Stroke

CLINICAL AND POPULATION SCIENCES

Number of Retrieval Attempts Rather Than Procedure Time Is Associated With Risk of Symptomatic Intracranial Hemorrhage

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BACKGROUND AND PURPOSE: Endovascular therapy is the standard of care in the treatment of acute ischemic stroke due to large-vessel occlusion. A direct association between the number of device passes and the occurrence of symptomatic intracranial hemorrhage (SICH) has been suggested. This study represents an in-depth investigation of the hypothesis that >3 retrieval attempts is associated with an increased rate of SICH in a large multicenter patient cohort.

METHODS: Two thousand six hundred eleven patients from the prospective German Stroke Registry were analyzed. Patients who received Endovascular therapy for acute large-vessel occlusion of the anterior circulation with known admission National Institutes of Health Stroke Scale and Alberta Stroke Program Early CT Score, final Thrombolysis in Cerebral Infarction, and number of retrieval passes were included. The primary outcome was defined as SICH. The secondary outcome was any type of radiologically confirmed intracranial hemorrhage within the first 24 hours. Multivariate mixed-effects models were used to adjust for cluster effects of the participating centers, as well as for confounders.

RESULTS: Five hundred ninety-three patients fulfilled the inclusion criteria. The median number of retrieval passes was 2 [interquartile range, 1–3]. SICH occurred in 26 cases (4.4%), whereas intracranial hemorrhage was identified by neuroimaging in 85 (14.3%) cases. More than 3 retrieval passes was the strongest predictor for SICH (odds ratio, 3.61 [95% CI, 1.38–9.42], P=0.0089) following adjustment for age, admission National Institutes of Health Stroke Scale, admission Alberta Stroke Program Early CT Score, and Thrombolysis in Cerebral Infarction, as well as time from symptom onset to flow restoration. Baseline Alberta Stroke Program Early CT Score of 8 to 9 (odds ratio, 0.26 [95% CI, 0.07–0.89], P=0.032) or 10 (odds ratio, 0.21 [95% CI, 0.06–0.78], P=0.020) were significant protective factors against the occurrence of SICH.

CONCLUSIONS: More than 3 retrieval attempts is associated with a significant increase in SICH risk, regardless of patient age, baseline National Institutes of Health Stroke Scale, or procedure time. This should be considered when deciding whether to continue a procedure, especially in patients with large baseline infarctions.

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Key Words: infarction ■ intracranial hemorrhage ■ ischemic stroke ■ neuroimaging ■ thrombectomy

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For Sources of Funding and Disclosures, see page 1587.

Nonstandard Abbreviations and Acronyms

ASPECTS	Alberta Stroke Program Early CT Score
EVT	endovascular therapy
GSR-ET	German Stroke Registry–Endovascular Treatment
ICH	intracranial hemorrhage
LVO	large-vessel occlusion
OR	odds ratio
SICH	symptomatic intracranial hemorrhage
TICI	Thrombolysis in Cerebral Infarction

Endovascular therapy (EVT) has become the standard of care in large-vessel occlusion (LVO) stroke.[1,2] The benefits of the procedure greatly outweigh the risks in selected populations, as has been shown, among others, by the HERMES study (Highly Effective Reperfusion Evaluated in Multiple Endovascular Stroke Trials).[3] However, EVT is associated with a number of possible complications.[4]

Intracranial complications include device malfunctions, vessel dissection and/or perforation with subsequent hemorrhage, vasospasms, as well as clot migration or embolization into previously unaffected territories. Furthermore, there is a risk of symptomatic intracranial hemorrhage (SICH) following EVT.[5] In the HERMES study, 4.4% of patients developed symptomatic intracranial hemorrhage.[3] Other procedure-related complication rates vary widely depending on their definition and reporting, with rates of embolization, dissection, and perforation reported to be in the range of 1% to 6%.[6]

SICH in particular has been found to be associated with poor outcome and high mortality rates.[7] This might partly explain the high rate of futile reperfusion (ie, patients with poor clinical outcome despite complete reperfusion after EVT).

Successful reperfusion with EVT often requires >1 device pass or retrieval attempt.[8] Recent retrospective studies have observed an association between the number of retrieval attempts and both symptomatic and nonsymptomatic intracranial hemorrhage.[9,10] However, these studies did not take procedure time into account. Thus, it is unknown if the number of retrieval attempts is solely a function of procedure time in regard to this complication.

The aim of the present study was to investigate the relationship between the number of retrieval attempts and intracranial hemorrhage. We hypothesized that the number of retrievals is positively associated with SICH, regardless of procedure time.

