Original research

Susceptibility vessel sign, a predictor of long-term outcome in patients with stroke treated with mechanical thrombectomy

Morin Beyeler (1), 1,2 Erich Rea, 1 Loris Weber, 1 Nebiyat Filate Belachew (1), 3,4 Enrique Barvulsky Aleman,⁴ Moritz Kielkopf,¹ Christoph C Kurmann (),³ Lorenz Grunder,³ Eike Immo I Piechowiak ^(D), ³ Thomas R Meinel ^(D), ¹ Mirjam R Heldner,¹ David Seiffge ⁽ⁱ⁾, ¹ Sara Pilgram-Pastor,³ Tomas Dobrocky ⁽ⁱ⁾, ³ Thomas Pabst,⁵ Martin D Berger,⁵ Simon Jung,¹ Marcel Arnold,¹ Jan Gralla,³ Urs Fischer,^{1,6} Johannes Kaesmacher ⁽ⁱ⁾, ³ Adnan Mujanovic ⁽ⁱ⁾, ³

ABSTRACT

Background The absence of the susceptibility vessel sign (SVS) in patients treated with mechanical thrombectomy (MT) is associated with poor radiological and clinical outcomes after 3 months. Underlying conditions, such as cancer, are assumed to influence SVS status and could potentially impact the longterm outcome. We aimed to assess SVS status as an independent predictor of long-term outcomes in MTtreated patients.

Methods SVS status was retrospectively determined in consecutive MT-treated patients at a comprehensive stroke center between 2010 and 2018. Predictors of long-term mortality and poor functional outcome (modified Rankin Scale (mRS) \geq 3) up to 8 years were identified using multivariable Cox and logistic regression, respectively.

Results Of the 558 patients included, SVS was absent in 13% (n=71) and present in 87% (n=487) on baseline imaging. Patients without SVS were more likely to have active cancer (P=0.003) and diabetes mellitus (P<0.001) at the time of stroke. The median long-term follow-up time was 1058 days (IQR 533-1671 days). After adjustment for active cancer and diabetes mellitus, among others, the absence of SVS was associated with long-term mortality (adjusted HR (aHR) 2.11, 95% CI 1.35 to 3.29) and poor functional outcome in the long term (adjusted OR (aOR) 2.90, 95% CI 1.29 to 6.55). **Conclusion** MT-treated patients without SVS have higher long-term mortality rates and poorer long-term functional outcome. It appears that this association cannot be explained by comorbidities alone, and further studies are warranted.

INTRODUCTION

Despite technical advances in stroke management, half the patients undergoing mechanical thrombectomy (MT) do not have a good functional outcome.¹ Several parameters obtainable by non-invasive admission imaging are known to impact patient outcome (eg, occlusion site, number of occluded vessels and infarct volumes).¹ The susceptibility vessel sign (SVS) can be assessed by

WHAT IS ALREADY KNOWN ON THIS TOPIC

 \Rightarrow The absence of the susceptibility vessel sign (SVS) on admission susceptibilityweighted imaging is associated with lower successful reperfusion rates after mechanical thrombectomy (MT) and overall poorer outcomes at 3 months. Furthermore, the absence of the SVS is associated with underlying conditions, such as cancer and diabetes mellitus, which are known to impact overall long-term outcomes. Whether SVS alone is associated with long-term outcomes in patients with stroke undergoing MT remains unknown.

WHAT THIS STUDY ADDS

 \Rightarrow The absence of SVS is independently associated with poorer outcomes and higher mortality rates during long-term follow-up after MT, even after adjustment for underlying conditions and interventional parameters that are known to be associated with the absence of SVS and poor outcomes.

HOW THIS STUDY MIGHT AFFECT RESEARCH, **PRACTICE OR POLICY**

 \Rightarrow A thorough understanding of potential factors affecting long-term outcomes and SVS status is essential for stroke physicians. Special consideration should be given to factors which are already known to be associated with the absence of SVS in the acute phase. Future studies should elucidate the association between SVS and other underlying conditions in patients with stroke.

susceptibility-weighted imaging (SWI) on admission and indicates a high proportion of deoxyhemoglobin which causes inhomogeneity in the magnetic field.²⁻⁴ Pathohistologically, this could reflect a larger proportion of erythrocytes in the thrombus composition.³ These erythrocyte-rich thrombi tend to induce signal loss on SWI (ie, indicating the

material is published online only. To view, please visit the journal online (http://dx. doi.org/10.1136/jnis-2023-020793).

► Additional supplemental

For numbered affiliations see end of article.

Correspondence to

Dr Adnan Mujanovic, University of Bern, Bern, Switzerland; adnan.mujanovic@insel.ch Dr Morin Beyeler; morin. beyeler@insel.ch

JK and AM contributed equally.

Received 11 July 2023 Accepted 17 October 2023



© Author(s) (or their employer(s)) 2023. No commercial re-use. See rights and permissions. Published by BMJ.

To cite: Beyeler M, Rea E, Weber L et al. J NeuroIntervent Surg Epub ahead of print: [please include Day Month Year]. doi:10.1136/jnis-2023-020793



1

presence of the SVS), while fibrin- and platelet-rich thrombi do not show this loss of signal (ie, appearing as absence of SVS).² Prior studies have also shown that MRI-based SVS correlates with the CT-based hyperdense vessel sign (HVS) regarding the thrombus composition.^{4 5} However, a direct transposition of the SVS evidence is not applicable and independent evidence for the HVS itself is required. Recent studies in patients with stroke undergoing MT reported that the absence of the SVS is associated with functional deterioration and an overall poorer outcome at 3 months.⁶⁷ The absence of SVS is assumed to be associated with underlying clinical conditions, such as cancer, which are known to impact overall long-term outcome.⁸ Moreover, hypercoagulopathy, which is often observed in cancer patients, is associated with a higher percentage of fibrin- and platelet-rich thrombi.9 Observational studies have also associated the absence of SVS with stroke of undetermined etiology; however, recent meta-analyses have not investigated stroke etiology in patients without SVS.¹⁰⁻¹² Therefore, the association between SVS and potential outcome drivers remains unclear,⁸⁻¹² and the extent to which the absence of SVS could be associated with patients' long-term outcome is presently unknown.^{6 13 14} We hypothesized that SVS status could serve as an independent predictor of long-term outcome in MT-treated patients.

METHODS

Study cohort

All consecutive stroke patients treated with MT between January 1, 2010 and December 31, 2018 from our institution's prospective registry were retrospectively assessed for eligibility. Inclusion criteria were: (1) acute ischemic stroke treated with MT; (2) SWI performed as baseline imaging with SVS status available; (3) long-term outcome and follow-up time available. Only patients undergoing MT with the stent-retrievers were considered for the present study. Patients with intravenous thrombolysis (IVT) administered before SWI acquisition were excluded. Furthermore, patients receiving IVT before blood examination were excluded from analyses involving blood biomarkers. To avoid potential survivorship bias, all eligible patients were included in the main analyses even if they had died before the 3-month follow-up.¹⁵ The STrengthening the Reporting of OBservational studies in Epidemiology (STROBE) checklist was used for the present study.

Data collection

Baseline and 90-day follow-up data were extracted from the stroke registry. These included sex, age at admission, prestroke independence (defined as a modified Rankin Scale (mRS) score \leq 2), prestroke anticoagulation/antiplatelet therapy, cerebrovascular risk factors (such as hypertension, diabetes mellitus, dyslipidemia, smoking, previous stroke, coronary artery disease), National Institutes of Health Stroke Scale (NIHSS) score on admission, time between last known well and admission, time between last known well and groin puncture, IVT before MT, and site of occlusion. Sites of occlusion were defined as internal carotid artery, M1 segment of the middle cerebral artery (MCA), M2 segment of the MCA, other anterior occlusions, and posterior occlusions. The presence of active cancer (known or occult at the time of stroke) was determined retrospectively by two neurologists (MB and MK). The definition of active cancer and detailed characteristics of cancers found in the study cohort were previously published by Beyeler *et al.*⁸ The assigned stroke etiology at discharge was defined by the TOAST (Trial of ORG 10172 in Acute Stroke Treatment) classification and extracted

from the clinical information system.¹⁶ The following laboratory values at admission were extracted: D-dimer in μ g/L, hemoglobin in g/L, C-reactive protein (CRP) in mg/L, leukocytes in g/L, thrombocytes in g/L, fibrinogen in g/L, and international normalized ratio (INR).

Imaging analysis

Imaging was performed on a 1.5T or 3T MRI scanner. The SWI sequences were performed as part of our institution's stroke protocol.7 Technical details on MRI scanners and our institution's stroke protocol are shown in online supplemental eTable I. To summarize, the presence or absence of SVS was determined retrospectively by two independent neuroradiologists blinded to clinical data and patient outcome (NFB and EBA). The presence of SVS was determined as a distinct signal loss which directly corresponded to the site of angiographically-confirmed occlusion and for which there was no alternative explanation (ie, neighboring vein, petechial hemorrhage or microcalcification in the neighboring parenchyma). The absence of SVS was defined as the absence of signal loss despite a clearly visible occlusion on the first angiographic imaging run (figure 1A–B). Inter-rater reliability regarding SVS evaluation (dichotomized: present or absent) was very good (Cohen κ =0.873, P<0.001).⁷ Alberta Stroke Program Early CT Score (ASPECTS) was assessed on diffusion-weighted imaging (DWI) by neuroradiologists with 5 years of experience. The final reperfusion grade was core lab adjudicated using the expanded Treatment in Cerebral Ischemia (eTICI) score.^{17 18} A score of eTICI2b50 or higher was considered as successful reperfusion.



Figure 1 Susceptibility vessel sign assessment. Admission MRI. (A) TOF shows an occlusion in the M1-MCA segment on the left side (left panel) with a visible SVS sign on SWI (right panel). (B) Similar to the previous case, TOF again shows an occlusion in the M1-MCA segment on the left side (left panel); however, the SVS sign on SWI is absent (right panel). MCA, middle cerebral artery; SWI, susceptibilityweighted imaging; TOF, time-of-flight angiography.

Long-term follow-up

Patients who had survived or died in the long term were identified using the Swiss Population Registry (SPR), which records the vital status of Swiss residents monthly. Two neurologists (MB and LW) contacted the surviving patients, their next of kin or healthcare providers between September 2019 and June 2020 to assess long-term functional outcome based on the mRS. Details of the informed consent process and data collection are published elsewhere.¹⁹ Long-term poor functional outcome was defined as mRS 3–6. For the survival analysis, follow-up time was defined as the time from the index ischemic stroke to the last update of the SPR or date of death, which is also reported in the SPR. For the functional outcome analysis, follow-up time was defined as the time from index ischemic stroke to the telephone interview or date of death extracted from the SPR.

Statistical analysis

Differences in baseline characteristics between patients with and without SVS were reported for continuous variables using median and interquartile range (IQR) and for categorical variables using frequency (percentage). Fisher's exact test and the Mann-Whitney U test were used to assess the differences between the two groups for categorical and continuous variables, respectively. For survival analyses, Kaplan-Meier curves with a logrank test stratified by SVS status were plotted to display mortality rates during the long-term follow-up. Adjusted hazard ratios (aHRs) and their 95% confidence intervals (CI) were assessed with multivariate Cox regression analysis. For outcomes analysis, odds ratios or adjusted odds ratios (aOR) and their 95% CI were calculated from univariate and multivariate logistic regression, respectively. Multivariate regression analysis included the following clinically relevant covariates: age at admission, sex, diabetes mellitus, active cancer, prestroke independence, time from last known well to admission, NIHSS score on admission, occlusion site, ASPECTS at admission, IVT, successful reperfusion (binary variable)/eTICI grade (ordinal variable with a stepwise increase), stroke etiology according to TOAST and CRP. Interaction modeling was used to identify conditions that could impact the association between SVS and long-term follow-up based on previously reported findings (ie, SVS status*active cancer interaction term with long-term follow-up defined as the dependent variable).⁸ For outcomes analyses (assessing the longterm mRS), subgroups with equal numbers of patients according to follow-up times were defined to limit the heterogeneity of the long-term follow-up due to the cross-sectional conduct of the telephone interview. Mixed-effects models with predefined follow-up times used as random effects were then applied. Due to the long recruitment period, sensitivity analyses were independently performed for the different follow-up groups. No imputation method was used for missing data. Statistical analyses were performed with Stata 16 (StataCorp) and R (version 3.6.0, R Core Team).

