

As items for efficacy assessment, patients with a Thrombolysis in Cerebral Infarction (TICI) scale score of 2b to 3 were regarded as achieving effective recanalization. Those with an mRS score of 0 to 2 after 90 days were regarded as having a favorable outcome. As items for safety assessment, symptomatic intracranial hemorrhage (sICH; intracranial hemorrhage with ≥4-point [NIHSS score] deterioration) and subarachnoid hemorrhage (SAH) on cephalic CT immediately after surgery were investigated. Furthermore, the interval from puncture until effective recanalization and number of passes were examined.

Statistical analysis

Category variables were expressed as the total number (%) and continuous variables as the median (interquartile range). The subjects were divided into two groups, elderly and non-elderly groups, consisting of patients aged ≥80 years and those aged <80 years, respectively, and the background factors and treatment results were retrospectively compared. For statistical analysis, the chi-square or Fisher's direct probability tests were used to compare category variables. To compare continuous variables between two groups, the Mann–Whitney *U*-test was used. To compare them among ≥3 groups, the Kruskal–Wallis test was used. A p-value of 0.05 was regarded as significant. For all statistical analyses, we used EZR (Ver. 1.36) software (Saitama Medical Center, Jichi Medical University, Saitama, Japan),[7] which is a statistical software involving dilation of R and R commander functions. Prior to this study, its protocol was approved by the ethics review board of our institution.

Results

Patient selection

Of the subjects who underwent MT, 48 patients (29.1%) comprised the elderly group and 117 (70.9%) comprised the non-elderly group. The compliance rates for treatment indication in the former and latter were 87.5% (42/48) and 74.4% (87/117), respectively; the percentage was slightly higher in the former (p = 0.10). On the other hand, 52 patients with acute major cerebral artery occlusion in the elderly group and 92 in the non-elderly group met the indication criteria. Among them, MT was not performed on 10 (19.6%) and 5 (5.4%) patients, respectively; the percentage was significantly higher in the elderly group (p = 0.01). In this group, the patients were excluded from the treatment due to an age of ≥85 years before onset or their families did not wish for them to undergo surgery, or when surgeons considered recovery after MT difficult based on the medical history or general condition. In the above patients in the non-elderly group, medical treatment was

prioritized based on symptoms and imaging findings, and MT was not conducted.

Patient background

The baseline characteristics are shown in **Table 1**. In the elderly group, the rates of males and smokers were significantly lower. Furthermore, the DWI-ASPECTS was higher in the elderly group, although there was no significant difference. There were no differences in the preoperative NIHSS score, site of occlusion, medical history, time from final healthy-state confirmation to arrival, or that from arrival to puncture between the two groups. Concerning the disease type of cerebral infarction, the rate of patients with cardiogenic cerebral embolism was slightly higher in the elderly group, but there was no significant difference.

Results of treatment

The results of treatment are shown in **Table 2**. The transfemoral approach was switched to the transbrachial approach in 3 patients (6.2%) in the elderly group and in 3 patients (2.6%) in the non-elderly group; the percentage was slightly higher in the former (p = 0.36). There was no difference in the rate of patients in whom a stent retriever was used between the two groups. There were no differences in the TICI 2b-3 recanalization rate on the first pass (elderly group: 62.5%, non-elderly group: 53.8%, p = 0.51) or final TICI 2b-3 recanalization rate (elderly group: 93.8%, non-elderly group: 91.5 %, p = 0.76) between the two groups. The time from puncture to recanalization was also similar between the two groups (elderly group: 33.5 (23–63), non-elderly group: 33.5 (23–58.5), p = 0.80). The rates of patients with an mRS score of 0 to 2 after 90 days in the elderly and non-elderly groups were 45.8% and 60.7%, respectively (p = 0.11); the percentage was slightly lower in the former. The mortality rates were 8.3% and 2.6%, respectively (p = 0.20); the percentage was higher in the former, but there was no significant difference. Furthermore, there were no differences in the incidences of sICH or SAH as items for safety assessment between the two groups.