METHODS

Patient Selection

The data that support the findings of this study are available from the corresponding author upon reasonable request. Two thousand six hundred eleven patients from the GSR-ET (German Stroke Registry–Endovascular Treatment; July 2015–April 2018) were screened for inclusion. The GSR-ET is an ongoing, open-label, prospective, multicenter registry of consecutively recruited EVT patients, with 25 participating stroke centers in Germany.[11]

The inclusion criteria for the present study were as follows: (1) acute ischemic stroke due to LVO in patients >18 years, (2) decision to perform EVT, (3) LVO in the anterior circulation confirmed on digital subtraction angiography and with documented location of occlusion, and (4) available data on the Alberta Stroke Program Early CT Score (ASPECTS) on admission imaging, admission National Institutes of Health Stroke Scale (NIHSS) score, number of retrieval attempts, final Thrombolysis in Cerebral Infarction (TICI) following angiography, modified Rankin Scale (mRS) at 90 days, and time from symptom onset to groin puncture, as well as time from symptom onset to final TICI. Exclusion criteria were occlusions of the extracranial internal carotid artery or internal carotid artery proximal to the carotid-T, concomitant stenting of significant (>70%) stenosis of the extracranial internal carotid artery, and spontaneous reperfusion before EVT was performed.

Study protocols and procedures were conducted in compliance with the Declaration of Helsinki and in accordance with ethical guidelines (the leading ethics committee of the Ludwig-Maximilians University Munich approved the GSR-ET and the study obtained additional approval from the local ethics committees of the participating hospitals).

Endovascular Treatment

EVT was performed according to the clinical routine of the referring stroke center. The technical approach was selected at the discretion of the attending neurointerventionalist. The decision to perform multiple retrieval attempts or to terminate the procedure was also made by the treating neurointerventionalist.

Data Acquisition and Management

Data acquisition was performed according to the protocol of the GSR-ET, as previously described.[11–13] In summary, data were collected by local neurointerventionalists and neurologists. The collected data underwent standardized quality checks to control for consistency, plausibility, and completeness.

ASPECTS was determined on admission nonenhanced CT scans or diffusion weighted imaging. The TICI score was assessed on the final digital subtraction angiography series by the interventionalist. The number of retrievals was documented by the neurointerventionalist immediately after the intervention and included both aspiration attempts as well as retrievals with stent retriever devices. The mRS was assessed at 90 days. Good clinical outcome was defined as a mRS at 90 days ≤2.

Statistical Analysis

All analyses were performed with the R statistics program (v.3.6.3, R Core Team 2020, Vienna Austria; RStudio IDE v. 1.2.5033,

Boston, MA). Normally distributed variables are displayed as mean and SD. Non-normally distributed data are displayed as median and interquartile range (IQR). Categorical variables are reported as proportions. We used the well-established framework of generalized mixed-effects logistic regression models with random intercepts to account for the cluster effect of the participating centers. The primary outcome of interest was SICH.[14,15] SICH was defined according to the criteria established by the ECASS II (European Cooperative Acute Stroke Study II).[16] The secondary outcome was occurrence of intracranial hemorrhage (ICH) confirmed by follow-up imaging within the first 24 hours after EVT, according to the GSR-ET study protocol.[11] The main explanatory variable of interest was the number of retrieval/device passes performed, which was dichotomized at ≤ 3 device passes. To incorporate the findings of recent studies,[17] the applied mixed-effects model was also adjusted for (the fixed effects of) age, baseline stroke severity (NIHSS), baseline ASPECTS, level of angiographic reperfusion (TICI), and treatment with intravenous thrombolysis, as well as for time from symptom onset to angiographic flow restoration. To further investigate the effect of time, the time from symptom onset to flow restoration was subdivided into (1) symptom onset to groin puncture and (2) procedural time (groin puncture to flow restoration). TICI scores were dichotomized at 0 to 2a versus 2b/3. Sensitivity analyses that included the localization of vessel occlusion (carotid-T, proximal M1, distal M1, M2 segment), intraarterial rtPA administration, and vessel injury (perforation or dissection) were performed. Furthermore, the presence of a possible interaction between procedural time and the number of retrieval passes was investigated. Model fits were compared using the likelihood-ratio test,[14,15] as well as the Bayesian and Akaike information criteria.[18] Figures were created using the ggplot2 grammar of graphics. $P<0.05$ were considered significant. Due to the explorative nature of our analyses, P values were not adjusted for multiple testing.