RESULTS

Study population

Of the 1317 patients undergoing MT, 577 had assessable SVS status. Of these, 19 had missing long-term follow-up data, resulting in 558 patients being finally included in the study (see online supplemental eFigure I). SVS was present in 87% of all patients (n=487/558) and absent in 13% (n=71/558) on baseline imaging.

Baseline characteristics

The baseline characteristics of patients with and without SVS are summarized in table 1. SVS was more often absent in female than in male patients (63.4% vs 36.6%). Compared with patients with SVS, those without SVS were less independent at the time of the stroke (mRS \leq 2: 82.9% vs 93.0%, P=0.009), more likely to have active cancer (21.1% vs 5.1%, P<0.001), diabetes mellitus (26.8% vs 12.7%, P=0.003), had a lower NIHSS score at admission (9 vs 12, P=0.049), a higher likelihood of stroke of undetermined etiology (56.3% vs 39.6%, P=0.010), and a higher level of CRP (4.5 vs 3 mg/L, P=0.030). For imaging characteristics, there was no difference between the two groups with respect to the MRI field strength or time between last known well and admission imaging. Patients without SVS had a poorer prognosis at 3 months and also during the long-term follow-up (table 1).

Neuroimaging

Association between absence of SVS and long-term mortality

The median long-term follow-up time was 1058 days (IQR 533–1671 days). In patients in whom the SVS was absent it was 587 days (IQR 44–1334 days) and, for patients in whom SVS was present, it was 1132 days (IQR 590-1710 days). The mortality rate in patients without SVS was higher during the long-term follow-up (figure 2, log-rank test P<0.001). In multivariable Cox regression analyses (figure 3), long-term mortality was associated with absence of SVS (aHR 2.11, 95% CI 1.35 to 3.29), active cancer (aHR 3.08, 95% CI 1.93 to 4.91), diabetes mellitus (aHR 1.78, 95% CI 1.19 to 2.64), lower ASPECTS (aHR 1.14, 95% CI 1.05 to 1.23), older age at admission (aHR 1.07, 95% CI 1.05 to 1.09) and elevated CRP (aHR 1.004, 95% CI 1.001 to 1.007). Higher levels of reperfusion were correlated with lower rates of long-term mortality, whether dichotomized for successful reperfusion (aHR 0.46, 95% CI 0.30 to 0.69, figure 3) or according to increasing eTICI grade (aHR 0.82, 95% CI 0.74 to 0.91, online supplemental eFigure II). Interaction analyses found no influence of active cancer, diabetes mellitus or successful reperfusion/ eTICI grade on the association between the absence of SVS and long-term mortality.

Association between absence of SVS and long-term functional outcome

For the analysis of functional outcome, follow-up groups were created, as summarized in online supplemental eFigure III. From the 476 patients with long-term outcome (mRS) available, 184 were included in the group with a follow-up time of 1.2 to 3 years (follow-up group 1), 150 in the group with a follow-up time of 3 to 5 years (follow-up group 2) and 142 in the group with a follow-up time of 5 to 9.5 years (follow-up group 3). Poor functional outcome (mRS 3-6) in the long term was associated with absence of SVS (aOR 2.90, 95% CI 1.29 to 6.55, online supplemental eFigure IV), active cancer (aOR 3.97, 95% CI 1.53 to 10.28), diabetes mellitus (aOR 2.85, 95% CI 1.39 to 5.85), low ASPECTS (aOR 1.23, 95% CI 1.07 to 1.40) and older age at admission (aOR 1.07, 95% CI 1.04 to 1.09). Higher levels of reperfusion were correlated with lower rate of poor functional outcome, whether dichotomized for successful reperfusion (aOR 0.32, 95% CI 0.16 to 0.67, online supplemental eFigure IV) or according to increasing eTICI score (aOR 0.75, 95% CI 0.63 to 0.88, online supplemental eFigure V). Again, interaction analyses found no influence of active cancer, diabetes mellitus or successful reperfusion/eTICI grade on the association between the absence of SVS and long-term poor functional outcome. In univariate sensitivity analyses of follow-up groups, the absence of

