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ORIGINAL RESEARCH

Mechanical thrombectomy for acute ischemic stroke with cerebral microbleeds

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ABSTRACT

Background The influence of cerebral microbleeds (CMBs) on post-thrombolytic hemorrhagic transformation (HT) in patients with acute ischemic stroke remains controversial.

Objective To investigate the association of CMBs with HT and clinical outcomes among patients with large-vessel occlusion strokes treated with mechanical thrombectomy.

Methods We analyzed patients with acute stroke treated with Merci Retriever, Penumbra system or stent-retriever devices. CMBs were identified on pretreatment T2-weighted, gradient-recall echo MRI. We analyzed the association of the presence, burden, and distribution of CMBs with HT, procedural complications, in-hospital mortality, and clinical outcome.

Results CMBs were detected in 37 (18.0%) of 206 patients. Seventy-three foci of microbleeds were identified. Fourteen patients (6.8%) had ≥2 CMBs, only 1 patient had ≥5 CMBs. Strictly lobar CMBs were found in 12 patients, strictly deep CMBs in 12 patients, strictly infratentorial CMBs in 2 patients, and mixed CMBs in 11 patients. There were no significant differences between patients with CMBs and those without CMBs in the rates of overall HT (37.8% vs 45.6%), parenchymal hematoma (16.2% vs 19.5%), procedure-related vessel perforation (5.4% vs 7.1%), in-hospital mortality (16.2% vs 18.3%), and modified Rankin Scale score 0–3 at discharge. CMBs were not independently associated with HT or in-hospital mortality in patients treated with either thrombectomy or intravenous thrombolysis followed by thrombectomy.

Conclusions Patients with CMBs are not at increased risk for HT and mortality following mechanical thrombectomy for acute stroke. Excluding such patients from mechanical thrombectomy is unwarranted. The risk of HT in patients with ≥5 CMBs requires further study.

INTRODUCTION

Cerebral microbleeds (CMBs), an imaging marker of cerebral small-vessel disease seen on T2* gradient-recall echo (GRE) or susceptibility-weighted imaging MRI sequences, are more prevalent in individuals with stroke, those with Alzheimer disease, and asymptomatic elderly individuals.[1 2] CMBs are associated with future bleeding risk in both ischemic and hemorrhagic strokes.[3 4] CMBs also predict mortality in the elderly, patients with memory disorders, and patients with stroke and atrial fibrillation.[5–7] CMBs may increase the risk of intracerebral hemorrhage related to antithrombotic therapy.[8] The association of CMBs with hemorrhagic transformation (HT) in patients with acute stroke after thrombolysis remains controversial.[9–13]

Patients with strokes from large-vessel occlusion benefit from mechanical thrombectomy with stent-retriever devices.[14–16] MRI-guided selection for endovascular thrombectomy may be associated with better clinical outcomes in basilar artery occlusion.[17] Severe leukoaraiosis, which is correlated with CMBs, increases the risk of hemorrhagic complications and mortality after reperfusion therapy.[18 19] However, little is known about the safety of mechanical thrombectomy for patients with acute stroke and CMBs. The purpose of this study was to investigate the association of CMBs with hemorrhagic complications and clinical outcome in a large cohort of patients with acute stroke by the routine use of MRI for mechanical thrombectomy.

SUBJECTS AND METHODS

Study population

All consecutive patients with acute stroke with large-vessel occlusion treated by mechanical thrombectomy were identified from a prospectively maintained database between August 2002 and October 2012 at a single academic institution. The mechanical clot retrieval devices included Merci Retriever (Stryker Neurovascular, Mountain View, California, USA), Penumbra system (Penumbra, Inc, Alameda, California, USA), stent-retriever with Solitaire FR device (Covidien/eV3, Dublin, Ireland), or Trevo Retriever (Stryker Neurovascular). Patients treated by thrombectomy were either ineligible for IV tissue plasminogen activator (tPA) or refractory to thrombolysis after receiving IV tPA within 4.5 h of stroke onset.[18 20] The local institutional review board approved the study. Informed consent was obtained from the patient or their representative.

