Original Article

Number of stentriever passes and outcome after thrombectomy in stroke

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A B S T R A C T

Background and purposes. – Stroke secondary to emergent large vessel occlusions (ELVO) involving the anterior circulation can be treated with intravenous tissue plasminogen activator (IV-tPA) or thrombectomy. Data regarding the influence of the number of stentriever passes needed for vessel recanalization on outcome is lacking.

Patients and methods. – We prospectively accrued data on consecutive patients with ELVO that were treated with thrombectomy. Procedural details including the number of stentriever passes needed to achieve vessel recanalization and clot length were collected. Functional outcome was determined with the modified Rankin Scale (mRS) at 90 days post stroke with mRS ≤ 2 considered favorable outcome. Data on demographics, risk factors, stroke severity, survival, and occurrence of symptomatic intracranial hemorrhage (sICH) was also collected.

Results. – On univariate analysis more than one pass needed to achieve recanalization impacted survival and functional outcome after 90 days as did age, stroke severity and collateral and reperfusion status. On multivariate logistic regression the number of passes needed to achieve revascularization (OR: 10.0, 95% CI: 2.28–43.94, $P = 0.002$), age (OR: 0.90, 95% CI: 0.84–0.96, $P = 0.001$) and collateral status (OR: 7.90, 95% CI: 1.87–33.35, $P = 0.005$) remained significant modifiers for favorable outcome. On logistic regression the only variable associated with the need to perform more than a single stentriever pass was time from symptom onset to target vessel recanalization (OR: 1.007, 95% CI: 1.002–1.012).

Conclusions. – The number of passes needed to achieve target vessel recanalization modifies outcome after thrombectomy and successful recanalization after a single pass is associated with favorable outcome.

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Introduction

Ischemic stroke can be treated with either intravenous tPA or thrombectomy [1]. In patients with emergent proximal large vessel anterior circulation occlusions (ELVO), outcome may be especially dismal without prompt reperfusion of the brain parenchyma [2].

In tPA-treated patients, larger clots are associated with higher likelihood of a poor outcome [3]. However, the influence of clot length on outcome after thrombectomy is unclear as previous studies have yielded conflicting results, with one showing a correlation between clot length and outcome [4] while others have failed to reproduce these results [5–8]. In this regard, it is plausible to assume that outcome could be affected by an increase in the number of stentriever passes needed for revascularization but data on this subject are scarce [9]. Therefore, we aimed to determine whether the number of stent-retriever passes needed for target vessel recanalization were associated with functional outcome in a homogenous group of patients with ELVO who underwent thrombectomy.

Patients and methods

We conducted a retrospective analysis of prospectively accrued data from a database of patients with ELVO who were treated with thrombectomy in a tertiary academic center between 2012 and 2015. All ELVO patients are consecutively enrolled in the database, as described earlier [10]. The Institutional Review Board

granted permission to include anonymous patients into the data set. The current study included patients who experienced an acute ischemic stroke due to occlusion of the internal carotid artery (ICA) or proximal middle cerebral artery (MCA) demonstrated on vascular imaging, and who underwent thrombectomy. All patients were treated with a thrombectomy device first (either Solitaire FR [Medtronic USA] or pRESET [Phenox GMBH Germany]) for as many passes as needed according to the decision of the treating endovascular specialist. Aspiration technique with Penumbra device was only rarely used as a second line ($n = 2$) and Solumbra technique was not used for this study. Treatment with IV-tPA prior to thrombectomy was allowed. Those with occlusion in the distal MCA or other vessels were excluded. Patient demographics and clinical details, including vascular risk factors, were recorded. Neurological deficits were measured with the National Institutes of Health Stroke Scale (NIHSS) [11] at admission and discharge and stroke severity was determined according to the admission NIHSS. Stroke etiology was classified with the Trial of Org 10172 in Acute Stroke Treatment (TOAST) classification [12]. Time metrics measured included time from onset to presentation to the emergency department (onset to door, OTD), door to imaging (DTI), onset to endovascular suite entry (OTE), and onset to target vessel recanalization (OTR). The time spent in the angio suite was calculated as the difference between OTE and OTR. Since the actual time of groin puncture was not documented in many cases we do not have data as to the actual net procedure time (reperfusion time–groin puncture time). Imaging variables, including clot visibility on admission non-contrast CT, Alberta Stroke Program Early CT Score (ASPECTS) [13] before and after treatment and collateral status on admission CTA were assessed similarly to previous reports [14]. Briefly, we used a modification of the ASPECTS collateral score using double pass CTA evaluation (early phase: immediately after contrast injection and delayed phase: 1 minute later). Collateral status was determined in comparison to the contralateral hemisphere. Values of poor (no collaterals on both phases or partial filling on the delayed phase only), intermediate (incomplete filling on the early phase or complete filling showing only on the delayed phase) or favorable (complete filling on the early phase or incomplete filling on the early phase that turns complete on the delayed phase) were assessed. Clot length was measured in mm using several angles and projections on digital subtraction angiography. Data on procedural variables, including the Thrombolysis in Cerebral Ischemia (TICI) score [15] at the end of the procedure and the number of passes needed to achieve the best possible recanalization were also studied. TICI2b-3 was considered as favorable target vessel recanalization and the need for fewer than two passes to achieve target vessel recanalization was considered favorable based on the results of a recent study [9].

