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Received, August 30, 2017.
Accepted, March 6, 2018.
Published Online, June 20, 2018.

Comparative Safety and Efficacy of Modified TICI 2b and TICI 3 Reperfusion in Acute Ischemic Strokes Treated With Mechanical Thrombectomy

BACKGROUND: Mechanical thrombectomy (MT) is the current standard of care for acute ischemic stroke (AIS) patients with emergent large-vessel occlusions (ELVO). Successful reperfusion of ELVO is traditionally defined by modified Thrombolysis in Cerebral Infarction (mTICI) grades of 2b or 3.

OBJECTIVE: To evaluate the comparative safety and efficacy of mTICI 2b and mTICI 3 reperfusion in AIS patients treated with MT.

METHODS: Consecutive ELVO patients who underwent MT at 6 high-volume centers were included in this analysis. Standard safety (3-mo mortality, symptomatic intracranial hemorrhage [sICH]) and efficacy (absolute and relative reduction in NIHSS-scores during hospitalization, functional-improvement [shift analysis in mRS-scores], and functional-independence [mRS-scores of 0-2] at 3-mo) were compared between patients who had mTICI 2b and mTICI 3 reperfusion post MT.

RESULTS: A total of 416 ELVO patients achieved successful reperfusion with mTICI 2b (n = 216) and mTICI 3 (n = 200) following MT. The mTICI 3 group had significantly ($P < .05$) greater absolute (11 vs 9 points) and relative (77% vs 63%) reduction in NIHSS-scores during hospitalization, lower sICH (6% vs 12%), and higher 3-mo functional-independence (55% vs 44%) rates. Successful reperfusion with mTICI 3 was independently ($P < .05$) associated with greater absolute and relative reduction in NIHSS-scores during hospitalization as well as higher odds of 3-mo functional improvement (common odds ratios: 1.67; 95% confidence interval: 1.10-2.56) and functional independence (odds ratio: 2.08; 95% confidence interval: 1.22-3.53) in multivariable regression models adjusting for confounders.

CONCLUSION: Successful reperfusion with mTICI 3 was associated with greater neurological improvement during hospitalization and better 3-mo functional outcomes in comparison to mTICI 2b reperfusion.

KEY WORDS: Outcome, Modified TICI2b reperfusion, Modified TICI3 reperfusion, Mechanical thrombectomy, Emergent large vessel occlusion, Stroke

Neurosurgery 84:680–686, 2019 DOI:10.1093/neuros/nyy097 www.neurosurgery-online.com

Recent randomized-controlled clinical trial (RCT) data have overwhelmingly established mechanical thrombectomy (MT) as the current standard of care for acute ischemic stroke (AIS) patients with emergent large-vessel occlusions (ELVO).[1] Successful reperfusion post MT is the strongest modifiable predictor of patient outcomes, and higher reperfusion rates are associated with improved functional outcomes at 3 mo.[2,3] Over the past 15 yr, successful reperfusion rates post MT have improved from 40% to 50% with older

ABBREVIATIONS: ADAPT, a direct aspiration first pass technique; **AIS,** acute ischemic stroke; **ASPECTS,** Alberta Stroke Program Early CT score; **CI,** confidence intervals; **cOR,** common odds ratios; **CT,** computed tomography; **ELVO,** emergent large-vessel occlusions; **ICA,** internal carotid artery; **MRI,** magnetic resonance imagining; **mRS,** modified Rankin scale; **MT,** mechanical thrombectomy; **mTICI,** Modified Thrombolysis In Cerebral Infarction; **NIHSS,** national institute of health stroke scale; **OR,** odds ratios; **RCT,** randomized-controlled clinical trial; **sICH,** symptomatic intracranial hemorrhage; **tPA,** tissue plasminogen activator; **ULRC,** unstandardized linear regression coefficients

thrombectomy devices to 80% to 90% with latest devices such as stent-retrievers or aspiration catheters.[4]

The degree of reperfusion following MT is currently and standardly assessed using the Modified Thrombolysis In Cerebral Infarction (mTICI) grades.[5] Successful reperfusion was graded as mTICI 2b or 3 grades in all recent RCTs of MT.[1] Recent small, retrospective studies have provided preliminary evidence indicating that successful reperfusion with mTICI 2b grade may be associated with adverse outcomes when compared to successful reperfusion with mTICI 3 grade.[6,7] In view of the former considerations, we conducted a multicenter study that sought to evaluate the comparative safety and efficacy of successful reperfusion following MT with mTICI 2b and 3 grades in patients with ELVO.