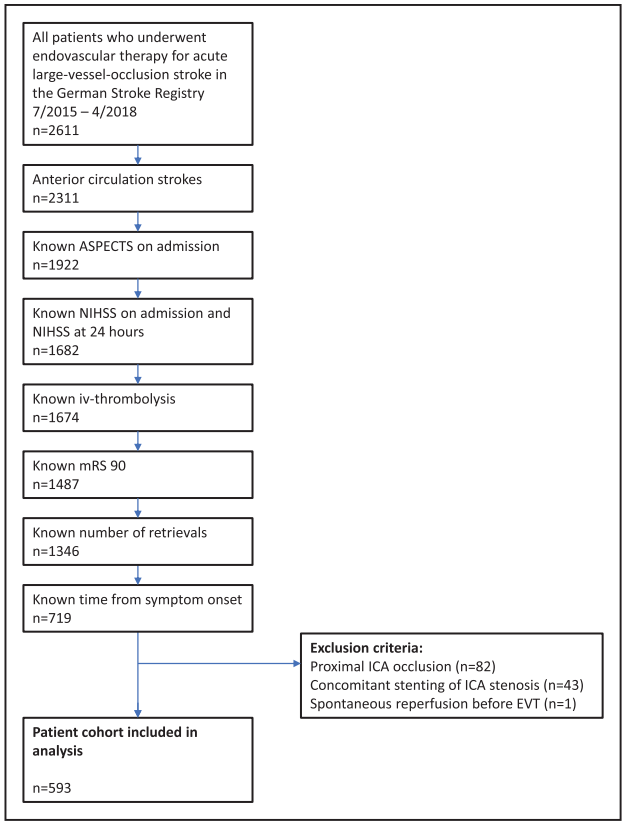

Figure 1. Patient selection flowchart.
ASPECTS indicates Alberta Stroke Program Early CT Score; EVT, endovascular therapy; ICA, internal carotid artery; mRS, modified Rankin Scale; and NIHSS, National Institutes of Health Stroke Scale.

RESULTS

Baseline Characteristics

We identified 2611 patients in the registry. All investigated outcome and predictor variables were available for 593 cases (Figure 1), 302 of which were male (50.9%). The mean age was 72.3 (±13.7) years (Table 1). The median baseline NIHSS score was 15 (minimum: 0, IQR, 10–19, maximum: 42). The median ASPECTS on admission imaging was 9 (minimum: 1, IQR, 8–10, maximum: 10). The median number of device passes was 2 (minimum: 0, IQR, 1–3, maximum: 20). TICI scores were distributed as follows: 0: 8 (1.3%); 1: 4 (0.67%); 2a: 35 (5.9%); 2b: 244 (41.1%); 3: 302 (50.9%). In other words, 47 (7.9%) were TICI 0 to 2a, whereas 546 (92%) were 2b to 3. intravenous thrombolysis was administered in 399 (67.3%) patients. Time from symptom onset to groin puncture (median, 193, IQR, 136–265), to flow restoration (minimum: 89, median: 241, IQR, 180–312), as well as the procedural time (median: 39, IQR: 25-61) all showed highly skewed, right-tailed distributions. The primary outcome of SICH occurred in 26 (4.4%) cases, whereas 85 (14.3%) patients had imaging-confirmed ICH within the first 24 hours. The absolute and relative frequencies of SICH and ICH, stratified by number of device passes, are depicted in Figure 2.

The 90-day mortality rate was 137 out of 593 (23.1%). Otherwise, the distribution of mRS at 90 days resembled a uniform distribution with cases of 0: 95 (16.0%); 1: 101 (17.0%); 2: 65 (11.0%); 4: 76 (12.8%); 5: 41 (6.9%). As previously noted, the number of patients were not equally contributed by each of the 17 participating centers. The top 3 recruiting centers (each of which treated >10% of the total collective) generated ≈48.2% of the study cohort. Another 8 centers, each providing 2% to 10% of the cases, accounted for ≈45.9%.

The rate of successful reperfusion (defined as TICI2b/3) was significantly higher in the group in which ≤3 retrieval attempts were performed (94.8% versus 76.6%, odds ratio [OR], 5.56 [95% CI, 2.81–10.91], $P<0.0001$). The devices used for endovascular treatment were reported in 563 patients: stent retriever devices (n=275, 49%), only aspiration catheters (n=114, 20%), and both aspiration and stent retriever devices (n=174, 31%). No significant differences were found in the occurrence of SICH between these groups (Table I and Table II in the Data Supplement).