| Image of the set | Table 1 Comparison of baseline characteristics, short-term and long-term outcomes between patients with and without susceptibility vessel sign | | | | | | |
|--|--|------------------|---------------------|-------------------|---------|--|--|
| Image of the state of the st | | All (n=558) | SVS present (n=487) | SVS absent (n=71) | P value | | |
| app at there index | Baseline | | | | | | |
| Index240500000000000000000000000000000000000 | Age at admission median (IQR) | 72.75 (61–80.7) | 72.66 (60–80.86) | 74.2 (62.44–80) | 0.71 | | |
| Interpartner betwee stores and set of the store store and set of the store store and set of the s | Sex (female), n/N (%) | 286/558 (51.3%) | 241/487 (49.5%) | 45/71 (63.4%) | 0.031 | | |
| Interactional controls and MAC pior to stake, nV (%)ENSY (17)%SHARE (17 | Independence before stroke (mRS ≤2), n/N (%) | 551/557 (91.7%) | 453/487 (93.0%) | 58/70 (82.9%) | 0.009 | | |
| Index days prior is stake, AV N(N)1925 (23%)924 (94.2)927 (95.4)9.7Bit heates6.559 (15%)6.2497 (17%)197 (65%)107Bipplipher9255 (5%)92485 (57%)471 (6.2%)10Bipplipher16355 (15%)12486 (5%)171 (12%)12%Problem16355 (15%)12486 (5%)171 (12%)12%Bipplipher16355 (15%)12486 (5%)171 (12%)12%Problem16357 (5%)12486 (5%)171 (12%)12%Bipplipher1269 (12%)12486 (5%)171 (12%)12%Bitter1261 (12%)1247 (12%)127 (13%)12%Bitter1261 (12%)127 (12%)12%12%Bitter1261 (12%)127 (12%)12%12%Bitter1261 (12%)127 (12%)12%12%Bitter1261 (12%)127 (12%)12%12%Bitter1261 (12%)12% (12%)12%12%Bitter1262 (12%)12% (12%)12% (12%)12%Bitter1262 (12%)12% (12%)12% (12%)12%Bitter1262 (12%)12% (12%)12% (12%)12%Bitter1262 (12%)12% (12%)12% (12%)12% (12%)Bitter1262 (12%)12% (12%)12% (12%)12% (12%)Bitter1262 (12%)12% (12%)12% (12%)12% (12%)Bitter1262 (12%)12% (12%)12% (12%)12% (12%)Bitter1252 (12%)12% (12%)12% (1 | Anticoagulation (vitamin K-antagonist and NOAC) prior to stroke, n/N (%) | 65/557 (11.7%) | 56/486 (11.5%) | 9/71 (12.7%) | 0.84 | | |
| Bit | Antiplatelet drugs prior to stroke, n./N (%) | 178/557 (32%) | 152/486 (31.3%) | 26/71 (36.6%) | 0.41 | | |
| Delesi915(45%)91497(5.3%)917(12.8%)903Hypertension36558 (55%)914967 (55.7%)4707 (55%)0.7Sinding23556 (58%)23486 (55.3%)1707 (23.9%)0.8Previous troke23556 (15%)23496 (15.3%)1707 (23.9%)0.8Previous troke2356 (15%)23496 (15.3%)1707 (15.5%)0.8Standardition2467 (15%)23496 (15.3%)1507 (15.5%)0.8Standardition1567 (15.3%)167.07 (15.5%)0.80.8Hirston standardition1567 (15.3%)167.07 (15.5%)0.80.8Immerina transmowello densign inni, median (08)161.01 (20.9%)17.04 (15.3%)0.90.8MitS on admission median (08)161.01 (20.9%)161.01 (20.9%)0.90.90.9Immerina transmowello densign inni, median (08)234164 39%)234164 39%)24164 39%0.00.9Immerina transmowello densign inni, median (08)24164 39%)24164 39%24164 39%0.00.9Immerina transmowello densign inni, median (08)24164 39%24164 39%< | Risk factors, n/N (%) | | | | | | |
| ImportancialSign (Sec (Sec (Sec (Sec (Sec (Sec (Sec (Sec | Diabetes | 81/558 (14.5%) | 62/487 (12.7%) | 19/71 (26.8%) | 0.003 | | |
| Ippendiam12568(28%)2948(57.5%)1471(52.8%)1711(53.8%)1711Smaling12558(11%)5148(12.6%)1711(15.2%)120Action carc2558(11%)2547(11%)120(12.1%)0.001State durations120(17-28%)120(12.7%)120(12.1%)0.011State durations120(17-28%)120(12.7%)120(12.7%)0.011State durations120(17-28%)120(12.3%)0.0120.011State duration median (0R)120(17-28%)120(12.3%)0.0120.011State duration median (0R)120(17-28%)120(12.3%)0.0120.011State duration median (0R)120(12.3%)120(12.3%)0.0120.012State duration median (0R)120(12.3%)120(12.3%)0.0120.0120.012State duration median (0R)120(12.3%)120(12.3%)120(12.3%)0.0120.0120.012State duration median (0R)12552(17.3%)120(12.3%)120(12.3%)0.0120.0120.012State duration median (0R)12552(17.3%)120(12.3%)120(12.3%)< | Hypertension | 366/558 (65.6%) | 318/487 (65.3%) | 48/71 (67.6%) | 0.79 | | |
| Index10057 (25.1%)12248 (25.3%)1.7/1 (25.9%)0.82Previous code51487 (10.5%)1.7/1 (15.5%)0.22Previous code0.3558 (11.1%)51487 (10.5%)1.7/1 (15.5%)0.21Actree career0.40558 (13.1%)1.56 (71.5%)1.67 (71.5%)0.31Strot control code1.2 (7-17.0%)1.2 (71.7%)1.4 (6.0-32.27)0.4 (6.0-32.1%)0.31J1K55 on admission min, madian (0,0%)1.2 (7.17.1%)1.57 (10.1-36.1%)0.7 (10.13.7%)0.51J1K55 on admission, maging innin, madian (0,0%)1.6 (10.1-32.0%)1.7 (10.13.3%)0.7 (10.13.7%)0.51J1K55 on admission, madian (0,0%)2.175 (2.8 (2.8 %)1.2 (2.4 %)0.2 (2.7 %)0. | Dyslipidemia | 323/556 (58%) | 279/485 (57.5%) | 44/71 (62.0%) | 0.52 | | |
| Present51487 (1059)51471 (1057)0.22Active anarer5058 (1130)21671 (210)1571 (1130)0.0000Nets12671-260012672-27114670-32200.33Time from fast knoon well to admission in min, median (0R)12671-260012672-27114670-32200.30Nets12671-30012710127-1789.51-610.000Nets14610-320016101-320016101-3200170 (180)0.000APREMIN, Median (0R)10101-20016101-32001600-37000.000APREMIN, Median (0R)217058 (0R)1600-30000.0000.000APREMIN, Median (0R)217058 (0R)1600-30000.0000.000APREMIN, Median (0R)217058 (0R)1010-30000.0000.000Note of maneses, median (0R)217058 (0R)1010-30000.0000.000Note of maneses, median (0R)1400020502 (187)14818 (0R)0.0000.000APREMIN, Median (0R)14052 (0R)14818 (0R)0.0000.0000.000APREMIN, Median (0R)14052 (0R)14818 (0R)0.0000.000APREMIN, Median (0R)14052 (0R)14818 (0R)0.0000.000< | Smoking | 140/557 (25.1%) | 123/486 (25.3%) | 17/71 (23.9%) | 0.88 | | |
| <table-container>Arroward40580 (7.1%)51497 (7.1%)4.071 (7.1%)</table-container> | Previous stroke | 62/558 (11.1%) | 51/487 (10.5%) | 11/71 (15.5%) | 0.22 | | |
| Structure <td>Active cancer</td> <td>40/558 (7.1%)</td> <td>25/487 (5.1%)</td> <td>15/71 (21.1%)</td> <td><0.001</td> | Active cancer | 40/558 (7.1%) | 25/487 (5.1%) | 15/71 (21.1%) | <0.001 | | |
| Time from lask kaowa well to admission in mir, median (10R)12 (6 (71-28)12 (7-17)12 (7-17)14 (70-32)0.81NH85 on admission, median (10R)116 (101-30)17 (704 (22.5)0.71 (08.5)0.70Shela MKI, NK (%)161 (101-30)161 (101-30)170 (103-377)0.51AFSECTS score, median (10R)8 (6-9)8 (6-9)8 (7-9)0.000AFSECTS score, median (10R)240 (16.3)120 (16.3)257 (16.5)0.52Number of maneovers, median (0R)11 (-2)1 (-2)1 (-3)0.61Number of maneovers, median (0R)14 (-2)1 (-2)1 (-3)0.61Number of maneovers, median (0R)24 (16.2)144841 (86.9%)0.501 (18.9%)0.61Successful repertision, nN (%)24 (15.2)144841 (86.9%)1507 (12.9%)0.71eTIC1 aregories, nN (%)24 (52.5)144841 (86.9%)1577 (12.9%)0.71eTIC2 aregories, nN (%)24552 (25.1%)144841 (26.3%)1577 (11.1%)eTIC2 aregories, nN (%)24552 (25.1%)144841 (26.3%)1577 (11.1%)eTIC2 aregories, nN (%)24552 (25.1%)344841 (7.1%)8771 (13.5%)eTIC2 aregories, nN (%)24552 (25.1%)146841 (24.1%)1577 (11.1%)eTIC2 aregories, nN (%)2474 (25.3%)140481 (26.3%)1577 (11.1%)eTIC2 aregories (16.1%)14752 (25.6%)158481 (26.1%)1577 (11.1%)eTIC2 aregories (16.1%)14752 (25.3%)140481 (24.1%)1577 (11.1%)eTIC2 aregories (16.1%)14752 (25.2%)158481 (26.1%) <td>Stroke characteristics</td> <td></td> <td></td> <td></td> <td></td> | Stroke characteristics | | | | | | |
| <table-container>INISE on admission, median (QR)12 (7-17)12 (7-18)9 (-9 (-10)0 (-0)3 Texts (MR, MR, (MS)144555 (33%)15 (7484 (23%)17 (7493 (23%)0.70 (03-77)0.70 (0</table-container> | Time from last known well to admission in min, median (IQR) | 126 (71–286) | 126 (73–277) | 146 (70–322) | 0.83 | | |
| 3 Feis MR, n/N (%)19446 (2%)2/71 (3%)0.35Time from last known well to insaging in min, median (0R)161 (011–320)161 (010–320)170 (013–377)0.10APECTS score, needinal (0R)217/558 (38.9%)192/467 (39.4%)257 (15.2%)0.52Number of mansuers, median (0R)224 (64–397)233 (66–391)268 (157–431)0.69Number of mansuers, median (0R)11-2)1 (1-2)1 (1-3)0.100.70Scocessilt repression, n/N (%)2452 (55%)18481 (86.9%)55/07 (78.9%)0.998eTIC1 of mansuers, median (0R)24552 (35%)18481 (35.%)67/1 (8.5%)0.998eTIC1 12552 (2.1%)11/481 (2.3%)67/1 (1.5%)67/1 (1.5%)67/1 (1.5%)eTIC1 25064552 (1.5%)56441 (11.6%)87/1 (1.3%)7/1 (1.3%)eTIC2 266711/525 (2.23%)11/481 (2.4%)15/7 (1.1%)7/1 (1.5%)eTIC2 266711/525 (2.23%)11/481 (2.4%)15/7 (1.1%)7/1 (1.5%)eTIC2 266711/525 (2.23%)11/6481 (2.4%)15/7 (1.1%)7/1 (1.5%)eTIC3 266711/525 (2.23%)11/6481 (2.4%)15/7 (1.1%)7/1 (1.5%)eTIC3 266711/525 (2.3%)16/6487 (4.1%)15/7 (1.1%)7/1 (1.5%)eTIC3 266711/525 (2.3%) </td <td>NIHSS on admission, median (IQR)</td> <td>12 (7–17)</td> <td>12 (7–18)</td> <td>9 (5–16)</td> <td>0.049</td> | NIHSS on admission, median (IQR) | 12 (7–17) | 12 (7–18) | 9 (5–16) | 0.049 | | |
| Inter form last kown well to imaging in min, median (IQR)111 (101–320)111 (101–305)170 (103–377)0.51ASPECTS core, median (IQR)8 (6-9)8 (6-9)8 (6-9)8 (7-9)0.700.70VI prior to MT, MK (%)2736 (889%)120/487 (39.4%)257/1 (52.5%)0.520.52Time from last known well to groin puncture in min, median (IQR)234 (164-397)233 (166-391)268 (157-431)0.60Number of maneuvers, median (IQR)11-2)1 (1-2)1 (1-3)0.76Successful repertasion, NN (%)24552 (43.5%)184481 (3.7%)6771 (8.5%)0.76eTICI atomotivers, median (IQR)24552 (43.5%)114481 (3.7%)6771 (8.5%)0.77eTICI atomotivers, median (IQR)24552 (43.5%)114481 (3.7%)6771 (8.5%)0.77eTICI atomotivers, median (IQR)24552 (43.5%)114481 (3.7%)8771 (13.5%)0.77eTICI atomotivers, median (IQR)24552 (23.5%)114481 (23.5%)15771 (21.5%)11451 (23.5%)eTICI atomotivers, median (IQR)24558 (63.5%)258487 (53.0%)3471 (47.5%)11451 (23.5%)eTICI atomotivers, median (IQR)221558 (93.8%)196487 (45.5%)1371 (13.5%)11451 (23.5%)MI2200586 (13.1%)10487 | 3 Tesla MRI, n/N (%) | 184/555 (33%) | 157/484 (32%) | 27/71 (38%) | 0.35 | | |
| <table-container><table-row><table-row><table-row><table-row><table-row><table-row><table-row><table-row><table-row><table-row><table-row><table-row><table-row><table-row><table-row><table-row><table-row><table-row><table-row><table-row><table-row><table-row><table-row><table-row><table-row><table-row><table-row><table-row><table-row><table-row><table-row><table-row><table-row><table-row><table-row><table-row><table-row></table-row></table-row></table-row></table-row></table-row></table-row></table-row></table-row></table-row></table-row></table-row></table-row></table-row></table-row></table-row></table-row></table-row></table-row></table-row></table-row></table-row></table-row></table-row></table-row></table-row></table-row></table-row></table-row></table-row></table-row></table-row></table-row></table-row></table-row></table-row></table-row></table-row></table-container> | Time from last known well to imaging in min, median (IQR) | 161 (101–320) | 161 (101–305) | 170 (103–377) | 0.51 | | |
| IVT prior to MT, n/M (%)217/158 (84.9%)12/427 (93.4%)25/71 (53.2%)0.52Time from last knoow ned to groin puncture in mi, median (10,R)23/4 (164-397)23/1 (166-391)268 (157-431)0.76Number of maneuvers, median (10,R)11/-2)11/-2011/-300.76Successful regersion, n/M (%)59/71 (78.9%)0.97eTIC1 of24/52 (63.9%)11/481 (2.3%)67/1 (8.5%)0.97eTIC1 of24/52 (76.1%)11/481 (2.3%)67/1 (1.3%)67/1 (1.3%)eTIC1 of24/552 (76.1%)34/481 (7.1%)87/1 (1.13%)eTIC1 of24/552 (76.1%)34/481 (7.1%)87/1 (1.13%)eTIC1 of24/552 (76.1%)34/481 (7.1%)87/1 (1.13%)eTIC1 of11/552 (2.3.1%)11/481 (2.4%)15/71 (2.1.%)eTIC1 of11/552 (2.3.9%)11/481 (2.4%)11/71 (2.5.%)eTIC1 of11/552 (2.3.9%)11/481 (2.4%)15/71 (2.1.%)eTIC1 of11/552 (2.3.%)11/481 (2.4%)11/71 (2.5.%)eTIC1 of11/552 (2.3.%)11/7481 (2.5.%)11/71 (2.5.%)eTIC1 of11/552 (2.3.%)11/7481 (2.3.%)11/71 (2.5.%)eTIC1 of11/552 (2.3.%)11/7481 (2.3.%)11/71 (3.5.%) <trr>eTIC1 of11/552 (</trr> | ASPECTS score, median (IQR) | 8 (6–9) | 8 (6–9) | 8 (7–9) | 0.003 | | |