METHODS

Study Population

Data on consecutive AIS patients with ELVO who underwent MT were prospectively collected at 6 high-volume endovascular centers during a 2-yr period (May 2013-May 2015) as previously reported.[8] The study was approved by the institutional review boards of the participating centers and the boards waived the need for patient consent. Baseline characteristics included age, sex, admission NIHSS-scores, and pretreatment with intravenous tissue plasminogen activator (tPA). Procedural details included onset-to-groin puncture time, degree of successful reperfusion using mTICI grades, location of occlusion (classified as proximal anterior circulation occlusions, distal in anterior circulation occlusions, tandem anterior circulation occlusions, and posterior circulation occlusions), and type of device used during MT (stent-retriever, direct aspiration using the ADAPT technique, combination of both).[8,9] Proximal anterior circulation occlusions included internal carotid artery (ICA) and M1 middle cerebral artery (MCA) occlusions, while M2 and M3 MCA occlusions were included in distal anterior circulation occlusions. The mTICI grade 0 is defined as no distal flow, grade 1 as anterograde reperfusion past the initial occlusion but limited distal branch filling with little or slow distal perfusion, grade 2a as anterograde reperfusion of less than half of the previously occluded target artery ischemic territory, grade 2b as anterograde reperfusion of more than half of the previously occluded target artery ischemic territory, and grade 3 as complete anterograde reperfusion of the previously occluded target artery ischemic territory. mTICI reperfusion grades were obtained from the reports of endovascular specialists participating in our study (total of 11 readers).[5] All patients with mTICI grades of 0, 1, and 2a were excluded from the present analyses. Data regarding number of passes during MT were obtained retrospectively through chart review, and this information was available only in one of the participating centers (n = 70). Similarly, data regarding baseline ASPECTS (Alberta Stroke Program Early Computed Tomography [CT] score) on CT head and collaterals pattern on CT angiogram were obtained retrospectively through chart review, and this information was available only from one center (n = 70).

Outcomes

The following safety outcomes were recorded as previously described[8,9]: (i) symptomatic intracranial hemorrhage (sICH), defined as presence of a parenchymal hematoma type 2 on brain CT and/or magnetic resonance imagining (MRI) gradient recall echo sequence, accounting for deterioration with an increase in NIHSS-score of $\geq$4 points within 36 h from treatment;[10] (ii) other serious complications during the procedure (ie, vessel dissection/perforation, vasospasm, or groin hematoma); and (iii) 3-mo mortality.

The following efficacy outcomes were assessed as previously described[8,9,11,12]: (i) 3-mo functional independence, defined as a modified Rankin scale (mRS) score of 0 to 2; (ii) 3-mo functional improvement defined as a 1-point decrease in 3-mo mRS-scores (shift analysis); and (iii) neurological improvement during hospitalization, quantified as the absolute and relative decrease in NIHSS-scores during hospitalization. More specifically, the absolute decrease in NIHSS-scores was computed as $NIHSS_{adm}$-$NIHSS_{dis}$, while the relative decrease in NIHSS-scores was calculated as [($NIHSS_{adm}$-$NIHSS_{dis}$) × 100]/$NIHSS_{adm}$. The assessments of serial NIHSS and mRS scores were performed by certified vascular neurologists who were unaware of mTICI grades that were independently scored during the procedure by endovascular specialists. Endovascular specialist and/or certified vascular neurologist from participating centers, who were unaware of the present study purpose, assessed the occurrence and degree of adverse events following MT. Adverse events were then recorded in individual endovascular databases of participating centers.