We further examined factors for a poor outcome. They included failure of the procedure (elderly group: 4 patients [8.3%], non-elderly group: 6 patients [5.1%]), completion/exacerbation of cerebral infarction (elderly group: 17 patients [35.4%], non-elderly group: 29 patients [24.8%]), surgery-related complications (elderly group: 1 patient [2.1%], non-elderly group: 2 patients [1.7%]), and systemic complications (elderly group: 4 patients [8.3%], non-elderly group: 1 patient [0.9%]). In the elderly group, systemic complications, such as severe pneumonia and heart failure, were frequently observed as factors for a poor outcome.

Furthermore, the outcome was favorable in none (0%) and 1 (20%) of the elderly and non-elderly patients, respectively, in whom endovascular treatment was not performed during the study period, although the indication criteria were met.

Results with respect to age

As shown in **Table 3**, the patients aged ≥80 years in the elderly group were divided into 3 subgroups: patients aged 80 to 84 years (n = 31), those aged 85 to 89 years (n = 13), and those aged ≥90 years (n = 4). The rate of patients with a favorable outcome decreased with an increase in the age and the mortality rate increased. Furthermore, the time from puncture to recanalization was longer at a more advanced age. In particular, the baseline NIHSS score in the ≥90-year-old group was lower than that in the other groups, and the DWI-ASPECTS was higher. In addition, the time from onset to arrival was shorter. Effective recanalization was similarly achieved in each group, but the rate of patients with an mRS score of 0 to 2 after 90 days (25%, n = 1) was low, and the mortality rate (25%, n = 1) was high. The cause of death was pneumonia. In 1 patient with a poor outcome, the NIHSS score reached 0, but disuse muscular weakness affected ambulation, suggesting the marked influence of aging on the nerve function and systemic tolerability.

Representative cases

Case 1: A 93-year-old woman

Left paralysis and right conjugate deviation suddenly developed. She was brought to our hospital by ambulance 71 minutes after onset. The preoperative NIHSS score was 15, and MRI-DWI demonstrated a light high-signal-intensity area in the posterior limb of the right internal capsule (DWI-ASPECTS: 10) (**Fig. 1A**). MRA revealed occlusion of the right ICA (**Fig. 1B**). After tPA was intravenously injected, endovascular treatment was performed (time from onset to puncture: 188 minutes). Angiography confirmed occlusion of the right ICA (**Fig. 1C**). A 9 Fr Optimo 90 cm (Tokai Medical Products, Aichi, Japan) was guided through the right femoral artery, but the access route was markedly tortuous and the distal right common carotid artery was reached. We attempted to guide a Penumbra ACE 60 to an area proximal to the thrombus using a Marksman (Medtronic) and ASAHI CHIKAI 14 (Asahi Intecc Co., Ltd., Aichi, Japan), but vascular torsion was marked

Table 1 Baseline characteristics

	Age ≥80 (n = 48)	Age <80 (n = 117)	p
Demographic characteristics			
Age, median (IQR)	83 (81–87)	70 (65–76)	<0.01
Male, n (%)	17 (35.4)	81 (69.2)	<0.01
Clinical characteristics			
Baseline NIHSS, median IQR)	20.5 (14–28)	21 (16–25)	1.0
Imaging characteristics			
DWI-ASPECTS, median (IQR)	8 (7–9)	7 (6–9)	0.09
Site of occlusion, n (%)			0.88
ICA	16 (33.3)	35 (29.9)	
M1	24 (50.0)	59 (50.4)	
M2	8 (16.7)	23 (19.7)	
Dominant side	27 (56.2)	49 (41.9)	0.13
Medical history, n(%)			
Previous stroke	7 (14.6)	22 (18.8)	0.67
Hypertension	29 (60.4)	77 (65.8)	0.63
Diabetes	7 (14.6)	28 (23.9)	0.26
Hyperlipidemia	12 (25.0)	25 (21.4)	0.76
Atrial fibrillation	33 (68.8)	64 (54.7)	0.13
Smoking	12 (25.0)	62 (53.0)	<0.01
Medications, n (%)			
Oral anticoagulant drugs	10 (20.8)	20 (17.1)	0.73
Antiplatelet drugs	9 (18.8)	16 (13.7)	0.56
Intravenous tPA	27 (56.2)	64 (54.7)	0.99
Cause of stroke, n (%)			0.09
Cardiogenic	44 (91.7)	95 (81.2)	
Atherosclerotic	3 (6.2)	21 (17.9)	
Others	1 (2.1)	1 (0.9)	
Process times, median (IQR)			
LKW to Door time, minutes	63 (44–189)	74 (40–185)	0.93
Door to Puncture time, minutes	101 (82–139)	94 (70.5–132)	0.51