| Time from last known well to groin puncture in min, median (IQR) 234 (164–397) 233 (166–391) 268 (157–431) 0.60 Number of manexwers, median (IQR) 11(-2) 1 (1-2) 1 (1-3) 0.76 Successful repertision, NN (%) 6701 (82.9%) 81481 (82.9%) 5671 (78.9%) 0.998 eTIC1 cargories, nN (%) 124552 (4.35%) 18481 (3.7%) 671 (8.5%) 0.998 eTIC1 1 12552 (2.17%) 114481 (2.3%) 171 (1.4%) 174 eTIC1 2a 424552 (7.61%) 34481 (71%) 871 (1.13%) 1571 (21.1%) eTIC1 2b67 132/52 (2.3.1%) 117481 (2.43%) 1571 (21.1%) 1571 (21.1%) eTIC1 3 1571 (21.1%) 1571 (21.1%) 1571 (21.1%) 1571 (21.1%) eTIC1 4 22552 (2.6.3%) 116481 (2.41%) 1571 (21.1%) 1571 (21.1%) eTIC1 3 116481 (2.41%) 1571 (21.1%) 116481 (2.41%) 1571 (21.1%) 116481 (2.41%) 1571 (21.1%) 116481 (2.41%) 1571 (21.1%) 116481 (2.41%) 1571 (21.1%) 116481 (2.41%) 1571 (21.1%) 1161 (2.5%) 116481 (2.41%) 1571 | IVT prior to MT, n/N (%) | 217/558 (38.9%) | 192/487 (39.4%) | 25/71 (35.2%) | 0.52 | | |
| Number of manequers, median (lQR)1 (1-2)1 (1-2)1 (1-2)1 (1-3)0.76Successful reperfusion, n/N (%)474/52 (86.9%)414/481 (86.9%)671 (85.%)0.98eTICI categories, n/N24/55 (4.55%)18/481 (2.7%)671 (8.5%)671 (8.5%)4eTICI 2a11/52 (2.7.7%)11/481 (2.3%)17/1 (1.3%)17/1 (1.3%)17/1 (1.3%)eTICI 2b5064455 (1.59%)54481 (1.6%)8/71 (1.1.3%)15/1 (2.1.5%)eTICI 2b5111/52 (2.3.7%)11/461 (2.4.3%)15/1 (2.1.5%)5/1 (2.1.5%)eTICI 2b5111/52 (2.5.2.3%)11/1 (4.4.1%)15/1 (2.1.5%)eTICI 2b5111/52 (2.2.7.5%)11/461 (2.4.1%)15/1 (2.1.5%)eTICI 2b5111/52 (2.2.7.5%)11/461 (2.4.1%)15/1 (2.1.5%)eTICI 2b5111/52 (2.2.7.5%)11/461 (2.4.1%)15/1 (2.1.5%)eTICI 2b5111/52 (2.2.7.5%)11/461 (2.4.1%)15/1 (2.1.5%)eTICI 2b5111/52 (2.3.7%)11/641 (2.4.1%)15/1 (2.1.5%)eTICI 2b5111/52 (2.2.7%)11/641 (2.4.1%)15/1 (2.1.5%)eTICI 2b5111/52 (2.2.7%)11/641 (2.4.1%)15/1 (2.1.5%)eTICI 2b5111/552 (2.1.5%)10/445 (2.5%)10/1 (2.5%)eTICI 2b5111/552 (2.1.5%)10/445 (2.5%)10/1 (2.5%)eTICI 2b5111/552 (2.1.5%)10/445 (2.5%)10/1 (2.5%)eTICI 2b5111/552 (2.1.5%)10/445 (2.5%)10/1 (2.5%)eTICI 2b5111/552 (2.5%)10/457 (2.5%)10/1 (2.5%)eTICI 2b5111/553 | Time from last known well to groin puncture in min, median (IQR) | 234 (164–397) | 233 (166–391) | 268 (157–431) | 0.60 | | |
| Successful reperfusion, n/N (%) 67/1 (78.9%) 61/0 (78.9%) 0.098 eTICI categories, n/N (%) 24/552 (4.5%) 14/841 (8.6.9%) 6/71 (8.5%) 5/71 (78.9%) 5/71 (78.9%) eTICI categories, n/N (%) 24/552 (4.5%) 14/841 (7.5%) 6/71 (8.5%) 7/71 (8.5%) <td>Number of maneuvers, median (IQR)</td> <td>1 (1–2)</td> <td>1 (1–2)</td> <td>1 (1–3)</td> <td>0.76</td> | Number of maneuvers, median (IQR) | 1 (1–2) | 1 (1–2) | 1 (1–3) | 0.76 | | |
| eTICL aregonies, nN (%) 24/552 (Å.5%) 1/441 (Å.7%) 6/1 (Å.5%) 8/4 eTICL 1 1/552 (Å.5%) 1/441 (Å.7%) 6/1 (Å.5%) 8/4 eTICL 3 24/552 (Å.1%) 3/441 (Å.1%) 6/1 (Å.5%) 8/4 eTICL 3 3/452 (Å.1%) 3/441 (Å.1%) 8/1 (Å.1%) 8/1 (Å.1%) eTICL 2667 13/552 (Å.3%) 1/441 (Å.4%) 15/1 (Å.1%) 15/1 (Å.1%) eTICL 3 13/552 (Å.3%) 1/4481 (Å.4%) 15/1 (Å.1%) 15/1 (Å.1%) eTICL 3 13/552 (Å.3%) 1/4481 (Å.4%) 15/1 (Å.1%) 15/1 (Å.1%) eTICL 3 13/552 (Å.3%) 1/4481 (Å.4%) 15/1 (Å.1%) 15/1 (Å.1%) eTICL 3 13/552 (Å.3%) 1/4481 (Å.4%) 15/1 (Å.1%) 15/1 (Å.1%) eTICL 3 1/4481 (Å.4%) 1/411 (Å.5%) 1/411 (Å.5%) 1/411 (Å.5%) eTICL 3 1/4481 (Å.4%) 1/411 (Å.5%) 1/411 (Å.5%) 1/411 (Å.5%) eTICL 3 1/4581 (Å.5%) 1/41681 1/411 (Å.5%) 1/411 (Å.5%) eTICL 3 1/4581 (Å.5%) 1/41681 | Successful reperfusion, n/N (%) | 474/552 (85.9%) | 418/481 (86.9%) | 56/71 (78.9%) | 0.098 | | |
| eTIC10 24/52 (4.35%) 18/481 (3.7%) 6/71 (8.5%) 0.51 eTIC11 12/55 (2.17%) 11/481 (2.3%) 17/1 (1.4%) eTIC12a 25/52 (7.6%) 34/481 (7.1%) 8/71 (1.3%) eTIC12b50 64/55 (1.5%) 64/81 (1.1%) 8/71 (1.3%) eTIC12b57 13/255 (2.3.7%) 11/481 (2.4.1%) 15/71 (2.1.%) eTIC13 13/755 (2.3.7%) 116/481 (2.4.1%) 15/71 (2.1.%) eTIC13 13/755 (2.3.7%) 116/481 (2.4.1%) 15/71 (2.5.%) eTIC13 13/755 (2.3.7%) 116/481 (2.4.1%) 15/71 (2.1.%) eTIC13 13/755 (2.3.7%) 116/481 (2.4.1%) 15/71 (2.5.%) eTIC3 13/755 (2.3.7%) 10/487 (2.6.%) 3/71 (1.7.%) M2 10/558 (2.3.%) 25/847 (5.3.%) 3/71 (1.3.%) M2 10/558 (2.3.%) 10/487 (2.6.%) 3/71 (1.3.%) M2 10/558 (2.3.%) 3/647 (7.4.%) 3/71 (1.3.%) M2 10/558 (2.3.%) 3/647 (1.4.%) 3/71 (3.%) M2 10/558 (2.5.%) 3/648 (7.1.%) 3/71 (3.% | eTICI categories, n/N (%) | | | | | | |
| eTIC1 12/52 (2.17%) 11/48 (2.3%) 17/1 (1.4%) eTIC1 2a 34/81 (7.1%) 34/81 (7.1%) 87/1 (1.3%) eTIC1 2b50 6/643 (11.6%) 87/1 (1.3%) 15/7 (21.1%) eTIC1 2b50 13/552 (23.3%) 16481 (24.1%) 15/7 (21.1%) eTIC1 2b50 13/552 (23.3%) 16481 (24.1%) 15/7 (21.1%) eTIC1 2b50 13/552 (26.3%) 12/9481 (26.8%) 15/7 (21.1%) eTIC3 3 16491 (24.1%) 15/7 (21.1%) 11/11 eTIC3 4 147552 (26.3%) 12/9481 (26.8%) 16/71 (1.5%) sTIC4 94/58 (16.9%) 86/87 (18.1%) 6/71 (8.5%) 11/11 M1 202558 (23.3%) 25/847 (35.0%) 3/71 (1.5%) 11/11 M2 100487 (20.5%) 10/12 (3.5%) 11/11 11/11 M2 100487 (20.5%) 3/71 (1.5%) 11/11 11/11 M2 100487 (20.5%) 3/71 (1.5%) 11/11 11/11 M2 100487 (20.5%) 3/71 (1.5%) 11/11 11/11 M2 10/15 (1.5%) <td>eTICI 0</td> <td>24/552 (4.35%)</td> <td>18/481 (3.7%)</td> <td>6/71 (8.5%)</td> <td rowspan="7">0.51</td> | eTICI 0 | 24/552 (4.35%) | 18/481 (3.7%) | 6/71 (8.5%) | 0.51 | | |
| eTICI 2a 42/552 (7.61%) 94/481 (7.1%) 8/71 (1.3%) eTICI 2b50 64/552 (11.5%) 56/481 (11.6%) 8/71 (1.3%) eTICI 2b57 13/2552 (23.31%) 117/481 (24.3%) 15/71 (21.1%) eTICI 2b67 13/1552 (23.73%) 116481 (24.1%) 15/71 (21.1%) eTICI 2 13/1552 (23.73%) 116481 (24.1%) 15/71 (21.1%) eTICI 3 13/1552 (23.5%) 16/481 (24.1%) 15/71 (21.5%) eTICI 3 13/1552 (23.3%) 16/481 (24.1%) 15/71 (21.5%) eTICI 3 13/1552 (23.3%) 16/481 (24.1%) 16/71 (25.5%) eTICI 3 13/1552 (23.3%) 25/8487 (53.0%) 34/71 (47.9%) M2 119/558 (13.5%) 10/04/87 (20.5%) 19/71 (26.8%) M2 119/558 (13.5%) 36/487 (7.4%) 8/71 (13.3%) Other anterior occlusion 4/758 (7.9%) 36/487 (7.4%) 8/71 (13.3%) Other anterior occlusion 19/558 (13.5%) 19/14 (26.5%) 19/14 (25.5%) Other anterior occlusion 22/558 (9.8%) 19/6487 (40%) 26/71 (37%) Cardioembolic | eTICI 1 | 12/552 (2.17%) | 11/481 (2.3%) | 1/71 (1.4%) | | | |
| eTICI 2b50 64452 (11.59%) 56481 (11.6%) 8/71 (13.%) eTICI 2b67 132552 (23.31%) 117481 (24.3%) 15/71 (21.1%) eTICI 3 131552 (23.37%) 116481 (24.1%) 15/71 (21.1%) eTICI 3 147552 (26.3%) 129481 (26.8%) 18/71 (25.%) it occulsion, n/N (%) 129481 (26.8%) 18/71 (85.%) 14/72 (35.%) ICA 94558 (16.9%) 258487 (30.9%) 34/71 (47.9%) 14/72 (35.%) M2 190588 (13.9%) 100487 (20.5%) 1971 (26.8%) 14/72 (35.%) other anterior occlusion 19558 (16.9%) 36487 (18.1%) 67/1 (8.5%) 14/72 (35.%) other anterior occlusion 19558 (15.9%) 100487 (20.5%) 1971 (26.8%) 14/72 (35.%) other anterior occlusion 19558 (15.9%) 36487 (18.1%) 67/11 (3%) 11/72 (35.%) other anterior occlusion 100588 (55.%) 100487 (20.5%) 1071 (19.%) 11/72 (35.%) other anterior occlusion 13558 (13.1%) 102% 21/13 (35.%) 1071 (35.%) other anterior occlusion 21/13 (25.8%) 104(40%) </td <td>eTICI 2a</td> <td>42/552 (7.61%)</td> <td>34/481 (7.1%)</td> <td>8/71 (11.3%)</td> | eTICI 2a | 42/552 (7.61%) | 34/481 (7.1%) | 8/71 (11.3%) | | | |
| eTIC 2b67 132/552 (23.91%) 117481 (24.3%) 15/71 (21.1%) eTIC 2c 131/552 (23.73%) 116481 (24.1%) 15/71 (21.1%) eTIC 3 16481 (24.1%) 15/71 (21.1%) 15/71 (21.1%) Site of coclusion, n/N (%) 129481 (26.8%) 18/71 (25.4%) 18/71 (25.4%) ICA 94558 (62.9%) 88/487 (18.1%) 6/71 (8.5%) 4/71 (47.9%) M2 100487 (20.5%) 19/71 (26.8%) 19/71 (26.8%) 19/71 (26.8%) other anterior occlusion 94558 (13.9%) 100487 (20.5%) 3/71 (11.3%) 6/71 (13.5%) other anterior occlusion 9578 (13.9%) 100487 (20.5%) 8/71 (13.5%) 6/71 (13.5%) other anterior occlusion 9578 (13.9%) 10487 (40.5%) 8/71 (13.5%) 6/71 (13.5%) Stroke of other detinget of occlusion 10258 (13.9%) 19/487 (40.5%) 2/71 (3.5%) 6/71 (3.5%) Stroke of other detinined etiology 2/758 (13.9%) 19/487 (40.5%) 2/71 (3.5%) 0/71 (5.5%) Stroke of undetermined etiology sother etiologies, n/N (%) 2/71 (35.8%) 3/71 (43.9%) 0/71 (5.5%) 0/71 (5.5%) | eTICI 2b50 | 64/552 (11.59%) | 56/481 (11.6%) | 8/71 (11.3%) | | | |
| eTIC 12c 113 17552 (23.73%) 116481 (24.1%) 15/71 (21.1%) eTIC 13 129481 (26.8%) 18/71 (25.4%) Site of occlusion, n/N (%) 129481 (26.8%) 18/71 (25.4%) ICA 94/558 (16.9%) 88/87 (18.1%) 6/71 (8.5%) Montpace M1 292/558 (52.3%) 258/467 (33.0%) 3/171 (47.9%) Montpace Posterior occlusion 199/58 (13.9%) 3/6487 (74.5%) 3/171 (25.8%) Montpace Other anterior occlusion 292/558 (52.9%) 3/6487 (74.5%) 3/171 (13.9%) Montpace Cardioembolic 222/558 (39.8%) 3/6487 (74.5%) 3/71 (13.9%) Montpace Cardioembolic 222/558 (39.8%) 19/6487 (40%) 2/71 (3%) Montpace More than one cause 1/258 (13.1%) 11 (0.2%) 0/71 (0%) Montpace Stroke of ther determined etiology 2/858 (58.1%) 1/1 (15%) 2/71 (3%) Montpace Stroke of undetermined etiology so ther etiologies, n/N (%) 2/71 (3%) 1/20 (3%) 0/11 (5%) 0.010 Baseline laboratory findings 1/20 (3%) 1/20 (| eTICI 2b67 | 132/552 (23.91%) | 117/481 (24.3%) | 15/71 (21.1%) | | | |
| eTIC 3 147/552 (26.63%) 129/481 (26.8%) 18/71 (25.4%) Site of occlusion, n/N (%) ICA 94/558 (16.9%) 84/847 (18.1%) 6/11 (8.5%) 0.019 M1 202/558 (52.3%) 258/487 (53.0%) 3/171 (47.9%) 0.0147 (26.8%) Posterior occlusion 19/558 (1.3%) 10/0487 (20.5%) 3/171 (1.3%) 0.0147 (26.8%) Other anterior occlusion 44/558 (7.9%) 3/64/87 (7.4%) 3/171 (5.9%) 0.014 Stroke etiology (TOAST), n/N (%) 222/558 (39.8%) 19/04/87 (40%) 2/171 (5.9%) 0.016 More than one cause 15/58 (0.1%) 10 (0.2%) 2/171 (3.7%) 0.016 More than one cause 15/58 (0.1%) 10 (0.2%) 2/171 (3.7%) 0.016 More than one cause 15/58 (0.1%) 10 (0.2%) 2/171 (3.7%) 0.010 Stroke of undetermined etiology 2/1558 (3.1%) 11 (15.%) 2/171 (3.7%) 0.010 Stroke of undetermined etiology so ther etiologies, n/N (%) 2/1558 (1.9%) 19/487 (40%) 0/17 (5.6%) 0.010 Building (upR) Stroke of undetermined etiology so ther etiologies | eTICI 2c | 131/552 (23.73%) | 116/481 (24.1%) | 15/71 (21.1%) | | | |
| Site of occlusion, n/N (%) ICA 94/58 (16.%) 8/48/ (18.1%) 6/1 (8.5%) 0.01 M 292/58 (52.3%) 258/487 (53.0%) 3/171 (79.9%) 9/171 (26.8%) M2 101/58 (21.3%) 10/487 (20.5%) 3/171 (13.9%) 9/171 (26.8%) Other anterior occlusion 4/558 (7.9%) 3/6487 (7.4%) 8/11 (13.9%) 9/171 (26.8%) Other anterior occlusion 5/58 (16.9%) 3/6487 (7.4%) 8/171 (13.9%) 9/171 (26.8%) Other anterior occlusion 5/58 (16.9%) 3/6487 (7.4%) 3/171 (3.9%) 9/171 (3.9%) Internation occlusion 2/558 (38.8%) 19/487 (0.9%) 3/171 (3.9%) 9/171 (3.9%) Internation occlusion 2/2558 (38.8%) 19/6487 (0.9%) 2/171 (3.9%) 9/171 (3.9%) Internation occlusion 10/171 (3.9%) 10/171 (3.9%) 2/171 (3.9%) 9/171 (3.9%) Internation occlusion 2/2558 (38.9%) 19/487 (0.9%) 3/174 (9.9%) 9/174 (3.9%) Internation occlusion 2/158 (31.9%) 1/169/10% 3/174 (9.9%) 9/174 (9.9%) Internation occlusion 2/169/10%< | eTICI 3 | 147/552 (26.63%) | 129/481 (26.8%) | 18/71 (25.4%) | | | |
| ICA94/558 (16.9%)88/487 (18.1%)6/71 (8.5%)0.010M1292/558 (52.3%)528/487 (53.0%)3/71 (47.9%)9/71 (6.8%)M2190/58 (1.3%)100/487 (20.5%)19/71 (26.8%)9/71 (1.3%)Other anterior occlusion44/558 (7.9%)3/6487 (7.4%)8/71 (1.3%)Other anterior occlusion5/58 (1.6%)5/487 (1.0%)4/71 (5.6%)Torre etiology (TOAST), n/N (%)222/558 (39.8%)19/6487 (40%)26/71 (37%)Arred ioembolic222/558 (39.8%)19/6487 (40%)26/71 (37%)More than one cause1/558 (0.1%)10.2%)0/71 (9%)Iarge artery atherosclerosis73/558 (31.8%)10.2%)0/71 (9%)Stroke of other determined etiology23/558 (41.9%)19/40%)0/71 (5%)Stroke of undetermined etiology so other etiologies, n/N (%)23/558 (41.8%)19/40%)0/71 (56.3%)Stroke of undetermined etiology so other etiologies, n/N (%)23/558 (41.8%)19/40%)0/71 (56.3%)Stroke of undetermined etiology so other etiologies, n/N (%)23/558 (41.8%)19/40%)0/71 (56.3%)Stroke of undetermined etiology so other etiologies, n/N (%)23/558 (41.8%)19/40%)0/71 (56.3%)Stroke of undetermined etiology so other etiologies, n/N (%)23/558 (41.8%)19/40%)0/71 (56.3%)Stroke of undetermined etiology0.01010.1%10.1%10.1%Stroke of undetermined etiology0.01010.1%10.1%Stroke of undetermined etiology0.1%10.1%10.1%10.1% <tr< td=""><td>Site of occlusion, n/N (%)</td><td></td><td></td><td></td><td></td></tr<> | Site of occlusion, n/N (%) | | | | | | |