Statistical Analyses

Statistical comparisons between patient subgroups were performed using the χ^2-test or Fisher's exact test for dichotomous variables, while the independent Student *t*-test or Mann–Whitney *U*-test were used for continuous variables. The Cochran–Mantel–Haenszel test was used to compare the distribution on the mRS-score at 3 mo between the 2 subgroups. Univariable and multivariable binary logistic regression models were used to evaluate associations between degree of successful reperfusion (mTICI 3 vs mTICI 2b) with 3-mo mortality, sICH and 3-mo functional independence before and after adjusting for baseline characteristics (age, sex, admission NIHSS-score, pretreatment with iv-tPA) and procedural details (onset to groin puncture time, location of occlusion, and type of device used). A cut off of $P < .1$ was used to select variables for multivariable analysis. Associations are presented as odds ratios (OR) with corresponding 95% confidence intervals (CI). A *P*-value of $\leq$.05 in multivariable analyses was considered statistically significant.

Univariable and multivariable ordinal logistic regression analyses (shift analysis) were used to evaluate associations between degree of successful reperfusion (mTICI 3 vs mTICI 2b) with 3-mo functional improvement before and after adjusting for baseline characteristics and procedural details. A cut off of $P < .1$ was used to select variables for multivariable analysis. Associations are presented as common odds ratios (cOR) with corresponding 95% CI. Statistical significance was achieved if the *P*-value was $\leq$ .05 in multivariable analyses. Simple and multiple linear regression analyses were used to evaluate associations between degree of successful reperfusion (mTICI 3 vs mTICI 2b) with absolute and relative reduction in NIHSS-scores during hospitalization before and after adjusting for baseline characteristics and procedural details. A cut off of $P < .1$ was used to select variables for multiple linear regression models. Associations are presented as unstandardized linear regression coefficients (ULRC) with corresponding 95% CI. A *P*-value of $\leq$ .05 in multiple linear regression models was considered significant. The Statistical Package for Social Science (SPSS version 11.5 for Windows; IBM Inc, Armonk, New York) was used for statistical analyses.

RESULTS

Our study population consisted of 583 patients with ELVO who underwent MT. A total of 167 patients were excluded because of unsuccessful reperfusion (mTICI 0, 1, and 2a). Successful reperfusion (mTICI 2b or 3) following MT was achieved in 416 patients. mTICI 2b reperfusion was achieved in 216 (52%) patients (mean age 62 ± 18 yr, men 50%, median admission NIHSS-score: 17 [IQR: 12-22]), while 200 patients (48%) had mTICI 3 reperfusion post MT (mean age 65 ± 16 yr, men 52%, median admission NIHSS-score: 17 [IQR: 13-21]).

Baseline characteristics, safety, and efficacy outcomes of the 2 groups are presented in Table 1. The 2 groups differed with regard to the baseline characteristics only in ELVO location. In particular, the mTICI3 group had fewer patients with proximal anterior circulation (ICA or M1 MCA) occlusions (56% vs 67%) and more patients with posterior circulation (basilar artery or vertebral artery) occlusions (17% vs 8%) compared to mTICI2b group. The mTICI 3 reperfusion group had significantly ($P < .05$) lower median discharge NIHSS-scores, lower rates of sICH (6% vs 12%), greater neurological improvement during hospitalization quantified as absolute (median reduction: 11 points [IQR: 6-16] vs median reduction: 9 points [IQR: 4-14]) and relative (median reduction: 77% [IQR: 49-95] vs median reduction: 63% [IQR: 28-89]) reduction in NIHSS-scores, and higher rates of 3-mo functional independence (55% vs 44%) compared to mTICI 2b reperfusion group. The median groin puncture to recanalization time tended to be longer in the TICI 2b group (43 min [IQR: 24-64] vs 37 min [IQR: 24-55]; $P = .062$). The mTICI 3 group tended to achieve lower 3-mo mRS-scores (median: 2 [IQR: 1-4] vs median: 3 [IQR:1-5]; $P = .064$; Figure). The mTICI2b and mTICI3 groups did not differ in the median (IQR) number of passes during MT (2[1-2] vs 2[1-2], respectively; $P = .562$]; however, this information was available only in 1 center representing a small subgroup of ELVO patients (n = 70). The mTICI2b and mTICI3 groups did not differ in terms of median baseline ASPECTS (9 [IQR: 8-10] vs 9 [IQR: 9-10], respectively; $P = .608$), and prevalence of good collateral