Data are median (IQR) or n (%). DWI-ASPECTS: diffusion weighted image-Alberta Stroke Program Early CT Score; ICA: internal carotid artery; IQR: interquartile range; M1: middle cerebral artery first segment, M2: middle cerebral artery second segment; NIHSS: National Institutes of Health Stroke Scale; LKW: last known well; tPA: tissue plasminogen activator

and the guiding catheter backup system was weak; therefore, the lesion was not reached. The Marksman was guided to the distal M1 segment, which was distal to the thrombus, and a Trevo XP 6 × 25 mm was deployed in the M1 segment to ICA (**Fig. 1D**). Using a combination technique (a stent-retrieving into an aspiration catheter with proximal balloon [ASAP] method[6]), MT was performed. A single pass led to TICI 2b recanalization (**Fig. 1E**). The time from puncture to recanalization was 25 minutes. After surgery, there was no SAH. The NIHSS score was 3 the day after surgery, demonstrating improvement. Only a minor infarcted focus was observed on MRI-DWI (**Fig. 1F**). The outcome after 90 days was favorable (mRS score: 2).

Case 2: A 90-year-old woman

Left paralysis developed, and she was brought to our hospital by ambulance 28 minutes after onset. The preoperative

Table 2 Procedural and clinical results

	Age ≥80 (n = 48)	Age <80 (n = 117)	p
Procedural results, n (%)			
Transbrachial approach	3 (6.2)	3 (2.6)	0.36
Use of stent retriever	25 (52.1)	57 (48.7)	0.86
TICI 2b-3 after first pass	30 (62.5)	63 (53.8)	0.51
TICI 2b-3 after all procedure	45 (93.8)	107 (91.5)	0.76
Process time, median (IQR)			
Puncture to recanalization time, minutes	33.5 (23–63)	33.5 (23–58.5)	0.80
Clinical results, n (%)			
mRS 0–2 (90 days)	22 (45.8)	71 (60.7)	0.11
Mortality	4 (8.3)	3 (2.6)	0.20
Adversed events, n (%)			
Symptomatic ICH	1 (2.1)	5 (4.3)	0.67
Any SAH	7 (14.6)	21 (17.9)	0.77

Data are median (IQR) or n (%). ICH: intracranial hemorrhage; IQR: interquartile range; mRS: modified Rankin Scale; SAH: subarachnoid hemorrhage; TICI: Thrombolysis in Cerebral Infarction

Table 3 Summary of clinical outcomes by age

	Age <80 (n = 117)	Age 80–84 (n = 31)	Age 85–89 (n = 13)	Age ≥90 (n = 4)	p
Baseline characteristics, median (IQR)					
Baseline NIHSS	21 (16-25)	20 (15.5–26.5)	28 (14–29)	13.5 (11–15)	0.09
DWI-ASPECTS	7 (6–9)	7 (6–8.5)	8 (7–10)	9.5 (8.5–10)	0.09
Clinical results, n (%)					
TICI 2b-3 after all procedure	107 (91.5)	28 (90.3)	13 (100)	4 (100)	0.79
mRS 0–2 (90 days)	71 (60.7)	15 (48.4)	6 (46.2)	1 (25)	0.28
sICH	5 (4.3)	0 (0)	1 (7.7)	0 (0)	0.42
Motality	3 (2.6)	1 (3.2)	2 (15.4)	1 (25)	0.04
Process times, median (IQR)					
LKW to door time, minutes	74 (40–185)	56.5 (42–169)	187 (61–412)	31 (29.5–51)	0.09
Door to puncture time, minutes	94 (70.5–132)	93.5 (67.5–137.5)	109 (95–131)	128 (122.5–158.5)	0.32
Puncture to recanalization time, minutes	33.5 (23–58.5)	31 (25–55)	51 (30–77)	71 (33–110)	0.49