| M1 292/58 (52.3%) 258/487 (53.0%) 34/71 (47.9%) M2 109/58 (21.3%) 100/487 (20.5%) 19/71 (26.8%) Posterior occlusion 4/1558 (7.9%) 36/487 (7.4%) 8/71 (11.3%) Other anterior occlusion 9/558 (1.6%) 5/487 (1.0%) 8/71 (11.3%) Stroke etiology (TOAST), n/N (%) 222/558 (39.8%) 19/6487 (40%) 26/71 (37%) 016 More than one cause 122/558 (39.8%) 19/6487 (40%) 26/71 (37%) 017 More than one cause 222/558 (39.8%) 19/6487 (40%) 26/71 (37%) 017 More than one cause 221/558 (31.9%) 19/6487 (40%) 26/71 (37%) 017 Stroke of undetermined etiology 24/758 (41.9%) 19/40% 40/71 (56%) 011 Baseline laboratory findings 234/558 (41.9%) 19/40% 40/71 (56.3%) 0.11 Lip, Jr, median (IQR) Stroke of undetermined etiology so ther etiologies, n/N (%) 888 (497–1758) 869 (495.5–1743) 1020 (543–2731) 0.17 Baseline Lip, GPL, median (IQR) 33(3–8) 33(3–8) 33(3–8) 33(3–8) 33(3–8 | ICA | 94/558 (16.9%) | 88/487 (18.1%) | 6/71 (8.5%) | 0.010 | | |
| M2 119/558 (21.3%) 100/487 (20.5%) 19/71 (26.8%) Posterior occlusion 44/558 (7.9%) 36/487 (7.4%) 8/71 (11.3%) Other anterior occlusion 9/558 (16.%) 5/487 (1.0%) 4/71 (5.6%) Stroke etiology (TOAST), n/N (%) 222/558 (39.8%) 19/487 (40%) 26/71 (37%) 0/16 More than one cause 1/558 (0.1%) 1 (0.2%) 0/71 (0%) 0/71 (3%) 0/71 (3%) Arge artery atherosclerosis 73/558 (13.1%) 71 (15%) 2/71 (3%) 0/16 Stroke of undetermined etiology 28/558 (41.9%) 19/48/7 (40%) 40/71 (56%) 0/11 Tarke of undetermined etiology so ther etiologies, n/N (%) 23/558 (41.9%) 19/48/7 (40%) 40/71 (56%) 0/11 Stroke of undetermined etiology so ther etiologies, n/N (%) 23/558 (41.9%) 19/48/7 (40%) 10/10 (56.%) 0/11 Baseline laboratory findings 19/48/7 (40%) 10/20 (54.2-731) 0.101 0.11 H ₀ µ ₁ | M1 | 292/558 (52.3%) | 258/487 (53.0%) | 34/71 (47.9%) | | | |
| Posterior occlusion 44/558 (7.9%) 36/487 (7.4%) 8/71 (11.3%) Other anterior occlusion 9/558 (1.6%) 5/487 (1.0%) 4/71 (5.6%) Stroke etiology (TOAST), n/N (%) 222/558 (39.8%) 196/487 (40%) 26/71 (37%) 016 Cardioembolic 222/558 (0.1%) 1 (0.2%) 0/71 (0%) 0/71 (0%) More than one cause 1/558 (0.1%) 1 (0.2%) 0/71 (3%) 0/16 Stroke of other determined etiology 28/558 (31.3%) 71 (15%) 2/71 (3%) 0/17 Stroke of undetermined etiology so ther etiologies, n/N (%) 234/558 (41.9%) 194 (40%) 40/71 (56.3%) 0.010 Baseline laboratory findings 234/558 (41.9%) 194/487 (40%) 40/71 (56.3%) 0.010 CARP, mg/L, median (IQR) 888 (497–1758) 869 (495.5–1743) 1020 (543–2731) 0.17 Mb g/L, median (IQR) 315 (24–146) 136 (24–147) 130.5 (119–144) 0.11 CRP, mg/L, median (IQR) 3 (3–8) 3 (3–8) 45 (3–12.5) 0.303 Leukocytes, g/L, median (IQR) 8.3 (6.6–10.3) 8.21 (6.6–10.3) 8.8 (7.2–10.3) | M2 | 119/558 (21.3%) | 100/487 (20.5%) | 19/71 (26.8%) | | | |
| Other anterior occlusion 9/558 (1.6%) 5/487 (1.0%) 4/71 (5.6%) Stroke etiology (TOAST), n/N (%) 22/258 (39.8%) 196/487 (40%) 26/71 (37%) 0.16 Cardioembolic 22/258 (39.8%) 196/487 (40%) 26/71 (37%) 0.17 More than one cause 1/558 (0.1%) 1 (0.2%) 0/71 (0%) 0.17 Large artery atherosclerosis 73/558 (13.1%) 71 (15%) 2/71 (3%) 0.16 Stroke of other determined etiology 24/558 (5%) 25 (5%) 3/71 (4%) 0.11 Stroke of undetermined etiology us other etiologies, n/N (%) 23/558 (41.8%) 194/487 (40%) 40/71 (56.3%) 0.010 Baseline laboratory findings 23/558 (41.8%) 194/487 (40%) 40/71 (56.3%) 0.11 B-dimer, µg/L, median (IQR) 888 (497–1758) 869 (495.5–1743) 1020 (543–2731) 0.17 Mb, g/L, median (IQR) 135 (124–146) 136 (124–147) 130.5 (119–144) 0.11 CRP, mg/L, median (IQR) 3(3–8) 3(3–8) 4.5 (3–12.5) 0.30 Leukocytes, g/L, median (IQR) 8.3 (6.6–10.3) 8.2 (1.6–10.3) | Posterior occlusion | 44/558 (7.9%) | 36/487 (7.4%) | 8/71 (11.3%) | | | |
| Stroke etiology (TOAST), n/N (%) 212/558 (39.8%) 196/487 (40%) 26/71 (37%) 016 More than one cause 1/558 (0.1%) 1 (0.2%) 0/71 (0%) 1 Large artery atherosclerosis 73/558 (13.1%) 71 (15%) 2/71 (3%) 1 Stroke of other determined etiology 28/558 (5%) 25 (5%) 3/71 (4%) 1 Stroke of undetermined etiology so other etiologies, n/N (%) 234/558 (41.9%) 194 (40%) 40/71 (56.3%) 0.010 Stroke of undetermined etiology vs other etiologies, n/N (%) 233/558 (41.8%) 194/487 (40%) 40/71 (56.3%) 0.010 Baseline laboratory findings 233/558 (41.8%) 194/487 (40%) 40/71 (56.3%) 0.11 P-dimer, µg/L, median (IQR) 888 (497–1758) 869 (495.5–1743) 1020 (543–2731) 0.17 Hb, g/L, median (IQR) 135 (124–146) 136 (124–147) 130.5 (119–144) 0.11 CRP, mg/L, median (IQR) 3(3–8) 3(3–8) 4.5 (3–12.5) 0.303 Leukocytes, g/L, median (IQR) 8.3 (6.6–10.3) 8.2 (16.6–10.3) 8.8 (7.2–10.3) 0.21 Leukocytes, g/L, median (IQ | Other anterior occlusion | 9/558 (1.6%) | 5/487 (1.0%) | 4/71 (5.6%) | | | |
| Cardioembolic 222/558 (39.8%) 196/487 (40%) 26/71 (37%) 0.016 More than one cause 1/558 (0.1%) 1 (0.2%) 0/71 (0%) 10 Large artery atherosclerosis 73/558 (13.1%) 71 (15%) 2/71 (3%) 10 Stroke of other determined etiology 28/558 (5%) 25 (5%) 3/71 (4%) 10 Stroke of undetermined etiology so other etiologies, n/N (%) 233/558 (41.8%) 194 (40%) 40/71 (56.3%) 0.010 Baseline laboratory findings 5 194/487 (40%) 40/71 (56.3%) 0.010 P-dimer, µg/L, median (IQR) 888 (497–1758) 869 (495.5–1743) 1020 (543–2731) 0.17 Hb, g/L, median (IQR) 135 (124–146) 136 (124–147) 130.5 (119–144) 0.11 CRP, mg/L, median (IQR) 3 (3–8) 3 (3–8) 3 (3–8) 8.8 (72–10.3) 0.303 Leukocytes, g/L, median (IQR) 8.3 (6.6–10.3) 8.21 (6.6–10.3) 8.8 (72–10.3) 0.21 Leukocytes, g/L, median (IQR) 21 (180.5–268) 20 (182–268) 25 (177–278) 0.92 | Stroke etiology (TOAST), n/N (%) | | | | | | |
| More than one cause 1/558 (0.1%) 1 (0.2%) 0/71 (0%) Large artery atherosclerosis 73/558 (13.1%) 71 (15%) 2/71 (3%) Stroke of other determined etiology 28/558 (5%) 25 (5%) 3/71 (4%) Stroke of undetermined etiology so other etiologies, n/N (%) 234/558 (41.9%) 194 (40%) 40/71 (56.3%) 0.010 Stroke of undetermined etiology so other etiologies, n/N (%) 233/558 (41.8%) 194/487 (40%) 40/71 (56.3%) 0.010 Baseline laboratory findings - | Cardioembolic | 222/558 (39.8%) | 196/487 (40%) | 26/71 (37%) | 0.016 | | |
| Large artery atherosclerosis 73/558 (13.1%) 71 (15%) 2/71 (3%) Stroke of other determined etiology 28/558 (5%) 25 (5%) 3/71 (4%) Stroke of undetermined etiology 234/558 (41.9%) 194 (40%) 40/71 (56%) Stroke of undetermined etiology vs other etiologies, n/N (%) 233/558 (41.8%) 194/487 (40%) 40/71 (56.3%) 0.010 Baseline laboratory findings 233/558 (41.8%) 194/487 (40%) 40/71 (56.3%) 0.010 CRP, mg/L, median (IQR) 888 (497–1758) 869 (495.5–1743) 1020 (543–2731) 0.17 CRP, mg/L, median (IQR) 135 (124–146) 136 (124–147) 130.5 (119–144) 0.11 CRP, mg/L, median (IQR) 3 (3–8) 3 (3–8) 4.5 (3–12.5) 0.030 Leukocytes, g/L, median (IQR) 8.3 (6.6–10.3) 8.21 (6.6–10.3) 8.8 (7.2–10.3) 0.21 Thrombocytes, g/L, median (IQR) 221 (180.5–268) 220 (182–268) 225 (177–278) 0.92 | More than one cause | 1/558 (0.1%) | 1 (0.2%) | 0/71 (0%) | | | |
| Stroke of other determined etiology 28/558 (5%) 25 (5%) 3/71 (4%) Stroke of undetermined etiology 234/558 (41.9%) 194 (40%) 40/71 (56%) 0.010 Stroke of undetermined etiology vs other etiologies, n/N (%) 233/558 (41.8%) 194/487 (40%) 40/71 (56.3%) 0.010 Baseline laboratory findings 5 5 5 194/487 (40%) 40/71 (56.3%) 0.010 P-dimer, µg/L, median (IQR) 888 (497–1758) 869 (495.5–1743) 1020 (543–2731) 0.17 Hb, g/L, median (IQR) 135 (124–146) 136 (124–147) 130.5 (119–144) 0.11 CRP, mg/L, median (IQR) 3(3–8) 3(3–8) 4.5 (3–12.5) 0.030 Leukocytes, g/L, median (IQR) 8.3 (6.6–10.3) 8.21 (6.6–10.3) 8.8 (7.2–10.3) 0.21 Thrombocytes, g/L, median (IQR) 211 (180.5–268) 200 (182–268) 225 (177–278) 0.92 | Large artery atherosclerosis | 73/558 (13.1%) | 71 (15%) | 2/71 (3%) | | | |
| Stroke of undetermined etiology 234/558 (41.9%) 194 (40%) 40/71 (56%) Stroke of undetermined etiology vs other etiologies, n/N (%) 233/558 (41.8%) 194/487 (40%) 40/71 (56.3%) 0.010 Baseline laboratory findings 5 5 5 5 5 5 6 9 9 5 7 5 6 9 9 40/71 (56.3%) 0.010 5 Baseline laboratory findings 5 5 5 6 9 9 5 7 7 0.17 6 7 6 7 7 0.17 130.5 (119–144) 0.11 0.1 | Stroke of other determined etiology | 28/558 (5%) | 25 (5%) | 3/71 (4%) | | | |
| Stroke of undetermined etiology vs other etiologies, n/N (%) 233/558 (41.8%) 194/487 (40%) 40/71 (56.3%) 0.010 Baseline laboratory findings D-dimer, µg/L, median (IQR) 888 (497–1758) 869 (495.5–1743) 1020 (543–2731) 0.17 Hb, g/L, median (IQR) 135 (124–146) 136 (124–147) 130.5 (119–144) 0.11 CRP, mg/L, median (IQR) 3 (3–8) 3 (3–8) 4.5 (3–12.5) 0.030 Leukocytes, g/L, median (IQR) 8.3 (6.6–10.3) 8.21 (6.6–10.3) 8.8 (7.2–10.3) 0.21 Thrombocytes, g/L, median (IQR) 221 (180.5–268) 220 (182–268) 225 (177–278) 0.92 | Stroke of undetermined etiology | 234/558 (41.9%) | 194 (40%) | 40/71 (56%) | | | |
| Baseline laboratory findings Baseline laboratory findings D-dimer, μg/L, median (IQR) 888 (497–1758) 869 (495.5–1743) 1020 (543–2731) 0.17 Hb, g/L, median (IQR) 135 (124–146) 136 (124–147) 130.5 (119–144) 0.11 CRP, mg/L, median (IQR) 3 (3–8) 3 (3–8) 4.5 (3–12.5) 0.030 Leukocytes, g/L, median (IQR) 8.3 (6.6–10.3) 8.21 (6.6–10.3) 8.8 (7.2–10.3) 0.21 Thrombocytes, g/L, median (IQR) 221 (180.5–268) 220 (182–268) 225 (177–278) 0.92 | Stroke of undetermined etiology vs other etiologies, n/N (%) | 233/558 (41.8%) | 194/487 (40%) | 40/71 (56.3%) | 0.010 | | |
| D-dimer, μg/L, median (IQR)888 (497–1758)869 (495.5–1743)1020 (543–2731)0.17Hb, g/L, median (IQR)135 (124–146)136 (124–147)130.5 (119–144)0.11CRP, mg/L, median (IQR)3 (3–8)3 (3–8)4.5 (3–12.5)0.030Leukocytes, g/L, median (IQR)8.3 (6.6–10.3)8.21 (6.6–10.3)8.8 (7.2–10.3)0.21Thrombocytes, g/L, median (IQR)221 (180.5–268)220 (182–268)225 (177–278)0.92 | Baseline laboratory findings | | | | | | |
| Hb, g/L, median (IQR) 135 (124–146) 136 (124–147) 130.5 (119–144) 0.11 CRP, mg/L, median (IQR) 3 (3–8) 3 (3–8) 4.5 (3–12.5) 0.030 Leukocytes, g/L, median (IQR) 8.3 (6.6–10.3) 8.21 (6.6–10.3) 8.8 (7.2–10.3) 0.21 Thrombocytes, g/L, median (IQR) 221 (180.5–268) 220 (182–268) 225 (177–278) 0.92 | D-dimer, μg/L, median (IQR) | 888 (497–1758) | 869 (495.5–1743) | 1020 (543–2731) | 0.17 | | |
| CRP, mg/L, median (IQR) 3 (3–8) 3 (3–8) 4.5 (3–12.5) 0.030 Leukocytes, g/L, median (IQR) 8.3 (6.6–10.3) 8.21 (6.6–10.3) 8.8 (7.2–10.3) 0.21 Thrombocytes, g/L, median (IQR) 221 (180.5–268) 220 (182–268) 225 (177–278) 0.92 | Hb, g/L, median (IQR) | 135 (124–146) | 136 (124–147) | 130.5 (119–144) | 0.11 | | |
| Leukocytes, g/L, median (IQR) 8.3 (6.6–10.3) 8.21 (6.6–10.3) 8.8 (7.2–10.3) 0.21 Thrombocytes, g/L, median (IQR) 221 (180.5–268) 220 (182–268) 225 (177–278) 0.92 | CRP, mg/L, median (IQR) | 3 (3–8) | 3 (3–8) | 4.5 (3–12.5) | 0.030 | | |
| Thrombocytes, g/L, median (IQR) 221 (180.5–268) 220 (182–268) 225 (177–278) 0.92 | Leukocytes, g/L, median (IQR) | 8.3 (6.6–10.3) | 8.21 (6.6–10.3) | 8.8 (7.2–10.3) | 0.21 | | |
| | Thrombocytes, g/L, median (IQR) | 221 (180.5–268) | 220 (182–268) | 225 (177–278) | 0.92 | | |