TABLE 1. Baseline Characteristics and Outcomes (Efficacy and Safety) of the Study Population Stratified According to Degree of Successful Recanalization (mTICI 2b vs mTICI3) at the End of MT

Variable	mTICI 2b recanalization (n = 216)	mTICI3 recanalization (n = 200)	P
Baseline characteristic			
Mean age (yr, SD)	62 (18)	65 (16)	.076
Female sex, n (%)	109 (50)	95 (48)	.546
Median admission NIHSS-score, points (IQR)	17 (12-22)	17 (13-21)	.585
Location of occlusion, n (%)			.017
—Proximal anterior circulation	145 (68)	112 (56)	
—Distal anterior circulation	26 (12)	21 (11)	
—Tandem occlusion	28 (13)	33 (17)	
—Posterior circulation	17 (8)	34 (17)	
Pretreatment with intravenous thrombolysis, n (%)	107 (50)	109 (55)	.373
Types of device used, n (%)			.942
Stent-retrivers	69 (32)	60 (30)	
ADAPT	37 (17)	36 (18)	
Combination of stent-retrievers and aspiration	110 (51)	104 (52)	
Median onset to groin puncture time, min (IQR)	224 (164-336)	240 (173-346)	.428
Efficacy outcomes			
Median groin puncture to recanalization time, min (IQR)	43 (24-64)	37 (24-55)	.062
Discharge NIHSS	5 (2-12)	3 (1-8)	.010
Absolute reduction in NIHSS during hospitalization	9 (4-14)	11 (6-16)	.003
Relative reduction in NIHSS during hospitalization	63 (28-89)	77 (49-95)	.006
mRS at 3 mo, median (IQR)	3 (1-5)	2 (1-4)	.064
mRS 0-2 at 3 mo, n (%)[a]	84 (44%)	101 (55%)	.040
Safety outcome			
Symptomatic intracranial hemorrhage, n (%)	25 (12%)	11 (6%)	.028
Other serious complications,[b] n (%)	13 (6%)	6 (3%)	.173
3 mo mortality,[f] n (%)	42 (22)	35 (19)	.461

[a]Three-month functional outcome was available in 376 patients. There were 40 cases with missing 3-mo follow-up data.
[b]Other complications including transient vasospasm, groin hematoma, vessel dissection, and/or perforation.
[f]Three-month mortality data was available in 376 patients. There were 40 cases with missing 3-mo mortality data.

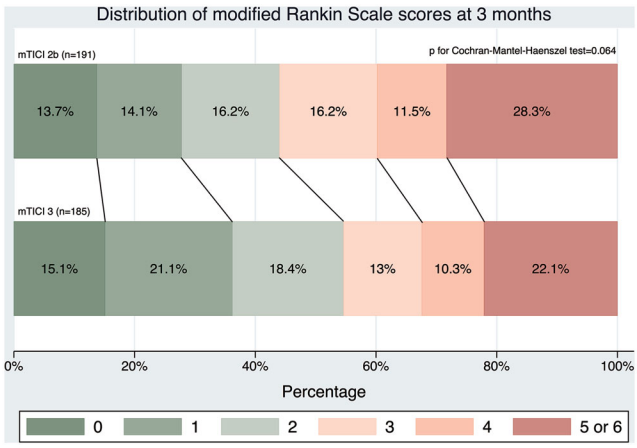

FIGURE. *Distribution of mRS scores at 3 mo stratified by complete reperfusion status (mTICI 3 vs mTICI 2b). Statistical comparisons were performed using Cochran–Mantel–Haenszel (CMH) test.*

pattern (69.6% vs 72.3%, respectively; $P > .999$). However, this information was available only in one center representing a small subgroup of ELVO patients (n = 70).