Data are median (IQR) or n (%). DWI-ASPECTS: diffusion weighted image-Alberta Stroke Program Early CT Score; IQR: interquartile range; LKW: last known well; NIHSS: National Institutes of Health Stroke Scale; mRS: modified Rankin Scale; sICH: symptomatic intracranial hemorrhage; TICI: Thrombolysis in Cerebral Infarction

NIHSS score was 10. MRI-DWI demonstrated a light high-signal-intensity area in the cortex of the right insula (DWI-ASPECTS: 10) (**Fig. 2A**). MRA revealed occlusion at the distal M1 segment of the right middle cerebral artery (**Fig. 2B**). After intravenous thrombolysis with tPA, endovascular treatment was performed (time from onset to puncture: 156 minutes). An approach through the right femoral artery was adopted, but the type III aortic arch made it difficult to guide a guiding catheter (**Fig. 2C**). This operation was attempted for 30 minutes, but it was impossible. The approach was switched to that through the right brachial artery, and a 6 Fr Shuttle Sheath 80 cm (Cook Medical, Bloomington, IN, U.S.A.) was guided into the right ICA. Angiography confirmed occlusion of the M1 distal segment (**Fig. 2D**). A Penumbra ACE 60 was guided to the site of M1 occlusion using a Marksman and ASAHI CHIKAI 14