Patient outcomes were assessed with the modified Rankin Scale (mRS) [16] 3 months after stroke, with mRS ≤ 2 was considered as favorable outcome. Survival and symptomatic intracranial hemorrhage (sICH) rates, determined according to the European Cooperative Acute Stroke Study (ECASS) III criteria [17] were also assessed.

For the purpose of the current analysis patients with favorable outcome (mRS ≤ 2) were compared to those with unfavorable outcome (mRS ≥ 3).

Statistical analysis was performed using the SPSS program. $P < 0.05$ was considered significant. The Chi^2 test or Fisher's exact test were used to explore the link between qualitative variables. The student's t-test was used to compare quantitative variable. The relationship between the number of passes needed to achieve target vessel recanalization and survival, sICH, and functional independence (mRS 0–2 after 90 days) was examined with univariate analysis. Variables that were found to be significantly associated with the dependent variable (good or poor outcome) were assessed

Table 1
Baseline characteristics of patients with ELVO undergoing EVT.

	mRS ≥ 3 $n = 48$	mRS ≤ 2 $n = 38$	P
Age (sd)	74.9 ± 10	61.5 ± 15	< 0.001
Gender male (%)	22 (46)	17 (44)	0.91
Hypertension (%)	41 (85)	24 (63)	0.017
Diabetes (%)	23 (48)	7 (19)	0.004
Atrial fibrillation (%)	30 (63)	14 (37)	0.018
Ischemic heart disease (%)	29 (60)	13 (34)	0.016
Smoking (%)	10 (21)	13 (34)	0.16
Hyperlipidemia (%)	30 (63)	11 (29)	0.002
Previous stroke (%)	11 (23)	4 (11)	0.13
Involved side (left; %)	22 (46)	24 (63)	0.11
TOAST (%)			0.067
Cardioembolic	38 (79)	21 (55)	
Atherosclerotic large vessel	6 (13)	9 (24)	
Other known	0 (0)	1 (2)	
Unknown	4 (8)	7 (19)	
Bridging with tPA (%)	20 (42)	13 (34)	0.48
Admission NIHSS (sd)	20.0 ± 5.0	16.6 ± 5.6	0.004
ASPECTS ≥ 7 (%)	43 (90)	35 (92)	0.132
Favorable Collaterals (%)	16 (33)	21 (55)	0.009
Onset to groin (min, sd)	185 ± 92	187 ± 185	0.89
Clot length (mm ± sd)	17.9 ± 6.4	17.8 ± 8.6	0.94
Single pass (%)	19 (40)	26 (68)	0.008
TICI 2b-3	38 (79)	36 (95)	0.039
Onset to recanalization (min, sd)	263 ± 115	275 ± 117	0.71

ASPECTS: Alberta Stroke Project Early CT Score; NIHSS: National Institutes of Health Stroke Scale; TICI: Thrombolysis in Cerebral Infarction; TOAST: Trial of Org 10172 in Acute Stroke Treatment.

in a multivariate logistic regression model. Variables that were associated with the need of more than a single stentriever pass in order to achieve recanalization were studied in a logistic regression model that controlled for clot length, age, baseline stroke severity, use of tPA, occlusion site, time from symptom onset to recanalization and baseline ASPECTS score.