| Table 1 Continued | | | | |
|--|-----------------|---------------------|--------------------|---------|
| | All (n=558) | SVS present (n=487) | SVS absent (n=71) | P value |
| Fibrinogen, g/L, median (IQR) | 3.08 (2.56–3.7) | 3.085 (2.59–3.67) | 3.01 (2.385–4.055) | 0.98 |
| INR, median (IQR) | 1.01 (1–1.07) | 1 (1–1.07) | 1.03 (1–1.08) | 0.11 |
| Stroke outcomes | | | | |
| Death before 3 months, n/N (%) | 102/558 (18.3%) | 79/487 (16.2%) | 23/71 (32.4%) | 0.003 |
| mRS at 3 months, median (IQR) | 2 (1–4) | 2 (14) | 3.5 (1–6) | 0.004 |
| Poor functional outcome at 3 months (mRS 3–6), n/N (%) | 239/539 (44.3%) | 197/469 (42.0%) | 42/70 (60.0%) | 0.006 |
| Long-term follow-up time, days, median (IQR) | 1058 (533–1671) | 1132 (590–1710) | 587 (44–1334) | <0.001 |
| Long-term deaths, n/N (%) | 189/558 (33.9%) | 151/487 (31.0%) | 38/71 (53.5%) | < 0.001 |
| Long-term mRS, median (IQR) | 3 (1–6) | 2 (1–6) | 6 (2–6) | < 0.001 |
| Long-term poor functional outcome (mRS 3–6), n/N (%) | 248/476 (52%) | 203/411 (49.4%) | 45/65 (69.2%) | 0.003 |