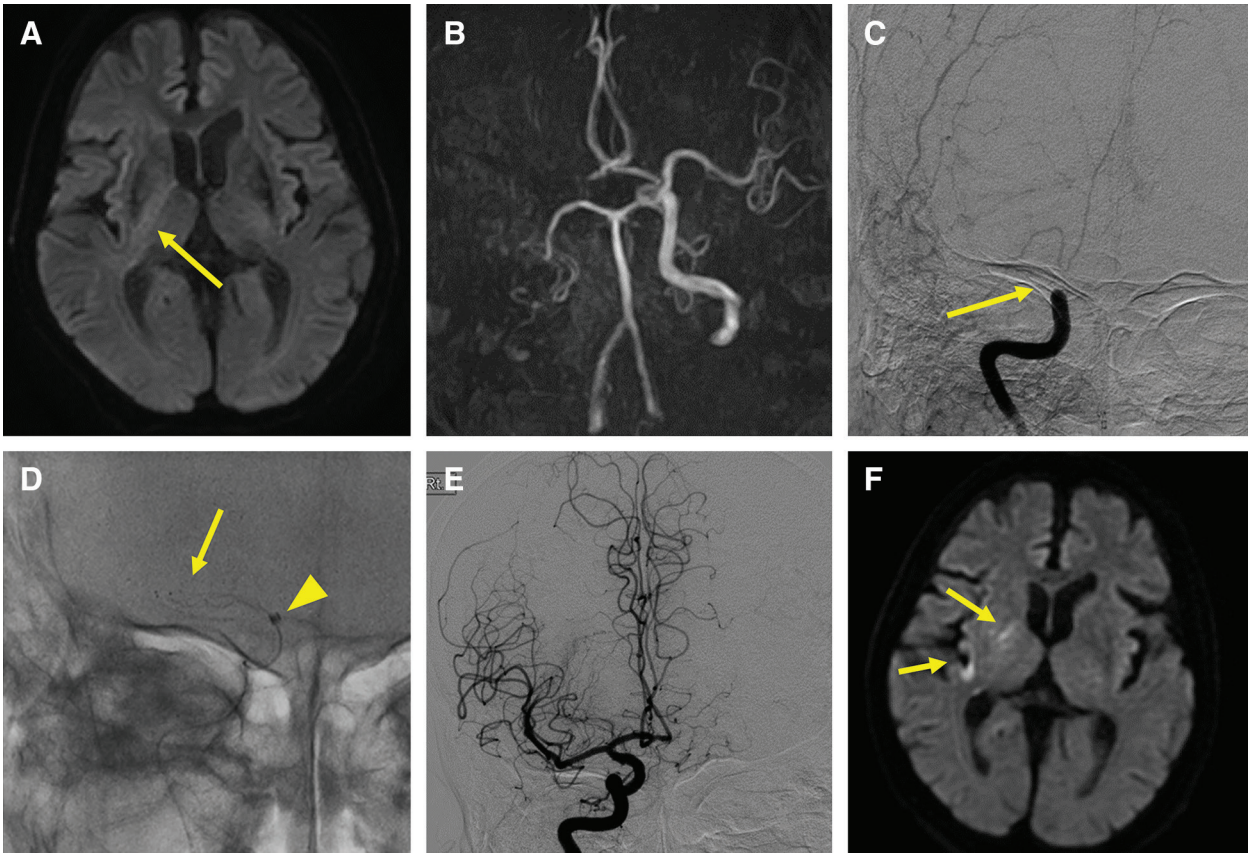

Fig. 1 Case 1. (**A**) Preoperative MRI-DWI. A light high-signal-intensity area was detected in the posterior limb of the right internal capsule (arrow). (**B**) Preoperative MRA. The right ICA was not visualized. (**C**) Frontal view of cerebral angiography. Occlusion at the end of the right ICA was observed (arrow). (**D**) Frontal view on fluoroscopy. A Trevo XP 6 × 25 mm was deployed in the M1 segment of the right middle cerebral artery (arrow) and a Penumbra ACE 60 was guided to the right ICA end such that it was elevated (arrow head). (**E**) Frontal view on angiography after MT. Recanalization of the right internal carotid artery was confirmed (TICI 2b). (**F**) MRI-DWI the day after surgery. A minor infarcted focus involving the right putamen/insula cortex was noted (arrows). DWI: diffusion weighted image; ICA: internal carotid artery; M1: middle cerebral artery first segment; MT, mechanical thrombectomy; TICI: Thrombolysis in Cerebral Infarction

and ADAPT led to M1 recanalization. However, occlusion at the M2 inferior trunk, where the perfusion area was extensive, remained. To achieve M2 recanalization, a stent retriever was used, but vascular torsion was marked, making it difficult to guide a microcatheter. Three sessions of Solitaire 4 mm × 20 mm passing led to TICI 2b recanalization (**Fig. 2E**). The time from femoral artery puncture to recanalization was 122 minutes. CT immediately after surgery revealed slight SAH. On MRI-DWI the day after surgery, the infarcted focus had enlarged, involving the deep white matter region with the corona radiata (**Fig. 2F**). The outcome after 90 days was unfavorable (mRS score: 5).

Discussion

Efficacy of MT in patients aged ≥80 years

The MR CLEAN trial[8] first demonstrated the efficacy of MT for anterior circulation major cerebral artery occlusion. A sub-analysis involving 419 patients aged <80 years and 81 aged ≥80 years revealed the efficacy of endovascular treatment in the two groups (<80 years: adjusted common odds ratio [acOR]: 1.60; 95% confidence interval [95% CI]: 1.13–2.28; ≥80 years acOR: 3.24; 95% CI: 1.22–8.62). In the elderly group, the acOR was higher, suggesting the superiority of endovascular treatment. A meta-analysis of a randomized controlled trial by the HERMES Collaborators[1] also yielded similar results; among elderly patients, the results were significantly better in the endovascular treatment group (endovascular treatment group: 29.8%, control group: 13.9%) and the mortality rate was lower (endovascular treatment group: 28.0%, control group: 45.2%).