MRI before thrombectomy was routinely performed in all patients without selection biases unless contraindicated according to the institutional protocol. MR images included the diffusion-weighted imaging, perfusion-weighted imaging, T2* GRE, and fluid-attenuated inversion recovery (FLAIR) sequences. All patients who had pretreatment GRE and FLAIR MR images were included in this study. We acquired data, including

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demographic characteristics, vascular risk factors, premorbid drugs (antiplatelets, anticoagulants, antihypertensive drugs, and statins), laboratory findings, admission National Institutes of Health Stroke Scale (NIHSS) score, site of arterial occlusion, and time intervals.

MR image analysis

MR images were acquired routinely on a 1.5 T Avanto (Siemens, Erlangen, Germany). Additionally, the 3.0 T Tim Trio system (Siemens, Erlangen, Germany) was also infrequently available for emergency patients from the beginning of 2009. On the 1.5 T scanner, GRE sequences used 5 mm slice thickness with no gap (repetition time 800 ms; echo time 15 ms; field of view 240 mm; 30° flip angle; matrix size 256×144).[21] On the 3.0 T scanner, GRE sequences used 5 mm slice thickness with slice spacing 6 mm (repetition time 690 ms; echo time 20 ms; field of view 240 mm; 30° flip angle; matrix size 320×210).

The presence, burden, and distribution of CMBs were reviewed on the pretreatment GRE sequences, and recorded using the Microbleed Anatomic Rating Scale and consensus recommendations for neuroimaging standards.[1 2 22] CMBs were defined as punctate, homogeneous, round, hypointense lesions <10 mm in diameter. Mimic lesions were not considered to be CMBs; these included symmetrical hypointensities in the globi pallidi (probably calcification or iron deposition), flow voids from cortical vessels, partial volume artifact from bone, and cavernous malformations. CMBs were categorized as lobar (frontal, parietal, temporal, occipital, and insular), deep (basal ganglia, thalamus, internal or external capsule, corpus callosum, deep and periventricular white matter), and infratentorial regions (brainstem and cerebellum). The number of CMBs was categorized as follows: no CMBs, 1 CMB, 2–4 CMBs, and ≥5 CMBs.[1 11] CMBs were also categorized according to their locations as strictly lobar, strictly deep, strictly infratentorial, or mixed CMBs.

On axial FLAIR sequences, white matter hyperintensity (WMH) was determined for the deep white matter and the periventricular white matter using the Fazekas scale (0–3), as previously described.[18 23] Presence of overall WMH was defined as either deep WMH (Fazekas score ≥2) or periventricular WMH (Fazekas score 3). Two investigators who were blinded to the follow-up images and clinical data independently reviewed pretreatment MR images to determine the presence of CMBs and WMH.

Outcome

Final revascularization status was assessed with the use of the Thrombolysis in Cerebral Infarction (TICI) score on the angiograms after endovascular treatment; this ranges from 0 (no perfusion) to 3 (full perfusion). Successful revascularization was defined as TICI 2b–3.[20 24] CT or GRE MR images at 24 h (18–36) after thrombectomy were reviewed to assess HT and subarachnoid hemorrhage (SAH). HT was classified into hemorrhagic infarct and parenchymal hematoma (PH) using the European Cooperative Acute Stroke Study definition. Four categories of HT were defined as follows: hemorrhagic infarction type 1, small petechiae along the margins of the infarct; hemorrhagic infarction type 2, more confluent petechiae within the infarcted area, but without space-occupying effect; PH type 1, a hematoma in <30% of the infarcted area with some slight space-occupying effect; and PH type 2, a dense hematoma in >30% of the infarcted area with substantial space-occupying effect.[25]

Procedure-related adverse events were recorded as vessel perforation, vessel dissection, vasospasm, device fracture, and groin hematoma. Neurologic status was quantified by the modified Rankin Scale (mRS) score at discharge that ranges from 0 (no symptoms) to 5 (severe disability and bedridden) and 6 (death). Moderate clinical outcome at discharge was defined as mRS≤3.