ASPECTS, Alberta Stroke Program Early CT Scores; CAD, coronary artery disease; CRP, C-reactive protein; eTICI, expanded treatment in cerebral infarction; Hb, hemoglobin; ICA, internal carotid artery; INR, international normalized ratio; IQR, interquartile range; IVT, intravenous thrombolysis; M1 and M2, first and second segment of the middle cerebral artery; MCA, middle cerebral artery; mRS, modified Rankin Scale; NIHSS, National Institutes of Health Stroke Scale; NOAC, non-vitamin K antagonist oral anticoagulant; SVS, susceptibility vessel sign; TOAST, Trial of ORG 10172 in Acute Stroke Treatment.

SVS was associated with poor functional outcomes in follow-up group 1 (OR 2.62, 95% CI 1.16 to 5.89) and follow-up group 3 (OR 5.06, 95% CI 1.10 to 23.21) but not in follow-up group 2 (OR 1.88, 95% CI 0.67 to 5.31). In the multivariate sensitivity analyses of the follow-up groups, the absence of SVS was not associated with poor functional outcomes in any of the follow-up groups (online supplemental eFigure VI).

DISCUSSION

This study's main finding is that the absence of SVS remained associated with poorer outcomes and higher mortality during the long-term follow-up even after adjustment for underlying conditions and interventional outcome parameters known to be associated with the absence of SVS and poor outcome (such as active cancer and diabetes mellitus).

Long-term outcome and survival rates

Reports on the association between the SVS and functional outcome are conflicting. A single-center retrospective registry study reported that poor outcome was more common in patients with SVS (present vs absent: 57.1% vs 33.3%, P=0.02).¹⁴ However, multivariable analysis identified only age





Beyeler M, et al. J NeuroIntervent Surg 2023;0:1-7. doi:10.1136/jnis-2023-020793

and reperfusion as independent predictors of clinical outcome. Conversely, Bourcier *et al* reported higher rates of poor outcome among patients without SVS (present vs absent: 35%vs 74%, P=0.004) and this association was also perceptible after correcting for other cofactors known to be associated with functional outcome (aOR 8.7; 95% CI 1.1 to 69.4).⁶ A post hoc analysis of the Contact Aspiration vs Stent Retriever for Successful Revascularization (ASTER) trial reported no difference in functional outcome at 3 months between patients with and without SVS (risk ratio (RR) 1.27, 95% CI 0.9 to 1.6; P=0.08); however, this trial was not powered to detect such an association.¹³ A recent meta-analysis reported that patients with SVS were more likely to have a poor functional outcome at 3 months (RR 1.5,



Figure 3 Association between long-term mortality and demographic characteristics, relevant risk factors, and stroke parameters. Adjusted hazard ratios (aHR) and 95% confidence intervals (CI) from the multivariate Cox regression analyses comparing long-term mortality and demographics, relevant risk factors and stroke parameters. Long-term mortality was associated with absence of SVS, diabetes mellitus, active cancer, low ASPECTS, older age at admission and increased CRP. Interaction analyses (*, **, ***) did not identify any substantial influence of diabetes mellitus, active cancer or successful reperfusion on the relationship between absence of SVS and long-term mortality. P interaction indicates P value for corresponding interaction terms. ASPECTS, Alberta Stroke Program Early CT Score; CRP, C-reactive protein; IVT, intravenous thrombolysis; LKW, last known well; NIHSS, National Institutes of Health Stroke Scale; SVS, susceptibility vessel sign.

 $95\%\,{\rm CI}$ 1.3 to 1.7), although wide heterogeneity among the studies was noted (I^2=87.8%, P<0.001). 12

Here we report similar results to those of Bourcier et alnamely, a poor 3-month outcome was more often observed in patients in whom SVS was absent. Moreover, this association was present even when looking at the adjusted long-term clinical outcome and survival rates. We assume that the non-significant results in the sensitivity analyses of follow-up groups are attributable to the small number of patients in each group, leading to imprecise estimates (online supplemental eFigure VI).²⁰ The association between SVS and long-term patient outcome could potentially be explained by thrombus composition: white thrombi are more common in patients without SVS and red thrombi in patients with SVS.² More specifically, red thrombi are easier to manipulate during the intervention and often vield higher reperfusion rates after the endovascular procedure.^{21 22} Patients with SVS would therefore be more likely to have a favorable outcome, as they would tend to have higher reperfusion rates after MT. Another potential explanation for differences in long-term outcome between patients with and without SVS might reflect underlying conditions, which would affect the thrombus composition and also the long-term survival rates. An association between cancer, diabetes mellitus and the SVS has been previously described in the same cohort.^{7 8} Fibrin-rich thrombi are strongly correlated with cancer-related stroke,⁹ and changes of the inner lining of blood vessels caused by diabetes mellitus increase the chances of adhesion of thrombi that are rich in fibrin and have a low erythrocyte count.^{23 24} Both conditions would therefore increase the chance of SVS being absent in this subgroup of stroke patients. However, we saw no significant interaction effect between these cofactors (successful reperfusion, active cancer and diabetes mellitus) and SVS status on long-term outcome rates. This further underlines present uncertainties between SVS and other factors that may affect the outcome.^{8–12}

A potentially relevant finding of this study is that the CRP level was higher in patients with absent SVS and was also associated with a higher mortality event rate after adjustment for SVS (figure 3). Therefore, a potential underlying acute or chronic inflammation could be related to the formation of fibrin- and platelet-rich thrombi, the absence of SVS and, finally, a poorer long-term outcome.²⁵ ²⁶ Further prospective studies could include other potential causes of acute and chronic inflammation to elucidate the association between possible inflammatory factors impacting the outcome and the absence of SVS. More aggressive treatment of such underlying conditions could then improve long-term outcome rates.

SVS positivity is subject to time-dependent variations in deoxyhemoglobin; however, detection of SVS in our study seemed to be independent of MRI field strength and time from last known well to imaging.³ Our results could be partly explained by our stringent inclusion criteria as we focused on patients presenting with large vessel occlusion in the early time window (see Methods). The acquisition of SWI sequences in institutions with available MRI for acute stroke diagnosis is of clinical relevance given the prognostic value of SVS (better reperfusion rate after thrombectomy and higher mid- and long-term survival) as well as its diagnostic value (detection of hemorrhage, concomitant microbleeds and recognition of underlying treatable conditions more quickly).^{7 8 27} Despite the known time-consuming cost of acquiring SWI sequences, Fischer et al showed that conducting brain MRI at admission (compared with brain CT) showed no difference in door-to-puncture time in MT-treated patients, even those with early presentation and severe stroke.²⁸ Additionally,

the development and implementation of faster SWI acquisition methods (highly accelerated wave–controlled aliasing in parallel imaging (CAIPI) SWI) should enable a reduction of SWI sequence acquisition times (currently ~5 min) by a factor of 3–5 in the future, making the SWI acquisition even more valuable.²⁹ Furthermore, as most sites use CT rather than MRI for acute stroke work-up, our findings must be confirmed in a CT-diagnosed stroke population to generalize the prognostic value of thrombus imaging characterization in the long-term outcome. Even if the correlation between SVS and HVS was described previously, the analyses performed in our study should be performed for HVS independently.^{4,5}

Limitations

Our study has several limitations. First, it is a single-center retrospective study with all the commonly attributed biases. Second, even if no difference in the identification of SVS was found between 1.5T and 3T MRI in this study, this limitation may have influenced the sensitivity for detecting SVS and consequently the predictive value of the absence of SVS for poorer long-term outcomes. Third, due to the retrospective design, not all underlying conditions, potentially leading to the absence of SVS and poor long-term outcomes, were systematically documented and assessable. Furthermore, the lack of direct histological examination of the thrombus composition limits the broader interpretation of the study results. Fourth, although patients were treated with second-generation devices, the long recruitment period with not well-established MT procedures at the beginning of recruitment, could have introduced biased reperfusion success assessment due to interventionalist experience and in-hospital workflows. Fifth, in the sensitivity analyses of the follow-up groups, the number of patients per subgroup was insufficient and caution is advised when interpreting these results.

CONCLUSION

The absence of SVS is independently associated with poor longterm outcome and higher mortality rates in patients with stroke after MT. It appears that this association cannot be explained by already associated comorbidities alone, and further studies are warranted.

Author affiliations

¹Department of Neurology, Inselspital, Bern University Hospital, and University of Bern, Bern, Switzerland

²Graduate School for Health Sciences, University of Bern, Bern, Switzerland ³Institute for Diagnostic and Interventional Neuroradiology, Inselspital, Bern University Hospital, and University of Bern, Bern, Switzerland ⁴Department of Neuroradiology, Medical Center, University of Freiburg, Faculty of

Medicine, University of Freiburg, Freiburg, Germany

⁵Department of Medical Oncology, Inselspital, Bern University Hospital, and University of Bern, Bern, Switzerland

⁶Neurology Department, University Hospital of Basel, University of Basel, Basel, Switzerland

Twitter Morin Beyeler @Morin_Beyeler, Christoph C Kurmann @chris_kurmann, Urs Fischer @FishingNeurons and Adnan Mujanovic @adnan_mujanovic

Contributors MB: conception and design, data acquisition, analysis and interpretation of data, and writing of the manuscript. ER: data acquisition and critical revision of the manuscript for important intellectual content. LW: data acquisition and critical revision of the manuscript for important intellectual content. CCK: data acquisition and critical revision of the manuscript for important intellectual content. EIIP: data acquisition and critical revision of the manuscript for important intellectual content. EIIP: data acquisition and critical revision of the manuscript for important intellectual content. UF: conception and design, critical revision of the manuscript for important intellectual content. JK: conception and design, analysis and interpretation of data, writing of the manuscript, critical revision of the manuscript for important intellectual content, and supervision. AM: conception and design, interpretation of data, critical revision of the manuscript for important and action as the guarantor of the study. All other authors contributed to critical revision of the

Neuroimaging

manuscript for important intellectual content.