Results

A total of 96 patients met inclusion criteria. Baseline status was typical for ELVO patients with median NIHSS score at admission 18.4 ± 5.1 and 70% of inclusions involving the M1 segment of the MCA. Before treatment, 81% of the patients were functionally independent (mRS 0–2) and a favorable ASPECTS score (≥ 7) was present on the baseline CT in 95% of patients. There was good collateral blood supply to the affected parenchyma in 50% of participants. The mean time from onset to the end of procedure was 260 ± 147 minutes, and the average clot length was 17.8 ± 7.8 mm. The average number of passes was 2 ± 1.5 and 47% of patients had optimal recanalization (TICI2b-3) after a single stent-retriever pass. Complete target vessel recanalization (TICI3) was achieved in 75% of the patients. Symptomatic ICH were detected in 5.3% of participants. The overall survival rate was 83% with 44% of the patients being independent after 90 days.

We compared patients who had a favorable outcome (mRS ≤ 2) at 90 days post stroke to those that did not reach functional independence (Table 1). Patients with favorable outcomes were significantly younger and less often had atrial fibrillation, diabetes, hypertension and ischemic heart disease (Table 1). Furthermore, patients with favorable outcomes had significantly lower NIHSS scores on admission and more often had favorable collaterals and favorable reperfusion status (Table 1).

The correlation between the number of passes and favorable outcome (mRS ≤ 2) was highly significant ($P = 0.008$, Table 1). In contrast, there was no significant association between the number of stentriever passes needed for recanalization and survival ($P = 0.35$) or sICH ($P = 1.00$).

Table 2

Multivariate logistic regression for variables that independently predict the need for >2 passes to achieve recanalization.

	OR	95% CI for OR		P
Clot length (mm)	0.97	0.91	1.04	0.416
Age (year)	1.02	0.98	1.05	0.341
tPA bridging	0.75	0.28	1.96	0.522
ICA/MCA	0.70	0.37	1.34	0.288
Admission NIHSS (point)	1.06	0.96	1.15	0.236
Onset to reperfusion (min)	1.01	1.002	1.012	0.010
Favorable ASPECTS	0.69	0.08	6.21	0.741

ASPECTS: Alberta Stroke Project Early CT Score; tPA: tissue plasminogen activator; ICA: internal carotid artery; MCA: middle cerebral artery; NIHSS: National Institutes of Health Stroke Scale; ASPECTS: Alberta Stroke Project Early CT changes in acute Stroke.

Table 3

Multivariate logistic regression for variables that independently predict favorable outcome (mRS ≤ 2).

P	95% CI for OR	OR	
0.002	2.30–43.90	10.0	Single pass
0.001	0.85–0.96	0.90	Age (per year)
0.005	1.90–33.30	7.90	Favorable collaterals
0.388	0.83–1.07	0.945	NIHSS at admission

NIHSS: National Institutes of Health Stroke Scale.

Of note, times from symptom onset to emergency room door (median 70 vs. 64 min; *P* = 0.61), door to imaging (median 24 vs. 29 min; *P* = 0.56), time from onset to start of endovascular procedure (median 185 vs. 187 min; *P* = 0.89) and time form onset to recanalization (median 235 vs. 235 min; *P* = 0.71) did not correlate with outcome.

In a regression analysis model aiming to determine which variables were associated with the need to perform > 1 stentriever pass in order to achieve recanalization (Table 2), the only variable that was found to impact the need for multiple passes was time from symptom onset to target vessel recanalization (OR 1.007 95% CI 1.002–1.012).

In a model of multivariate logistic regression that controlled for age, collateral state, baseline stroke severity, and reperfusion state, as well as whether more than one pass was needed to reanalyze the occluded vessel, the number of stent-retriever passes needed to achieve revascularization (OR 10.0, 95%CI 2.28–43.94, *P* = 0.002) was the most significant modifier for the chances of obtaining a favorable outcome (Table 3). Other factors that remained significant modifiers of favorable outcome (Table 3) included age (OR 0.90, 95%CI 0.84–0.96, *P* = 0.001) and collateral status (OR 7.90, 95%CI 1.87–33.35, *P* = 0.005).