We also conducted sensitivity analyses evaluating the association of the degree of successful reperfusion with outcomes stratified by ELVO location (anterior vs posterior). The mTICI 3 reperfusion group in the posterior circulation (n = 51) tended to have lower 3-mo mortality rates (39% vs 69%; $P = .051$) and higher 3-mo functional independence rates (45% vs 19%; $P = .111$ by Fisher's exact test). The rates of sICH were similar in mTICI 3 and mTICI 2b groups in posterior circulation occlusion (3% vs 0%; $P > .999$ by Fisher's exact test). The mTICI 3 reperfusion group in the anterior circulation (n = 365) had lower sICH rates (6% vs 13%; $P = .037$) and tended to have higher rates of 3-mo functional independence (57% vs 46%; $P = .065$). The rates of 3-mo mortality were similar in mTICI 3 and mTICI 2b groups in anterior circulation occlusion (15% vs 18%; $P = .497$).

Table 2 summarizes the results of all multivariable analyses evaluating the associations of mTICI 3 successful reperfusion with safety and efficacy outcomes after adjustment for potential confounders. Successful reperfusion with mTICI 3 was independently ($P < .05$) associated with greater absolute (ULRC: 2 points 2 [95% CI: 1-4]) and relative (ULRC: 12% [95% CI: 2-23]) reduction in NIHSS-scores during hospitalization as well as higher odds of 3-mo functional improvement (cOR: 1.67; 95% CI: 1.10-2.56) and functional independence (OR: 2.08; 95% CI: 1.22-3.53). The relationships of mTICI 3 successful reperfusion with groin puncture to recanalization time and sICH did not reach statistical significance in multivariable analyses.

DISCUSSION

This retrospective multicenter study indicates that achieving mTICI 3 reperfusion following MT in ELVO patients is associated with greater neurological improvement during hospitalization and better 3-mo functional outcomes compared with mTICI2b reperfusion. This association is independent of demographics, baseline stroke severity; location of occlusion, pretreatment with iv-tPA, onset to groin-puncture time, and type of device used during the procedure.

To date, this is the largest multicenter study comparing outcome differences between mTICI2b or 3 reperfusion groups post MT. Our observations are in line with another recent study demonstrating improved functional outcomes and lower sICH rates with mTICI3 reperfusion.[7] However, our study included a larger sample (416 vs 222) of ELVO patients with anterior and posterior circulation occlusions in contrast to the French study that evaluated only patients with anterior circulation occlusions. The findings of an additional retrospective study evaluating consecutive isolated MCA occlusions and reporting independent associations between mTICI 3 reperfusion and greater neurological improvement during hospitalization as well as shorter duration of hospitalization lend further support to our observations.[6] Unlike our study, however, that study was unable to determine whether neurological improvement during hospitalization translated into functional improvement 3 mo.

A recent individual patient data meta-analysis of 5 RCTs demonstrated that 46% of patients in the MT arm achieved mRS scores of 0 to 2 at 3 mo.[1] Despite the efficacy of the treatment for some patients, a large numbers of patients are still disabled at 3 mo despite MT. Therefore, it is critical to focus on modifiable variables that might improve outcomes after MT. The present analysis of this large dataset demonstrates that the rate of functional independence at 3 mo can be improved to 55% with complete reperfusion compared to 44% with mTICI2b reperfusion. Since successful reperfusion is the single most important modifiable predictor of favorable functional outcome, this begs the question of whether or not there is a benefit to "complete" reperfusion (mTICI 3) instead of settling for "near complete" reperfusion (mTICI2b)? Continued advancements in technology and technique may allow interventionalists to avoid periprocedural thrombus fragmentation and migration into distal vessels that could contribute to incomplete reperfusion.[4,13]

On the other hand it should be kept in mind that once mTICI 2b reperfusion is achieved, the possible benefits of continued efforts to achieve mTICI 3 reperfusion should be weighed against the risk of distal vessel injury such as perforation or dissection. Moreover, the additional time spent to achieve complete reperfusion may be detrimental, since shorter time to reperfusion has been shown to predict favorable outcomes.[1] In the present study, the rate of serious procedural complications was similar in the two groups. The total procedural time was not significantly different in these 2 groups but we do not have data regarding the number of passes taken in each case from all the centers number of passes taken in each case from all the centers. Location of residual clot in the cerebral circulation and territory of brain affected by the residual clot were the 2 important factors considered by the