The DAWN trial[9] demonstrated the efficacy of MT 6 to 24 hours after the time of final healthy-state confirmation. In this trial, patients aged ≥80 years were assigned to Group A, and inclusion criteria consisted of an NIHSS score of ≥10 and infarct volume of <21 mL. Even among elderly patients with a long interval from the time of final healthy-state confirmation, the rate of patients with a

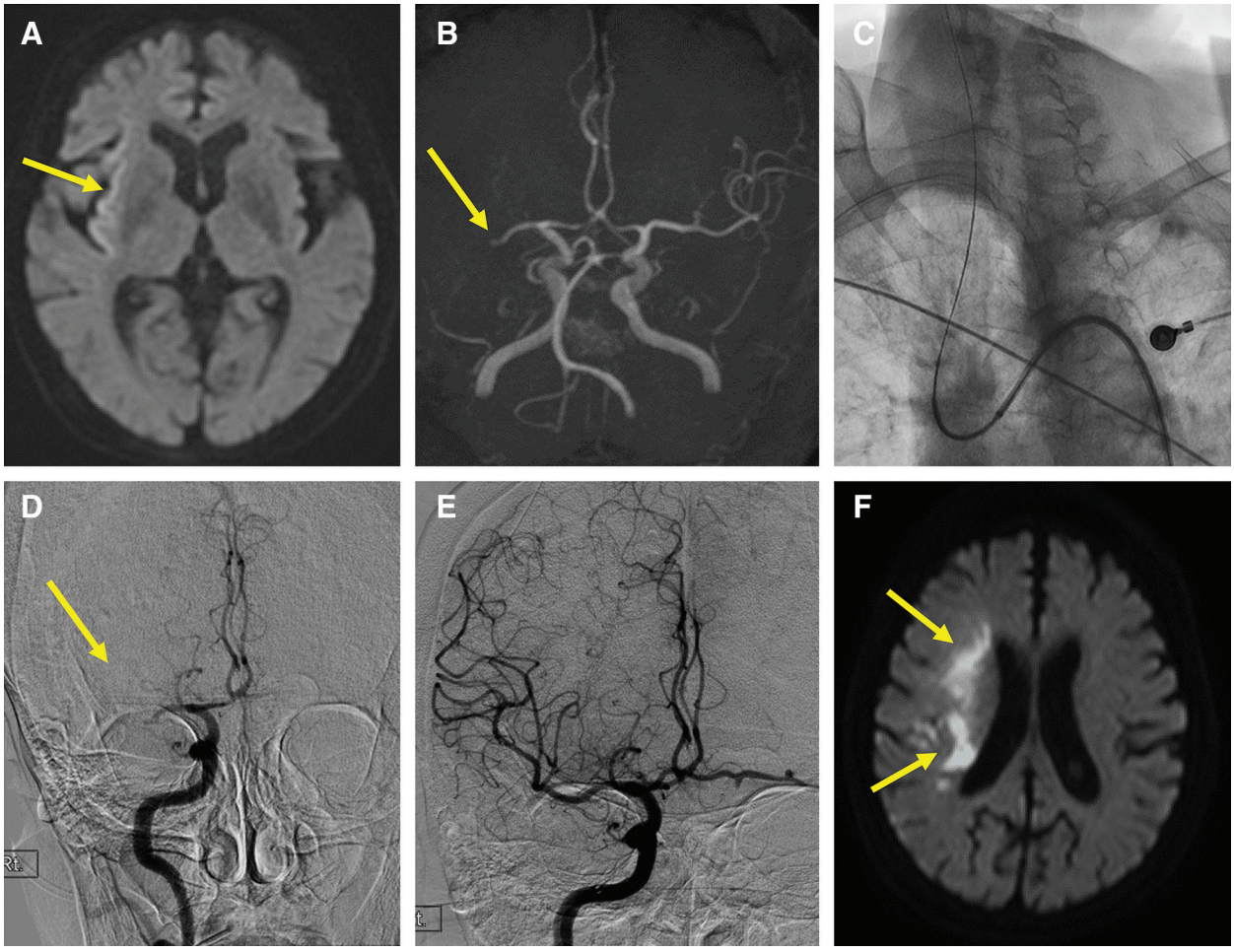

Fig. 2 Case 2. (**A**) Preoperative MRI-DWI. A light high-signal-intensity area was detected in the right insula cortex (arrow). (**B**) Preoperative MRA. Occlusion at the distal M1 segment of the right middle cerebral artery was observed (arrow). (**C**) Frontal view on fluoroscopy. An approach to the right common carotid artery was attempted through the right femoral artery, but the type III aortic arch made it difficult to guide a 9 Fr balloon guiding catheter. (**D**) Frontal view on angiography. Occlusion at the distal M1 segment of the right middle cerebral artery was observed (arrow). (**E**) Frontal view of angiography after MT. MT using ADAPT (1 pass) and a Solitaire 4 × 20 mm led to TICI 2b recanalization. (**F**) MRI-DWI the day after surgery. An infarcted focus was detected in the deep white matter region involving the corona radiata (arrows). ADAPT: a direct aspiration first-pass technique; DWI: diffusion weighted image; M1: middle cerebral artery first segment; MT, mechanical thrombectomy; TICI: Thrombolysis in Cerebral Infarction

favorable outcome was significantly higher in the endovascular treatment group (endovascular treatment group: 32.0%, control group: 3.5%) and the rate of those with an mRS score of 5 to 6 was lower (endovascular treatment group: 44%, control group: 62%). Thus, a sub-analysis of several randomized trials in which the efficacy of MT was established confirmed the efficacy of MT in elderly patients, as reported for young patients.

Treatment results in comparison with patients aged <80 years