Statistical analysis

We compared patient demographic, angiographic characteristics, intracranial hemorrhage, procedure-related complications, and clinical outcomes between patients with and without CMBs. Univariate analysis was performed using the two-sample t test or Mann–Whitney U test for continuous variables, and the Fisher exact test and χ^2 test for categorical variables. We analyzed the association of the presence, burden, and distribution of CMBs as well as CMBs coexisting with WMH with intracranial hemorrhage, in-hospital mortality, and outcome at discharge. The calculation of OR and 95% CIs was assessed in all tests. After adjustment for age, NIHSS score, hypertension, diabetes mellitus, atrial fibrillation, glucose, systolic blood pressure, and time to endovascular treatment >5 h, the associations of any CMBs with intracranial hemorrhage, in-hospital mortality, and outcome at discharge were further assessed in a multiple regression analysis. We used SPSS software, V.20 for the analysis.

RESULTS

Two hundred and sixty-three consecutive patients were treated with mechanical thrombectomy during the 10-year study period. MR scans or interpretable MR images were not acquired in 52 patients. Five patients were excluded from the study because they were transferred to another facility within 24 h after thrombectomy procedure and no outcome data could be obtained. A total of 206 patients were included in the study for analysis. One hundred and ninety-two patients had anterior circulation stroke, whereas 14 patients had vertebrobasilar occlusions. Mean age was 66.8±17.6 years and 119 (57.8%) were women. Mean presentation NIHSS score was 17.7±6.6 points. One hundred and sixty-one patients (78.2%) were treated primarily with a Merci Retriever, 27 patients (13.1%) with a primary Penumbra system, and 18 patients (8.7%) with a primary stent-retriever device. Intracranial angioplasty or stenting was used in 17 patients. Carotid artery stenting was performed in 16 patients. Eighty-five patients (41.3%) were given IV or IA tPA thrombolysis, including IV tPA in 69 patients (33.5%), IA tPA in 11 patients (5.3%), and IV combined with IA tPA in 5 patients (2.4%).

CMBs on pretreatment GRE MR images were identified in 37 patients (18.0%). Patients with CMBs were older than those without CMBs, more often had a history of diabetes mellitus, and had a more severe degree of WMH. There were no differences in other baseline characteristics (table 1). A total of 73 foci of microbleed were identified among patients with CMBs. The median number of CMBs was 1 (IQR 1–17). Twenty-three patients (11.2%) had 1 CMB, 13 patients (6.3%) had 2–4 CMBs, and only 1 patient (0.5%) had ≥5 CMBs. Strictly lobar CMBs were present in 12/37 patients (32.4%), strictly deep CMBs in 12 patients (32.4%), strictly infratentorial CMBs in 2 patients (5.4%), and mixed CMBs in 11 patients (29.7%). Half of the microbleed lesions (n=37) were located in lobar regions, whereas the other lesions were in either deep (n=28) or infratentorial (n=8) regions. The number and locations of CMBs are shown in online supplementary table S1. CMBs with ipsilateral vessel occlusion were presented in 23 patients. Interpretable