TABLE 2. Multivariable Analyses (Binary Logistic Regression, Ordinal Logistic Regression, and Linear Regression) Evaluating the Association of the Degree of Recanalization (mTICI 3 vs mTICI 2b) at the End of MT With Safety and Efficacy Outcomes

Outcome	Multivariable analyses		*P*
	Variables included in the final model	Associations	
Time from groin puncture to recanalization (min)	1. Degree of complete recanalization	ULRC (95% CI)[a]: –22 (–45 to 2)	.069
	2. Location of occlusion		
NIHSS discharge (points)	1. Degree of complete recanalization	ULRC (95% CI)[a]: –2 (–4 to –1)	.004
	2. Time from groin puncture to recanalization		
	3. Age		
	4. Admission NIHSS-score		
Absolute NIHSS reduction during hospitalization (points)	1. Degree of complete recanalization	ULRC (95% CI)[a]: 2 (1 to 4)	.005
	2. Time from groin puncture to recanalization		
	3. Admission NIHSS-score		
Relative NIHSS reduction during hospitalization (%)	1. Degree of complete recanalization	ULRC (95% CI)[a]: 12 (2 to 23)	.024
	2. Time from groin puncture to recanalization		
	3. Age		
mRS 0 to 2 at 3 mo	1. Degree of complete recanalization	OR (95% CI)[b]: 2.08 (1.22 to 3.53)	.007
	2. Time from groin puncture to recanalization		
	3. Age		
	4. Admission NIHSS-score		
	5. Pretreatment with intravenous thrombolysis		
	6. Location of occlusion		
Functional improvement at 3 mo	1. Degree of complete recanalization	cOR (95% CI)[c]: 1.67 (1.10 to 2.56)	
	2. Time from groin puncture to recanalization		
	3. Age		
	4. Admission NIHSS-score		
	5. Pretreatment with intravenous thrombolysis		
	6. Location of occlusion		
sICH	1. Degree of complete recanalization	OR (95% CI)[b]: 0.51 (0.23 to 1.14)	.101
	2. Time from groin puncture to recanalization		
	3. Age		

ULRC, unstandardized linear regression coefficient; CI, confidence intervals; OR, odds ratio; cOR, commons odds ratio
[a]Multiple linear regression analyses.
[b]Multivariable binary logistic regression.
[c]Multivariable ordinal logistic regression.
Relative NIHSS reduction during hospitalization was calculated as follows: [(Admission NIHSS – Discharge NIHSS) × 100]/Admission NIHSS.
Functional improvement at 3 mo was defined by 1-point reduction in 3-mo mRS score (shift analysis).

interventionalists when considering further attempts. If the residual clot was located in more distal branches such as distal M3/M4 of MCA, further attempts were avoided considering the risks of vessel dissection and perforation. Similarly, attempts were made to clear the residual clot safely if it was affecting an eloquent brain territory. One of our study limitations is related to the unavailable information on the number of cases where interventionalists made further attempts from already achieved mTICI 2b reperfusion to reach mTICI3. A number of explanations can be provided for achieving different reperfusion grades (mTICI 2b vs mTICI 3) after MT. First, residual small clots in distal branches can lead to mTICI 2b reperfusion compared to complete (mTICI 3) reperfusion. Alternatively, differences in collaterals pattern and/or ASPECTS score on initial imaging may contribute. It's possible that the patients with good ASPECTS score on initial imaging are more likely to achieve mTICI3 reperfusion post MT. Although we did not document any differences in ASPECTS score and collaterals pattern between mTICI2b and mTICI3 groups, this information was not available from all participating centers. This represents a limitation of the

present study since the lack of association may be attributed to type II error due to limited sample size (n = 70) in this sub-analysis.