As described above, several randomized controlled trials previously demonstrated the efficacy of MT in those aged ≥80 years. However, in these trials, many patients were excluded and only a small number of patients was investigated; therefore, its efficacy remains controversial. Based on the clinical data, the outcome of elderly patients was poorer than that of non-elderly patients. The TRACK Registry,[10] a post-marketing survey regarding Trevo XP in the United States, reported that an age of ≥80 years was a prognostic factor (odds ratio [OR]: 0.65, 95% CI: 0.65–0.99) and that the rate of patients with an mRS score of 0 to 2 after 90 days slightly decreased with age. The STRATIS Registry,[11] a post-marketing survey regarding Solitaire in the United States, examined numerous items in detail in each age group, and the rate of patients with a favorable outcome was significantly lower among elderly patients despite a similar recanalization rate (rate of patients with an mRS

score of 0 to 2 after 90 days: <65 years, 64.3%; 65–69 years, 57.0%; 70–74 years, 63.6%; 75–79 years, 51.7%; 80–84 years, 52.4%; 85–89 years, 38.3%; and ≥90 years, 26.5%). In particular, the outcome was the poorest for patients aged ≥90 years. Furthermore, the mortality rate increased with age; it was 35.1% among those aged ≥90 years. Thus, the advantages of MT in elderly patients were unclear.

Regarding the results of MT in patients aged ≥80 years, Zhao et al.[12] conducted a meta-analysis of 3954 patients (16 articles published between 2014 and 2019) and reported that the rate of patients with an mRS score of 0 to 2 after 90 days was significantly lower among those aged ≥80 years (elderly group: 26.1%, non-elderly group: 46.6%, OR: 0.40; 95% CI: 0.32–0.50, p <0.001). Furthermore, the effective recanalization rate was significantly lower in the elderly group (elderly group: 66.3%, non-elderly group: 68.1%, OR: 0.72; 95% CI: 0.55–0.95, p = 0.02) and the mortality rate was significantly higher (elderly group: 29.2%, non-elderly group: 16.6%, OR: 2.26; 95% CI: 1.73–2.95, p <0.001). However, there was no significant difference in the incidence of sICH (elderly group: 7.4%, non-elderly group: 6.3%, OR: 1.28; 95% CI: 0.89–1.84, p = 0.18). The reasons why the outcome was poor in the elderly group included a reduction in cerebral ischemic tolerance or recovery power, high incidence of systemic complications, and the influence of marked vascular torsion on thrombus retrieval device functions. On the other hand, advances in treatment techniques and devices have improved the results of treatment in the elderly; the efficacy may be further improved.