Discussion

Our findings indicate that achieving reperfusion with a single stentriever pass was linked to higher likelihoods of obtaining functional independence at 90 days. The influence of the number of passes on outcome remained significant after accounting for other variables that were expected to affect prognosis.

The number of passes needed to achieve target vessel recanalization may depend on clot burden, clot constituents, stability, porosity and prior use of systemic thrombolysis, as well as on operator experience, among other factors. Indeed, our results indicate that longer times from onset were observed in patients needing more than a single stentriever pass in order to achieve recanalization. We can speculate that with time the clot becomes more organized and more elongated and that these physiological changes may make clot retrieval in one piece more challenging thus necessitating a higher number of passes for complete clot removal.

The influence of number of passes on outcome after thrombectomy has been rarely studied but may be an important measure for outcome that could dictate not only how aggressively to pursue recanalization but also when to quit if unsuccessful. The current set of results corroborates recently published data from the North American Acute Stroke Solitaire Registry Database, which showed that obtaining target vessel recanalization following a single stentriever pass was indeed related with higher rates of favorable outcome [9]. The authors achieved recanalization on the first pass in 25% of their patients and this phenomenon was more common in patients with MCA occlusions compared with ICA occlusions. Furthermore, they were able to associate recanalization after a single pass with use of balloon guide catheters and with shorter procedure times [9] but these variables were not assessed in the current study. Previous retrospective studies showed conflicting results with one study showing better functional status in patients that reanalyzed after a single pass [18] and another failing to show a significant association between the number of passes and outcome [5].

In conclusion, the current results suggest that a lower number of passes needed to reanalyze the target vessel is associated with a higher likelihood of favorable outcome. However, because all current data is based on registries or retrospective data, whether a single pass should be set as a cutoff number for favorable outcome should be tested in a larger prospective cohort. It should be noted that our results do not imply that failure to achieve target vessel recanalization after a single stentriever pass should lead to abandonment of further passes but merely suggest that the chances of favorable outcome are increased if reperfusion was achieved after a single pass.

It seems plausible to assume that with an increased number of passes needed for revascularization the overall procedure time should also increase. Therefore, we also explored the link between overall time spent in the angio suite and the chances for favorable outcome. Surprisingly, our results indicate that the overall time from entry to the angio suite to target vessel recanalization did not impact the chances for attaining a favorable outcome. This may appear counterintuitive since we would have expected a longer procedure time to indicate a more complicated procedure or a larger clot burden that would be linked to poor outcome. However, it should be noted that we measured the time from onset to entry to the angio suite and time from angio suite entry to recanalization rather than the net procedure time (groin puncture to recanalization). Thus, a possible explanation to this finding is that the overall time spent in the angio suite is influenced by many independent factors (operator experience, use of general anesthesia vs. sedation, patient's age, efficiency of supporting medical staff, etc.) all of which do not directly point to a more complicated procedure in itself.

Our study has several limitations. First, the number of included patients is relatively small thus limiting the power to detect differences between the groups. Thus, the very small numbers of fatalities and sICH prevented us from exploring the impact of single pass recanalization on these parameters. However, we used prospectively enrolled patients and selected a homogenous group of patients with similar vascular lesions thus increasing the power to detect differences. Another weakness is that we did not directly evaluate clot properties such as clot density, composition and porosity, which could have influenced outcome.

Conclusion

Our findings corroborate those seen in the recent SWIFT registry and suggest that obtaining target vessel recanalization after a single pass is associated with favorable outcome. Our results further suggest that this effect is not necessarily related to overall procedure time or to time from symptom onset. If these findings will be

corroborated in prospective randomized studies, we believe that the number of passes could be included in a scale for prediction of favorable outcomes following thrombectomy together with other variables such as age, collateral state and initial stroke severity.

Authors' contribution

Rawan Kharouba MD, Pavel Gavriliuc MD, Nour Eddine Yagh-mour MD – Data curation; formal analysis.

John M. Gomori MD – Validation; visualization writing – review & editing.

Jose E. Cohen MD – Conceptualization, writing – review & editing.

Ronen R. Leker MD FAHA – Conceptualization, formal analysis, project administration; supervision; validation, writing – original draft.

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Disclosure of interest

The authors declare that they have no competing interest.

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