Table 1. Baseline Data, Procedural, and Clinical Outcome

Variable	
Age, y (mean, SD)	72.3 (13.7)
Female sex, %	49.1%
Hypertension, %	72.8%
Diabetes mellitus, %	19.8%
Dyslipidemia, %	32.4%
Atrial fibrillation, %	44.7%
Initial NIHSS score (median, Q1–Q3)	15 [10–19]
Initial ASPECTS (median, Q1–Q3)*	9 [8–10]
Initial occlusion site, %	
Left hemisphere*	50.0%
Location of vessel occlusion	
Carotid-T	19.4%
M1 proximal	37.4%
M1 distal	24.5%
M2	25.5%
IVT, %	67.3%
Onset to admission, min (median, Q1–Q3)	116 [55–193]
Stroke cause	
Cardioembolism	57.9%
Dissection	0.68%
Atherosclerosis	16.9%
Other determined cause	5.1%
Unknown cause	19.4%
Onset to groin puncture, min (median, Q1–Q3)	193 [136–265]
Groin puncture to final TICI, min (median, Q1–Q3)	39 [25–61]
Onset to final TICI, min (median, Q1–Q3)	241 [180–312]
Number of device passes	2 [1–3]
Intraarterial tPA, %	1.9%
Other anti-thrombotics (aspisol, tirofibane, ticagrelor)	2.2%
Periprocedural vessel perforation/dissection	1.5%
Intracranial stenting	0.9%
Successful reperfusion (TICI score 2b/3)	92.0%
SICH	4.4% (n=26)
ICH	14.3% (n=85)
mRS at 90 days (median, Q1–Q3)	3 [1–5]
Mortality	23.1%
Functional independence	44.0%

ASPECTS indicates Alberta Stroke Program Early CT Score; ICH, intracranial hemorrhage; IVT, intravenous thrombolysis; mRS, modified Rankin Scale; NIHSS, National Institutes of Health Stroke Scale; SICH, symptomatic intracranial hemorrhage; TICI, Thrombolysis in Cerebral Infarction; tPA, tissue-type plasminogen activator.

Primary Multivariate Analyses: Postinterventional SICH

The primary mixed-effects logistic regression model (Table 2) showed a model fit of Akaike information criteria=221.5. The random effects intercept for centers showed a variance of 3.7×10^{-3} and SD=0.64 on the logit scale.

The model revealed an independent significant positive association between >3 retrieval passes (OR, 3.61 [95% CI, 1.38–9.42], *P*=0.0089) and the occurrence of SICH. Furthermore, we found significant negative associations between ASPECTS of 8 to 9 (OR, 0.26 [95% CI, 0.07–0.89], *P*=0.032) or ASPECTS of 10 (OR, 0.21 [95% CI, 0.06–0.78], *P*=0.020) and SICH compared to reference cases with ASPECTS 0-5 (Figure 3A). However, achieving a successful reperfusion rate of TICI 2b to 3 showed no significant effect (*P*=0.17) on the SICH risk compared to cases with unsuccessful recanalization of TICI 0 to 2a. No associations were found for the time from symptom onset to groin puncture (*P*=0.99), or for the total angiographic procedural time (*P*=0.88).

Sensitivity Analyses

None of the investigated locations of occlusion were associated with the occurrence of SICH when additionally included in the model: carotid-T (*P*=0.90), proximal M1 (*P*=0.90), distal M1 (*P*=0.96), M2 segment (*P*=0.85). However, ASPECTS 8 to 9 (*P*=0.033), ASPECTS 10 (*P*=0.022), and <3 device passes (*P*=0.0090) stayed significantly protective against SICH. Including an interaction term between procedural time and number of device passes (>3 or <3) revealed a nonsignificant interaction (*P*=0.53). It is of note, however, that in this time interaction model, ASPECTS 8 to 9 (*P*=0.037) and ASPECTS 10 (*P*=0.020) remained significantly inversely associated with SICH. Furthermore, excluding the number of device passes and the corresponding interaction term from the model revealed no statistically significant association between the time from symptom onset to groin puncture (*P*=0.98) or procedural time (*P*=0.53) and SICH. However, ASPECTS 8-9 (*P*=0.043) and ASPECTS 10 (*P*=0.017) remained significant protective factors against SICH.