Table 1 Patient baseline characteristics

Characteristics	No CMBs (n=169)	CMBs (n=37)	p Value
Age, years	65 (18)	77 (14)	<0.001
Female sex	95 (56.2%)	24 (64.9%)	0.364
Baseline NIHSS, score	18 (7)	18 (5)	0.842
Cardioembolic stroke source	102 (60.4%)	26 (70.3%)	0.350
Systolic blood pressure, mm Hg	154 (31)	159 (27)	0.324
Diastolic blood pressure, mm Hg	82 (18)	82 (15)	0.935
Blood glucose, mg/dL	135 (51)	144 (47)	0.350
Medical history			
Hypertension	109 (64.5%)	26 (70.3%)	0.570
Diabetes mellitus	30 (17.8%)	13 (35.1%)	0.025
Dyslipidemia	54 (32.0%)	10 (27.0%)	0.695
Atrial fibrillation	66 (39.1%)	16 (43.2%)	0.712
Coronary artery disease	32 (18.9%)	11 (29.7%)	0.179
Previous stroke	29 (17.2%)	5 (13.5%)	0.807
Premorbid drugs			
Aspirin	44 (26.3%)	11 (29.7%)	0.685
Clopidogrel	11 (6.6%)	2 (5.4%)	1.000
Warfarin	25 (15.0%)	5 (13.5%)	1.000
Statins	44 (26.3%)	15 (40.5%)	0.108
Antihypertensive drugs	81 (48.5%)	21 (56.8%)	0.468
White matter hyperintensity	60 (35.9%)	22 (59.5%)	0.010
Most proximal occlusion site			
Internal carotid artery	53 (31.4%)	10 (27.0%)	0.696
Middle cerebral artery M1	91 (53.8%)	25 (67.6%)	0.146
Middle cerebral artery M2	12 (7.1%)	1 (2.7%)	0.471
Vertebrobasilar artery	13 (7.7%)	1 (2.7%)	0.473
Intravenous tPA failure	65 (38.5%)	9 (24.3%)	0.131
Intra-arterial lytic use	13 (7.7%)	3 (8.1%)	1.000
Mechanical thrombectomy			
Merci Retriever	131 (77.5%)	30 (81.1%)	0.826
Penumbra aspiration	24 (14.2%)	3 (8.1%)	0.426
Stent-retriever	14 (8.3%)	4 (10.8%)	0.538
Intracranial angioplasty or stenting	14 (8.3%)	3 (8.1%)	1.000
Carotid artery stenting	15 (8.9%)	1 (2.7%)	0.314

Data are represented as mean (SD) or number (percentage).
CMBs, cerebral microbleeds; NIHSS, National Institutes of Health Stroke Scale; tPA, tissue plasminogen activator.

pretreatment FLAIR MR images were obtained in 204 patients. Overall WMH was identified in 82 patients (40.2%), whereas 22 patients (10.8%) presented with CMBs coexisting with WMH.

The successful revascularization rates with TICI score 2b–3 were similar between patients with CMBs and those without CMBs (35.1% vs 38.5%). HT occurred in 44.2% patients (n=91), including hemorrhagic infarct in 25.2% (n=52) and PH in 18.9% (n=39). Patients with baseline CMBs had similar rates of either any HT (37.8% (14/37) vs 45.6% (77/169)) or any PH (16.2% (6/37) vs 19.5% (33/169)) when compared with those without CMBs. In the CMBs subgroup comparison by distribution (lobar, deep, or infratentorial) and number (1, 2–4, or ≥5), there was no difference in the rates of HT or PH between patients with any CMBs and those without. The associations of baseline CMBs with HT and PH are shown in table 2. Patients with CMBs had similar rates of either any PH-2 (5.4% (2/37) vs 7.1% (12/169)) or any SAH (18.9% (7/37) vs 21.3% (36/169)) when compared with those without CMBs. The associations of CMBs with PH-2 and SAH are shown in online supplementary table S2.

In-hospital mortality was 18.0% (n=37). The rate of in-hospital mortality was not significantly higher in patients with any CMBs (16.2% (6/37) vs 18.3% (31/169)). In the CMBs subgroup comparison by distribution (lobar, deep, or infratentorial) and number (1, 2–4, or ≥5), there was no difference in the rates of in-hospital mortality between patients with any CMB and those without CMB. Seventy-two patients (35.0%) had a moderate clinical outcome (mRS score 0–3) at discharge. There was no difference in the rates of moderate outcome at discharge between patients with any CMB and those without CMB. The associations of baseline CMBs with clinical outcomes are shown in table 3. Patients with HT and PH had greater in-hospital mortality and lower rates of moderate outcome at discharge. CMBs coexisting with any WMH or a number of CMBs ≥2 were not associated with hemorrhage and in-hospital mortality, although WMH alone significantly increased the risk of hemorrhage and in-hospital mortality.

The rate of procedure-related vessel perforation was not significantly different in patients with any CMBs compared with those without CMBs (5.4% vs 7.1%). The rates of other complications, including vessel dissection, vasospasm, device fracture, and groin hematoma were not significantly different in the two groups.