Limitations

Several other limitations of the present report must be acknowledged. First, this was an observational study with self-reported safety and efficacy outcomes lacking central adjudication of digital subtraction angiography images. Second, the methods used for MT and specific devices were heterogeneous and were selected according to the treating physicians' preference. Third, 3-mo functional outcomes were available in 90% of our study population. Fourth, although we did not document any difference in number of passes between mTICI2b and mTICI3 groups, this information was not available during MT from all participating centers. This represents a major limitation of the present study since the lack of association may be attributed to type II error due to limited sample size (n = 70) in this sub-analysis. This information is clinically relevant considering that a recent study showed that first pass mTICI3 reperfusion is associated with better outcomes compared to multipasses mTICI3 reperfusion.[14] Fifth, we did not collect information on asymptomatic ICH in our database, which could be a complication when efforts are made to reach mTICI3 reperfusion from already achieved mTICI2b reperfusion, and could lead to minor deficits. Sixth, the final infarct volume following MT was not prospectively documented because of the lack of standardized follow-up neuroimaging protocol post MT across participating centers. Moreover, our reperfusion scale did not include the recently proposed mTICI 2c grade, which is defined as near complete perfusion except for slow flow in a few distal cortical vessels, or presence of small distal cortical emboli.[15] Its unknown if inclusion of the mTICI2c grade instead of mTICI2b in successful reperfusion category will make any difference in reported outcomes. Last and most important, we documented that the mTICI2b group differed from mTICI3 group in terms of numbers of patients in proximal anterior circulation and posterior circulation occlusions in univariable analysis. Although the location of occlusion was included as a potential confounder in our multivariable regression models, this imbalance in baseline characteristics may be a source of unmeasured selection bias.

Strengths

While these are significant limitations, the present study also has some strengths that should be recognized. This is a large and inclusive sample of ELVO patients, which allows for multivariable analyses adjusting for numerous confounders, and the results from this highly experienced multicenter collaborative group, reflects everyday clinical practice experience.

CONCLUSION

Our preliminary data show that mTICI 3 reperfusion is associated with better early outcomes in comparison to mTICI 2b reperfusion in ELVO patients treated with MT. Our findings require confirmation from prospectively collected, independently adjudicated data set. These findings indicate that future thrombectomy RCTs should differentiate between these two reperfusion groups in terms of safety and efficacy outcomes. Should our findings be externally validated by independent investigators using a more robust methodological approach, then successful reperfusion with mTICI3 should represent the future standard of care in everyday clinical practice of MT for AIS.

Disclosures

Dr Frei is a consultant for Codman, MicroVention, Penumbra, and Stryker; is a member of the speaker's bureaus for Codman, MicroVention, Penumbra, and Stryker; and is a stock shareholder of Penumbra. Dr Turk is a consultant for Medtronic, Penumbra, MicroVention, and Stryker and has received research grants from Medtronic, Penumbra, MicroVention, and Stryker. Dr Baxter serves on the speakers' bureaus of Medtronic, Penumbra, Pulsar, Silk Road, and Stryker. Dr Froehler is a consultant for Blockade Medical and Medtronic and has received grant funding from Medtronic, MicroVention, NINDS/NIH, Penumbra, and Stryker. Dr Mocco received funding support from Medtronic Neurovascular, Microvention, Penumbra, and Stryker Neurovascular; is an investor with Blockade Medical, Cerebrotech, and TSP; and has served as a consultant for Cerebrotech, Endostream, Pulsar, Rebound, and TSP. Dr Hoit is a consultant for Codman Neurovascular, Medtronic, MicroVention, Penumbra, Sequent, and Stryker. Dr Elijovich is a consultant for Codman Neurovascular, Medtronic, MicroVention, Penumbra, Sequent, and Stryker. Dr Turner is a consultant for Blockade, Codman, Devora Medical, Medtronic, MicroVention, Penumbra, Pulsar Vascular, Q'Apel, Rebound Medical, and Stryker. Dr Arthur is a consultant for Codman, Medtronic, Microvention, Penumbra, Sequent, Siemens, Stryker and has received research support from Sequent and Siemens. The authors have no personal, financial, or institutional interest in any of the drugs, materials, or devices described in this article.

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