Secondary Analyses: Postinterventional ICH Within the First 24 Hours

The same models as above revealed no significant associations between any of the aforementioned variables with regard to radiographically confirmed ICH within the first 24 hours following EVT. However, the signs of the estimated effects stayed consistent for all included predictors (Figure 3B). More than 3 retrieval passes had a nonsignificant relationship (OR, 1.47 [95% CI, 0.80–2.70], *P*=0.16) with the occurrence of postinterventional ICH. ASPECTS of 8 to 9 (OR, 0.84 [95% CI, 0.37–1.92], *P*=0.45) and ASPECTS 10 (OR, 0.69 [95% CI, 0.29–1.64], *P*=0.30) also did not reach statistical significance compared to the reference of ASPECTS 0 to 5. Similarly, the effects of successful TICI 2b-3 recanalization (*P*=0.45), intravenous thrombolysis (*P*=0.21), age

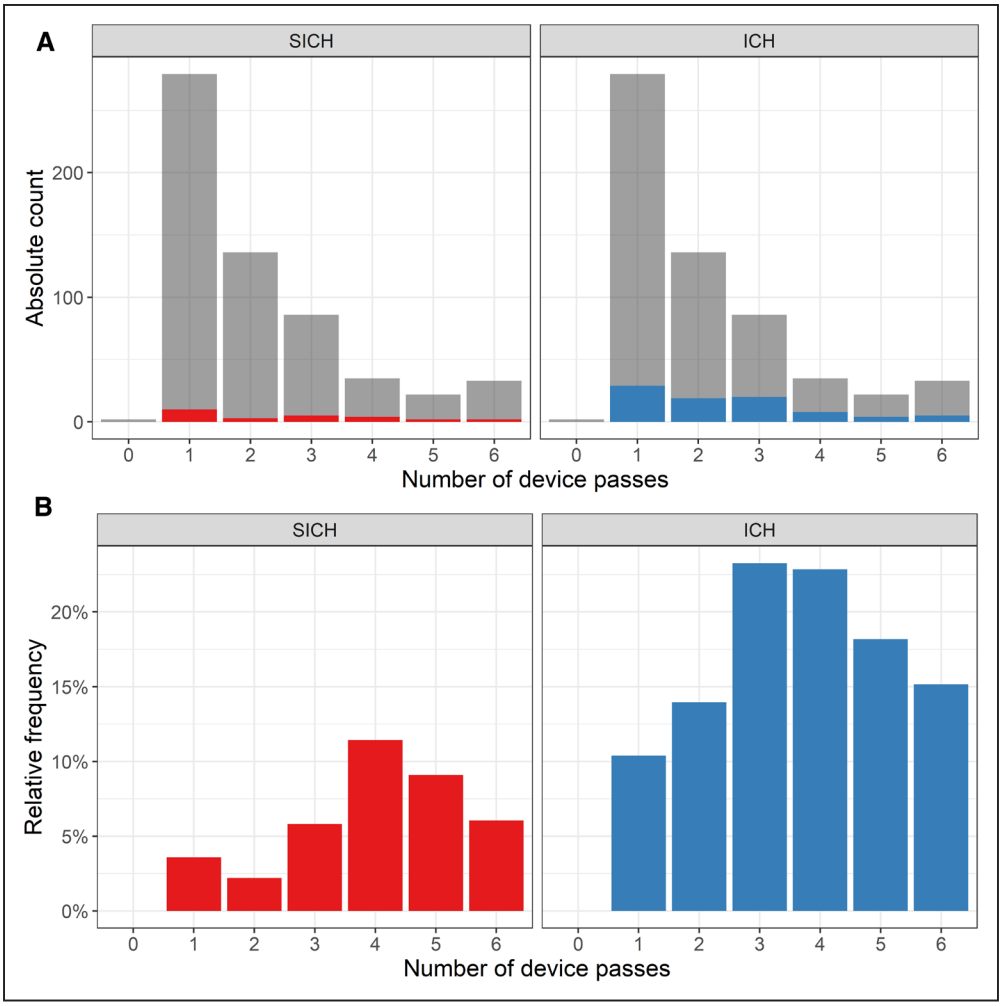

Figure 2. Number of symptomatic intracranial hemorrhage ([SICH], red) and any type of intracranial hemorrhage ([ICH], blue) by number of retrieval attempts.
A, Absolute count, the gray bars depict the absolute number of cases who underwent a certain number of retrieval attempts. The respective number of cases with SICH or ICH are overlaid in color. **B**, Relative frequencies by number of retrieval attempts. More than 6 retrievals were aggregated. 0 means no retrieval attempt was performed.

(*P*=0.25), and baseline NIHSS (*P*=0.33) did not reach statistical significance in any of these scenarios.