In a multiple regression analysis after adjustment for age, hypertension, diabetes mellitus, atrial fibrillation, NIHSS score, glucose, systolic blood pressure, and time to endovascular treatment >5 h, the presence of CMBs was not associated with overall HT and in-hospital mortality in patients treated with either thrombectomy or IV tPA followed by thrombectomy (table 4). CMBs were also not associated with PH and PH-2 in patients treated with mechanical thrombectomy.

DISCUSSION

This study with routine acquisition of MRI for acute stroke analyzes the use of mechanical thrombectomy in catheter angiography-confirmed large-vessel occlusions, focusing on the influence of baseline CMBs on hemorrhagic and procedural complications and mortality. CMBs are not uncommon in our cohort, as they were present in 18% of patients on pretreatment GRE MRI. In these patients with baseline CMBs, 97% (36/37) patients had <5 CMBs. Mechanical thrombectomy is a treatment option for severe stroke with large-vessel occlusions, especially if carried out after IV tPA administration.[14–16] Our study showed that mechanical thrombectomy was not more dangerous for patients with CMBs, and in one-third of patients treated with IV tPA followed by mechanical thrombectomy, baseline CMBs were not associated with an increased rate of bleeding and mortality. Our findings suggest that CMBs should not be an exclusion criterion for mechanical thrombectomy.

The relationship of baseline CMBs with intracranial hemorrhage after mechanical thrombectomy in our study is consistent with recent studies of thrombolysis for acute stroke. In a multicenter series of 570 patients with acute stroke, the rate of baseline CMBs was 15.1%, and six patients (1.1%) had ≥5 CMBs. Symptomatic HT after IV tPA occurred in 5.8% of patients with CMBs and 2.7% of patients without CMBs.[9] In another series of 392 patients with acute stroke, the rate of CMBs was 20.2%, and nine patients (2.3%) had ≥5 CMBs. There was no association between the CMB burden and bleeding risk after different revascularization procedures.[10] In a series of 326 patients with acute stroke treated with IV tPA, similar rates of any CMBs (24.8%) and multiple (≥5) CMBs (3.1%) were found. However, patients with multiple CMBs had an increased post-thrombolytic bleeding risk.[11] The negative effect of a small

Table 2 Association of cerebral microbleeds with hemorrhage after thrombectomy

Characteristics	Comparison of HT			Comparison of PH		
	No HT (n=115)	HT (n=91)	p Value	No PH (n=167)	PH (n=39)	p Value
Age, years	64 (18)	70 (17)	0.023	66 (18)	70 (18)	0.173
Female sex, %	73 (63.5)	46 (50.5)	0.067	99 (59.3)	20 (51.3)	0.374
NIHSS, score	17 (7)	19 (6)	0.093	17 (7)	20 (6)	0.007
Glucose, mg/dL	116 (70–417)	128 (80–414)	0.036	120 (70–417)	134 (89–238)	0.075
Any CMBs, %	23 (20.0)	14 (15.4)	0.466	31 (18.6)	6 (15.4)	0.818
CMBs distribution						
Strictly lobar, %	7 (6.1)	5 (5.5)	1.000	10 (6.0)	2 (5.1)	1.000
Strictly deep, %	8 (7.0)	4 (4.4)	0.555	10 (6.0)	2 (5.1)	1.000
Strictly infratentorial, %	1 (0.9)	1 (1.1)	1.000	2 (1.2)	0 (0.0)	1.000
Mixed, %	7 (6.1)	4 (4.4)	0.758	9 (5.4)	2 (5.1)	1.000
CMBs number, %						
1	13 (11.3)	10 (11.0)	1.000	19 (11.4)	4 (10.3)	1.000
2–4	10 (8.7)	3 (3.3)	0.152	11 (6.6)	2 (5.1)	1.000
≥5	0 (0.0)	1/91 (1.1)	0.442	1 (0.6)	0/39 (0.0)	1.000
CMBs coexisting with WMH, %						
Overall WMH	37 (32.5)	45 (50.0)	0.014	60 (36.4)	22 (56.4)	0.029
CMBs and overall WMH	14 (12.3)	8 (8.9)	0.501	18 (10.9)	4 (10.3)	1.000
CMBs and deep WMH	9 (7.9)	5 (5.6)	0.586	10 (6.1)	4 (10.3)	0.313
CMBs ≥2 and overall WMH	4 (3.5)	1 (1.1)	0.386	4 (2.4)	1 (2.6)	1.000