The results of MT in patients aged ≥80 years in our study were better than those previously reported; the recanalization rate was high (final TICI 2b-3: 93.8%), and the rate of patients with an mRS score of 0 to 2 after 90 days was 45.8%. This was possibly because this study involved only patients with anterior circulation system occlusion, excluding those with a preoperative mRS score of ≥3. However, the arbitrary evaluation by physicians to indicate treatment for elderly patients may have markedly influenced the results. The data with respect to the age groups are presented in **Table 3**. The number of patients aged ≥85 years was small, and the DWI-ASPECTS was slightly high. TICI 2b-3 recanalization was achieved regardless of procedures. This suggest that the preoperative state was strictly evaluated in the elderly patients and that those with a small ischemic core were more frequently selected. Furthermore, the incidence of cerebral embolism increases with age, and we selected safe and appropriate retrieval procedures, leading to successful retrieval in all patients.

On the other hand, the outcome in the elderly group was poorer than that in the non-elderly group despite a high recanalization rate, although there was no significant difference. This was possibly because time was required for device guiding due to age-related vascular torsion, prolonging the time to recanalization. Several clinical trials, such as the HERMES trial,[1] reported that the rate of patients with a favorable outcome decreased with prolongation of the time from onset. This study also suggested the influence of the time from onset on the outcome. Furthermore, as factors for a poor outcome, the onset of systemic complications, such as pneumonia and heart failure, or an age-related reduction in the physical strength delays rehabilitation in many cases; a reduction in tolerability markedly influences the outcome. We often encounter patients in whom there is no improvement in the outcome of walking training despite a mild neurological status, leading to a wheelchair-bound state. However, all patients on whom endovascular treatment was not performed due to an advanced age although the indication criteria were met had an mRS score of 5 or 6, leading to a poor outcome. Therefore, this treatment may be significant even in elderly patients.

Limitations of ADAPT in elderly patients

Son et al.[13] examined the results of MT in which thrombus aspiration with a Penumbra aspiration catheter was selected as a first-choice procedure and reported that the effective recanalization rate and operative time in patients aged ≥80 years were similar to those in non-elderly patients, suggesting the safety and efficacy of MT in elderly patients. Regarding treatment procedures, the rate of patients in whom a stent retriever was selected was higher in the elderly group (elderly group: 29.4%, non-elderly group: 7.5%, p <0.01). This was possibly because aspiration-catheter guiding was considered to be difficult due to marked vascular torsion or stenotic lesions in many elderly patients. At our hospital, ADAPT with a large-diameter aspiration catheter is also selected as a first-choice procedure, but success or failure of large-diameter catheter guiding depends on the backup power of the guiding system and degree of vascular torsion until the thrombus is reached. In many elderly patients, the femoral to internal carotid arteries are markedly tortuous. As in the representative cases, many patients required a switch to the trans-brachial approach, as did those in whom a balloon-guiding catheter did not reach the ICA (**Figs. 1** and **2**). When the cervical internal carotid to middle cerebral arteries are markedly tortuous, it is difficult to guide an aspiration catheter. In

addition, even when the thrombotic site is reached, a mismatch between the axes of the thrombus and aspiration catheter may affect aspiration-power transmission, leading to unsuccessful retrieval. As shown in **Table 3**, the time from puncture to recanalization was compared among the age groups. There was no difference between the <80-year-old and 80- to 84-year-old groups, but the time was prolonged in the 85- to 89-year-old and ≥90-year-old groups, suggesting the marked influence of difficulties in treatment procedures. Therefore, especially in patients aged ≥85 years, strategies to manage tortuous blood vessels, such as the selection of a device system that facilitates peripheral approaching, must be arranged.

Limitation

This was a retrospective, single-center sturdy. Its power was insufficient for confirming the efficacy and safety of this treatment in the elderly. In the future, patient data should be accumulated and a large-scale prospective study should be conducted. In clinical practice, activities of daily living, medical history, and preoperative imaging findings are more strictly evaluated at a more advanced age, and the content of informed consent for deciding therapeutic intervention also differ; there may be a bias for patient selection. Concerning thrombectomy procedures, the safety is more closely considered in elderly patients. This may have influenced the results of treatment.

Conclusion

The efficacy and safety of MT were demonstrated even in elderly patients by achieving recanalization at a high rate through strict preoperative assessment based on the clinical background and imaging findings, as reported for non-elderly patients.

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Disclosure Statement

The authors declare no conflict of interest.

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