DISCUSSION

The present study investigated the occurrence of intracranial hemorrhage after EVT for acute ischemic stroke in a large multicenter patient cohort. The main finding was that the risk of symptomatic (however not asymptomatic) intracranial hemorrhage is increased after >3 retrieval attempts during EVT, even after adjusting for procedure time, while an ASPECTS of ≥ 8 was protective against SICH. We adjusted our analyses for well-known predictors of outcome after EVT,[3] namely age, NIHSS, ASPECTS on admission, therapy with intravenous thrombolysis, and time from symptom onset to groin puncture, as well as procedure time and TICI grade.

A previous study of 632 patients found an increased risk of SICH in patients who underwent >3 retrieval attempts.[19] However, time from symptom onset to reperfusion was only included as a binary factor in the multivariable analysis, and procedure time was not adjusted for. The rate of SICH was higher than in the present study (16.0% versus 4.4%). The authors classified the hemorrhages according to the Heidelberg bleeding classification, in contrast to our study, where the ECASS 2 definition was applied. From our analysis, we conclude that it is the number of retrieval attempts performed rather than the procedure time that is associated with higher risk of SICH. The underlying mechanism for increased SICH with increasing number of retrieval attempts is beyond the scope of this study. However, it is obvious that any additional procedural step is associated with an additional complication risk. Additional stress on the intima by each aspiration and pulling maneuver might also weaken the vessel wall.[20]

Cappellari et al[21] recently published a validated nomogram for the prediction of SICH after EVT. Apart from

Table 2. Symptomatic Intracranial Hemorrhage: Summary Table of Predictor Estimates by the Primary Multivariate Mixed-Effects Logistic Regression Model With Cluster Effects for Centers

Predictor variable	Coefficient*	SE*	OR (95% CI)†	*Z* value	*P* value
Age‡	−0.021	0.017	1.02 (0.99–1.06)	1.224	0.221
NIHSS score‡	−0.030	0.034	0.98 (0.91–1.05)	−0.670	0.503
ASPECTS 0–5	Ref.	…	…	…	…
ASPECTS 6–7	−0.439	0.636	0.64 (0.19–2.24)	−0.689	0.490
ASPECTS 8–9	−1.364	0.637	0.26 (0.07–0.89)	−2.142	0.032§
ASPECTS 10	−1.563	0.67	0.21 (0.06–0.78)	−2.327	0.020§
No. of passes (>3)	1.282	0.490	3.61 (1.38–9.42)	2.618	0.009§
Minutes symptom onset to groin puncture	2.107×10^{-5}	0.001	1.00 (1.00–1.00)	0.019	0.985
Minutes groin puncture to final TICI	4.263×10^{-4}	0.003	1.00 (0.99–1.01)	0.150	0.881
IVT	0.468	0.473	1.60 (0.63–4.04)	0.990	0.322
Successful reperfusion (TICI score 2b–3)	1.461	1.073	4.31 (0.53–35.27)	1.362	0.173
(Intercept)	−5.25	1.81	0.01 (0.00–0.18)	−2.908	3.64×10^{-3}

ASPECTS indicates Alberta Stroke Program Early CT Score; IVT, intravenous thrombolysis; NIHSS, National Institutes of Health Stroke Scale; OR, odds ratio; and TICI, Thrombolysis in Cerebral Infarction.

*Coefficients and SEs are reported on the logit scale.

†Please note, that CIs are not necessarily symmetrical for mixed-effects models.

‡Age and NIHSS were treated as continuous variables; ASPECTS and successful reperfusion were treated as factors.

§$P<0.05$.

the first-pass effect, the study did not take into account the number of retrievals, and the first-pass effect was not included in the final model as a significant predictor. However, the model by Cappellari et al[21] incorporated ASPECTS as a significant predictor of SICH. Similarly, we observed that a low ASPECTS of ≤5 is associated with SICH, as has also been shown in other retrospective studies.[22] This is of particular importance as EVT might be performed in patients with low admission ASPECTS in the future, depending on the results of ongoing randomized controlled trials.[23] In addition, we found that an ASPECTS of 8 or higher was an independent, statistically significant protective factor against SICH and may serve as a surrogate for more developed collateral circulation networks.[24] We did not reproduce the other predictors of SICH implemented in the nomogram (age, NIHSS on admission, reperfusion status, and time to reperfusion).

In yet another study by Mazighi et al,[25] time from symptom onset to final TICI was also reported to be significantly associated with SICH. Their collaborative-pooled database analysis reported that a 30-minute decrease in time between symptom onset and recanalization was associated with a 20% reduction in intracranial hemorrhage. Both Cappellari et al[21] and Mazighi et al[25] reported longer times from symptom onset to final TICI (median 314 minutes versus 241 minutes in our patient cohort). It is possible that the association of time from symptom onset with SICH is more pronounced in patients that are treated at a later timepoint.