Data are represented as mean (SD), median (IQR) or number (percentage). HTs were categorized as hemorrhagic infarction or parenchymal hematoma according to the European Cooperative Acute Stroke Study definition.
CMBs, cerebral microbleeds; HT, hemorrhagic transformation; NIHSS, National Institutes of Health Stroke Scale; PH, parenchymal hematoma; WMH, white matter hyperintensity.

number of CMBs on the intracranial bleeding risk is also supported by a study of intracranial and extracranial stenting for 133 patients with symptomatic large artery atherosclerosis.[26] These results suggest that a small number of CMBs does not increase the risk of intracranial hemorrhage after IV thrombolysis, mechanical thrombectomy, and intracranial stenting.

Data for the predictive value of CMBs on mortality are limited, particularly with respect to revascularization therapy. Our study provides new data showing that baseline CMBs do not increase the risk of in-hospital mortality after mechanical thrombectomy. In a recent study, CMBs were associated with an increased risk of mortality for patients with stroke and nonvalvular atrial fibrillation, and multiple CMBs predicted the risk of all-cause mortality.[7] Multiple CMBs were also associated with increased mortality in a memory disorders clinical population.[6] Our data suggest that neither the presence nor the number of

Table 3 Association of cerebral microbleeds with outcomes after thrombectomy

Characteristics	Modified Rankin Scale 0–3			In-hospital mortality		
	No (n=134)	Yes (n=72)	p Value	No (n=169)	Yes (n=37)	p Value
Age, years	70 (17)	62 (19)	0.003	65 (18)	77 (12)	<0.001
Female sex, %	68 (50.7)	51 (70.8)	0.008	105 (62.1)	14 (37.8)	0.010
NIHSS, score	20 (6)	14 (7)	<0.001	17 (7)	22 (6)	<0.001
Glucose, mg/dL	128 (70–417)	113 (86–279)	0.001	117 (70–417)	146 (97–321)	<0.001
Any CMBs, %	25 (18.7)	12 (16.7)	0.850	31 (18.3)	6 (16.2)	1.000
CMBs distribution						
Strictly lobar, %	8 (6.0)	4 (5.6)	1.000	10 (5.9)	2 (5.4)	1.000
Strictly deep, %	10 (7.5)	2 (2.8)	0.222	11 (6.5)	1 (2.7)	0.698
Strictly infratentorial, %	2 (1.5)	0 (0.0)	0.543	1 (0.6)	1 (2.7)	0.328
Mixed, %	5 (3.7)	6 (8.3)	0.198	9 (5.3)	2 (5.4)	1.000
CMBs number, %						
1	18 (13.4)	5 (6.9)	0.245	19 (11.2)	4 (10.8)	1.000
2–4	7 (5.2)	6 (8.3)	0.384	11 (6.5)	2 (5.4)	1.000
≥5	0 (0.0)	1 (1.4)	0.350	1 (0.6)	0 (0.0)	1.000
CMBs coexisting with WMH, %						
Overall WMH	62 (47.0)	20 (27.8)	0.011	58 (34.7)	24 (64.9)	0.001
CMBs and overall WMH	16 (12.1)	6 (8.3)	0.484	19 (11.4)	3 (8.1)	0.772
CMBs and deep WMH	11 (8.3)	3 (4.2)	0.387	11 (6.6)	3 (8.1)	0.722
CMBs ≥2 and overall WMH	4 (3.0)	1 (1.4)	0.658	4 (2.4)	1 (2.7)	1.000

Data are represented as mean (SD), median (IQR) or number (percentage).
CMBs, cerebral microbleeds; NIHSS, National Institutes of Health Stroke Scale; WMH, white matter hyperintensity.