Bourcier et al. reported that >3 passes with a stent retriever is an independent predictor of parenchymal hematoma.[17] Their collective included post hoc analyses of a subset of the ASTER trial (Contact Aspiration vs Stent Retriever for Successful Revascularization; n=381), with 281 patients who underwent successful reperfusion (TICI 2b/3). We applied a similar mixed binary logistic regression approach to their analysis, with similar results: >3 passes were not associated with an increased risk of any (CT-confirmed) ICH within 24 hours. Bourcier et al. reported considerably higher proportion of any ICH cases compared with that which was observed in our cohort (131/276 or 47.5% versus 14.3%). Nonetheless, the rate of overall parenchymal hematoma was similar (42/276; 15.3%).

A fundamental question in clinical practice in cases of persistent occlusion is when to terminate the procedure. The establishment of a definite cut-off threshold for the number of device passes is beyond the scope of this study, as the decision depends on the collective assessment of multiple factors (eg, patient age, clinical history, imaging features, technical difficulties, etc), all of which have to be weighed by the interventionalist. However, our findings could aid interventionalists in the decision to stop or continue a procedure by pointing to the increased risk of SICH with increasing retrieval attempts, particularly when considering the accompanying declining rate of TICI 2b/3 reperfusions. Because we observed an ASPECTS of ≥ 8 to be protective against SICH, it is possible that more retrieval attempts could be performed in patients without signs of early infarction. Furthermore, multiple attempts were associated with SICH, regardless of procedural time. This underlines the importance of first-pass reperfusion as a therapeutic goal for LVO.[26,27]

A possible limitation of our study could be attrition bias; information regarding the included explanatory

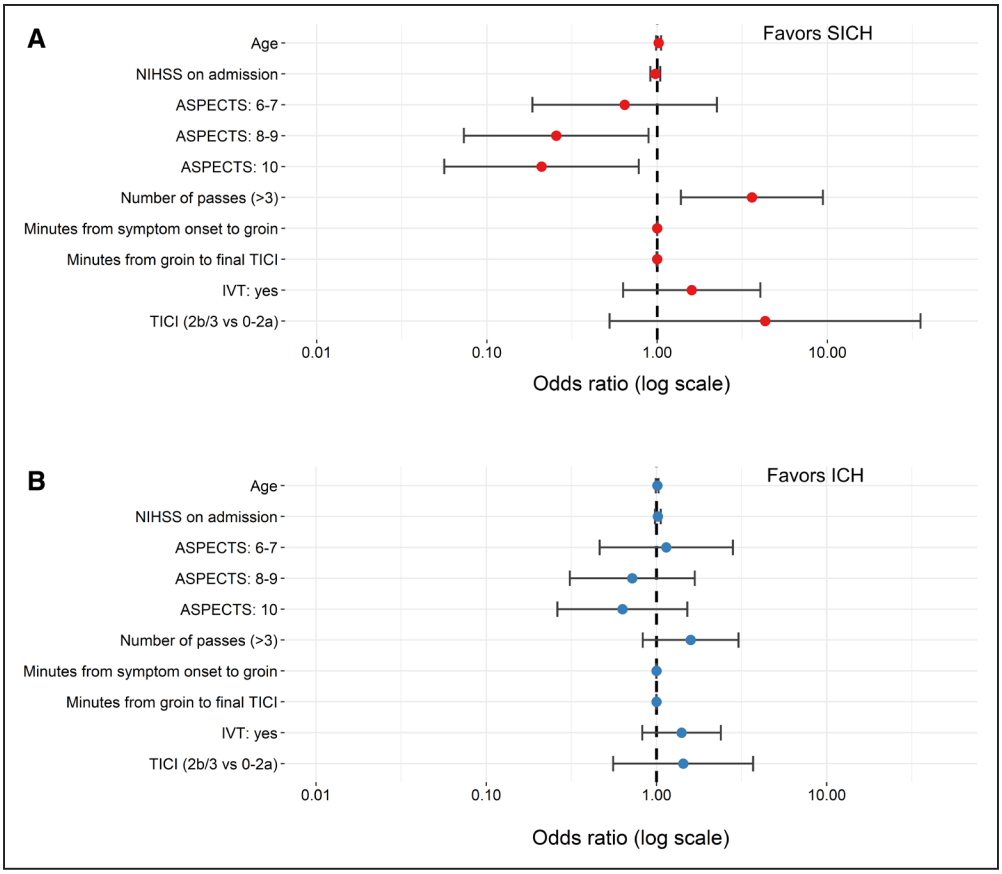

Figure 3. Primary generalized mixed-effects logistic regression model-based with 95% CI across all participating centers, incorporating random intercepts to account for the cluster effect of the participating centers.
A, Symptomatic intracranial hemorrhage (SICH). More than 3 retrievals were significantly associated with risk of SICH. Alberta Stroke Program Early CT Score (ASPECTS) 8-9 and 10 were negatively associated with SICH, compared to the reference group (ASPECTS ≤5). The other independent variables did not show any significant association with SICH. **B**, Intracranial hemorrhage (ICH). No significant association with any independent variable was found. IVT indicates intravenous thrombolysis; NIHSS, National Institutes of Health Stroke Scale; and TICI, Thrombolysis in Cerebral Infarction.

variables was only available for a quarter of the total collective in the registry. However, our baseline data, as well as procedural and outcome data, are comparable to the published data of the whole dataset of the German Stroke Registry,[12] with the exception that we have a higher proportion of TICI 2b/3 cases in our subset (92% versus 83%). A possible explanation is that we only included patients with known procedure time. Despite this, the results of our outcome analysis are in line with those from the literature. In particular, the rate of SICH in our patient cohort was found to be the same as in the HERMES study (4.4% in the intervention population).[3] Further limitations have to be acknowledged. The overall number of complications was low, and results might differ in larger patient cohorts. In cases of low outcome prevalence (< 10% or even <5%), logistic regression frameworks might become unstable and yield unstable estimates due to (perfect) separation of the data.[28] Nonetheless, all of our models converged stably and showed consistent predictor estimates across all outcomes.[14,15] The data used in this analysis were collected and validated by the reporting stroke center without use of a central imaging core lab. Due to the design of our registry, we were not able to further differentiate types of ICH according to the ECASS II definition.[16] The subgroup analysis between aspiration and stent retriever techniques revealed no significant differences in the occurrence of SICH, but thorough documentation of the thrombectomy technique and device per attempt would be needed to further address this point. A clear-cut distinction is difficult in our cohort, as switching between aspiration and stent retrieval was left to the discretion of the treating neurointerventionalist. Furthermore, the reasons for multiple retrieval attempts are heterogenous (eg, recalcitrant thrombus, intracranial atherosclerosis, and/or clot migration or embolization during EVT), and a further characterization would require a different study design. Our results represent the overall effect of EVT in a multicentric cohort with heterogeneous treatment strategies of mostly early LVO, hence results might differ in patients presenting in the late time window.

CONCLUSIONS

In EVT procedures where >3 retrieval attempts are required, interventionalists should be aware of the significantly increasing risk of SICH and incorporate this knowledge into the decision to continue or stop a procedure, especially in patients with large baseline infarcts.

ARTICLE INFORMATION

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Drs Flottmann, Maros, Brekenfeld, and Fiehler conceptualized the study. Drs Maros, Flottmann and McDonough performed data analyses and wrote the article; Dr Maros performed mixed-effects modeling, generated predicted probabilities and Dr Flottmann created figures. Drs Flottmann, Broocks, and Leischner performed data preparation. Drs Leischner, Deb-Chatterji, Alegiani, Thomalla, and members of the German Stroke Registry composed the cohort. Drs Fiehler, Brekenfeld, and Thomalla supervised the clinical aspects of the study. Drs Fiehler, Brekenfeld, and Flottmann supervised the work and wrote the article. All authors critically reviewed the article and approved the final version.

Disclosures

Dr Thomalla reports personal fees from Acandis, grants and personal fees from Bayer, personal fees from Bristol Myers Squibb/Pfizer, personal fees from Boehringer Ingelheim, personal fees from Daiichi Sankyo, personal fees from Portola, and personal fees from Stryker outside the submitted work. Dr Fiehler reports grants and personal fees from Acandis, grants and personal fees from Cerenovus, grants and personal fees from Medtronic, grants and personal fees from Microvention, personal fees from Penumbra, and personal fees from Phenox outside the submitted work; and chief executive officer of Eppdata. Dr Maros reports grants from German Federal Ministry for Economic Affairs and Energy, Zentrales Innovationsprogramm Mittelstand (ZF 4514602TS8) outside the submitted work. Unrelated consultancy for Smart Reporting GmbH and Siemens Healthineers AG. Dr Flottmann reports personal fees from Eppdata GmbH outside the submitted work. The other authors report no conflicts.

Supplemental Materials

Online Tables I–II

APPENDIX

German Stroke Registry - Steering Committee

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