Table 4 Multivariate analysis for association of cerebral microbleeds with hemorrhage and outcomes after thrombectomy

	Overall thrombectomy (n=206)		Thrombectomy and IV tPA (n=74)		Thrombectomy without IV tPA (n=132)	
	Any CMBs, OR (95% CI)	p Value	Any CMBs, OR (95% CI)	p Value	Any CMBs, OR (95% CI)	p Value
HT	0.64 (0.27 to 1.50)	0.302	1.26 (0.25 to 6.25)	0.777	0.44 (0.15 to 1.30)	0.138
SAH	0.94 (0.34 to 2.60)	0.906	1.43 (0.26 to 7.98)	0.681	0.81 (0.20 to 3.31)	0.764
mRS 0–3, at discharge	0.98 (0.38 to 2.53)	0.960	1.03 (0.14 to 7.50)	0.978	1.19 (0.38 to 3.73)	0.766
In-hospital mortality	0.57 (0.17 to 1.84)	0.343	–	0.999	0.91 (0.24 to 3.49)	0.892

CMBs, cerebral microbleeds; HT, hemorrhagic transformation; IV, intravenous; mRS, modified Rankin Scale; SAH, subarachnoid hemorrhage; tPA, tissue plasminogen activator.

CMBs predicts the risk of in-hospital mortality after mechanical thrombectomy. This conflicting result may be related to fewer patients having multiple CMBs in our cohort.

The location of CMBs may be related to different underlying pathologic processes. Strictly lobar CMBs indicate cerebral amyloid angiopathy, whereas deep or infratentorial CMBs suggest hypertensive or atherosclerotic microangiopathy.[2] Lobar CMBs have been shown to be associated with an increased risk of subsequent intracerebral hemorrhage.[4] In an elderly population, lobar CMBs predicted the risk of stroke-related mortality, whereas non-lobar CMBs were associated with increased cardiovascular-related mortality.[5] In patients with stroke with non-valvular atrial fibrillation, strictly lobar CMBs were also associated with hemorrhagic stroke mortality.[7] However, our data did not show an association between CMBs and intracranial hemorrhage or in-hospital mortality after mechanical thrombectomy, regardless of the location of the CMBs. Together with the lack of association between CMBs and endovascular procedure-related complications, our findings provide new evidence that mechanical thrombectomy is a safe treatment for large-vessel occlusion strokes even in the presence of several CMBs.

Our study underscores that WMH clearly increases the risk of hemorrhage and in-hospital mortality after mechanical thrombectomy. However, this association was not found in patients with CMBs coexisting with WMH. Evidence suggests that the development of cerebral small-vessel disease is attributable to endothelial dysfunction and blood–brain barrier (BBB) disruption.[27] Reperfusion injury and further BBB disruption may contribute to hemorrhage after revascularization therapy. Although the focal deposition of hemosiderin implies red blood cell extravasation caused by BBB disruption, these CMBs did not translate into intracerebral hemorrhage after endovascular intervention therapy. Whether the extent and degree of BBB dysfunction in WMH are more severe than those in CMBs is not known.

Our study has limitations, including a relatively small sample size, although these data are unique owing to the routine acquisition of MRI before reperfusion at our center. Susceptibility-weighted imaging sequences on a 3.0 T MR scanner have better sensitivity and reliability than GRE sequences for detection of CMBs,[28] yet our study provides practical data from routinely used sequences. In our cohort, CMBs were identified on GRE sequences, but additional CMBs may be detected on susceptibility-weighted imaging sequences. We cannot exclude the possibility that multiple CMBs may increase the risk of hemorrhage and mortality after thrombectomy. We also did not compare CMBs with symptomatic HT. The impact of baseline CMBs on cognitive impairment and 3-month clinical outcome was not investigated in this analysis, extending the possibility that other neurological manifestations may be considered.

CONCLUSIONS

Our findings show that a small number of baseline CMBs (<5) does not increase the risk for intracranial hemorrhage, procedural complications, or in-hospital mortality in patients with large-vessel occlusion strokes treated with either mechanical thrombectomy or IV tPA followed by mechanical thrombectomy. Excluding such patients from acute interventional stroke treatment is unwarranted. The risk of HT in patients with ≥5 CMBs requires further study.

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