Funding This work was supported by grants provided by the Kurt und Senta Hermann-Stiftung (grant number WNK-228), by the Swiss Academy of Medical Sciences (SAMS) within the framework of the Young Talents in Clinical Research Program (grant number YTCR 03/19) and grants from the Clinical Trials Unit Bern, University of Bern (grant number 84801869).

Competing interests MB reports research support from the Kurt und Senta Hermann-Stiftung. JK reports grants from the Swiss Academy of Medical Sciences/ Bangerter Foundation, Swiss Stroke Society, and Clinical Trials Unit Bern during the conduct of the study. UF reports grants during the conduct of the study from Medtronic, Stryker, and CSL Behring, unrelated to the submitted work. JG is a global principal investigator of STAR (Solitaire FR Thrombectomy for Acute Revascularisation), Clinical Event Committee member of the PROMISE study (Prospective, Multicenter, Observational, Single-Arm European Registry on the ACE Reperfusion Catheters and the Penumbra System in the Treatment of Acute Ischemic Stroke; Penumbra), and a principal investigator and consultant for the SWIFT DIRECT study (Solitaire With the Intention for Thrombectomy Plus Intravenous tPA Versus DIRECT Solitaire Stent-Retriever Thrombectomy in Acute Anterior Circulation Stroke; Medtronic) and receives Swiss National Science Foundation grants for magnetic resonance imaging in stroke. MA reports personal fees from Bayer, Bristol-Myers Squibb, Medtronic, Amgen, Daiichi Sankyo, Nestlé Health Sciences, Boehringer Ingelheim, and Covidien during the conduct of the study. TRM reports research support from the Bangerter Rhyner Foundation, Swiss National Foundation, and the Swiss Heart Foundation. SJ reports grants from the Swiss National Science Foundation and the Swiss Heart Foundation. EIIP reports grants from the Swiss National Science Foundation. MRH reports grants from Swiss National Science Foundation, SITEM Research Support Funds and Swiss Heart Foundation, not directly related to this manuscript.

Patient consent for publication Not applicable.

Ethics approval The local ethics committee approved the study in accordance with Swiss law (reference ID: 2019–00547, Kantonale Ethikkomission Bern).

Provenance and peer review Not commissioned; externally peer reviewed.

Data availability statement Data are available upon reasonable request.

Supplemental material This content has been supplied by the author(s). It has not been vetted by BMJ Publishing Group Limited (BMJ) and may not have been peer-reviewed. Any opinions or recommendations discussed are solely those of the author(s) and are not endorsed by BMJ. BMJ disclaims all liability and responsibility arising from any reliance placed on the content. Where the content includes any translated material, BMJ does not warrant the accuracy and reliability of the translations (including but not limited to local regulations, clinical guidelines, terminology, drug names and drug dosages), and is not responsible for any error and/or omissions arising from translation and adaptation or otherwise.

ORCID iDs

Morin Beyeler http://orcid.org/0000-0001-5911-7957 Nebiyat Filate Belachew http://orcid.org/0000-0001-5285-5922 Christoph C Kurmann http://orcid.org/0000-0001-5670-5675 Eike Immo I Piechowiak http://orcid.org/0000-0002-0647-9273 David Seiffge http://orcid.org/0000-0002-647-9273 David Seiffge http://orcid.org/0000-0002-6167-3343 Johannes Kaesmacher http://orcid.org/0000-0002-6187-7289 Adnan Mujanovic http://orcid.org/0000-0002-6839-7134

REFERENCES

- 1 Goyal M, Menon BK, van Zwam WH, *et al*. Endovascular thrombectomy after large-vessel ischaemic stroke: a meta-analysis of individual patient data from five randomised trials. *Lancet* 2016;387:1723–31.
- 2 Bourcier R, Duchmann Z, Sgreccia A, et al. Diagnostic performances of the susceptibility vessel sign on MRI for the prediction of macroscopic thrombi features in acute ischemic stroke. J Stroke Cerebrovasc Dis 2020;29:105245.
- 3 Brinjikji W, Duffy S, Burrows A, et al. Correlation of imaging and histopathology of thrombi in acute ischemic stroke with etiology and outcome: a systematic review. J Neurointerv Surg 2017;9:529–34.

- 4 Flacke S, Urbach H, Keller E, *et al*. Middle cerebral artery (MCA) susceptibility sign at susceptibility-based perfusion MR imaging: clinical importance and comparison with hyperdense MCA sign at CT. *Radiology* 2000;215:476–82.
- 5 Liebeskind DS, Sanossian N, Yong WH, et al. CT and MRI early vessel signs reflect clot composition in acute stroke. Stroke 2011;42:1237–43.
- 6 Bourcier R, Volpi S, Guyomarch B, et al. Susceptibility vessel sign on MRI predicts favorable clinical outcome in patients with anterior circulation acute stroke treated with mechanical thrombectomy. AJNR Am J Neuroradiol 2015;36:2346–53.
- 7 Belachew NF, Dobrocky T, Aleman EB, et al. Susceptibility vessel sign in patients undergoing mechanical thrombectomy for acute ischemic stroke. AJNR Am J Neuroradiol 2021;42:1949–55.
- 8 Beyeler M, Belachew NF, Kielkopf M, et al. Absence of susceptibility vessel sign in patients with malignancy-related acute ischemic stroke treated with mechanical thrombectomy. *Front Neurol* 2022;13:930635.
- 9 Fu C-H, Chen C-H, Lin Y-H, *et al*. Fibrin and platelet-rich composition in retrieved thrombi hallmarks stroke with active cancer. *Stroke* 2020;51:3723–7.
- 10 Zhang R, Zhou Y, Liu C, et al. Overestimation of susceptibility vessel sign: a predictive marker of stroke cause. Stroke 2017;48:1993–6.
- 11 Kim SK, Yoon W, Kim TS, et al. Histologic analysis of retrieved clots in acute ischemic stroke: correlation with stroke etiology and gradient-echo MRI. AJNR Am J Neuroradiol 2015;36:1756–62.
- 12 Liu M, Li L, Li G. The different clinical value of susceptibility vessel sign in acute ischemic stroke patients under different Interventional therapy: a systematic review and meta-analysis. *J Clin Neurosci* 2019;62:72–9.
- 13 Bourcier R, Mazighi M, Labreuche J, *et al.* Susceptibility vessel sign in the ASTER trial: higher recanalization rate and more favourable clinical outcome after first line stent retriever compared to contact aspiration. *J Stroke* 2018;20:416.
- 14 Kim SK, Yoon W, Heo TW, et al. Negative susceptibility vessel sign and underlying intracranial atherosclerotic stenosis in acute middle cerebral artery occlusion. AJNR Am J Neuroradiol 2015;36:1266–71.
- 15 Elston DM. Survivorship bias. J Am Acad Dermatol 2021;2021:1–2.
- 16 Adams HP, Bendixen BH, Kappelle LJ, et al. Classification of subtype of acute ischemic stroke. Definitions for use in a multicenter clinical trial. TOAST. Trial of Org 10172 in Acute Stroke Treatment. Stroke 1993;24:35–41.
- 17 Liebeskind DS, Bracard S, Guillemin F, et al. eTICI reperfusion: defining success in endovascular stroke therapy. J Neurointerv Surg 2019;11:433–8.
- 18 Beyeler M, Weber L, Kurmann CC, et al. Association of reperfusion success and emboli in new territories with long term mortality after mechanical thrombectomy. J Neurointerv Surg 2022;14:326–32.
- 19 Beyeler M, Weber L, Buffle E, et al. Long-term outcome and quality of life in patients with stroke presenting with extensive early infarction. SVIN 2022;2.
- 20 Oxman AD, Guyatt GH. A consumer's guide to subgroup analyses. *Ann Intern Med* 1992;116:78–84.
- 21 Mereuta OM, Abbasi M, Fitzgerald S, *et al.* Histological evaluation of acute ischemic stroke thrombi may indicate the occurrence of vessel wall injury during mechanical thrombectomy. *J Neurointerv Surg* 2022;14:356–61.
- 22 Dutra BG, Tolhuisen ML, Alves HCBR, et al. Thrombus imaging characteristics and outcomes in acute ischemic stroke patients undergoing endovascular treatment. Stroke 2019;50:2057–64.
- 23 Gao Q, Qi P, Wang J, et al. Effects of diabetes mellitus complicated by admission hyperglycemia on clot histological composition and ultrastructure in patients with acute ischemic stroke. *BMC Neurol* 2022;22:130.
- 24 Ye G, Gao Q, Qi P, *et al*. The role of diabetes mellitus on the thrombus composition in patients with acute ischemic stroke. *Interv Neuroradiol* 2020;26:329–36.
- 25 Man SFP, Connett JE, Anthonisen NR, et al. C-reactive protein and mortality in mild to moderate chronic obstructive pulmonary disease. Thorax 2006;61:849–53.
- 26 Maluf CB, Barreto SM, Giatti L, *et al*. Association between C reactive protein and all-cause mortality in the ELSA-Brasil cohort. *J Epidemiol Community Health* 2020;74:421–7.
- 27 Khaladkar SM, Chanabasanavar V, Dhirawani S, *et al*. Susceptibility weighted imaging: an effective auxiliary sequence that enhances insight into the imaging of stroke. *Cureus* 2022;14:e24918.
- 28 Fischer U, Branca M, Bonati LH, et al. Magnetic resonance imaging or computed tomography for suspected acute stroke: association of admission image modality with acute recanalization therapies, workflow metrics, and outcomes. Ann Neurol 2022;92:184–94.
- 29 Conklin J, Longo MGF, Cauley SF, et al. Validation of highly accelerated WAVE-CAIPI SWI compared with conventional SWI and T2*-weighted gradient recalled-echo for routine clinical brain MRI at 3T. AJNR Am J Neuroradiol 2019;40:2073–80.

SUPPLEMENTAL MATERIALS

Susceptibility Vessel Sign, a Predictor of Long-Term Outcome in Stroke Patients

Treated with Mechanical Thrombectomy

eTable I - Technical Information on SWI sequence

| Field strength | 1.5T | 3T |
|--|--|--|
| MRI scanner | Avanto, Aera | Sykra, Prsima, Verio, Vida |
| MRI sequence included in standard stroke protocol | -ax DWI -ax FLAIR -ax SWI -ax intracranial TOF -ax DSC Perfusion -ax T1 post contrast -cor extracranial CE-MRA | -ax DWI -ax FLAIR -ax SWI -ax intracranial TOF -ax DSC Perfusion -ax T1 post contrast -cor extracranial CE-MRA |
| Scanner parameters for SWI | TR, 49 ms; TE, 40 ms; flip angle, 15.0°; section thickness, 1.6, 1.8, or 2.0 mm; and intersection gap, 0 mm. | TR, 27 ms; TE, 20 ms; flip angle, 15.0°; section thickness, 2.0 mm; and intersection gap, 0 mm. |

MRI: magnet resonance imaging; T: Tesla; TR: repetition time; TE: time-to-echo. Device manufacturer: Siemens Healthcare GmbH, Erlangen, Germany. All the scanners were upgraded between 2016 – 2018 with slight modification of scanning parameters.



eFigure I - Study flowchart

Inclusion and exclusion of study participants. MRI indicates magnetic resonance imaging; SVS, susceptibility vessel sign; and SWI susceptibility-weighted imaging.





These included demographic characteristics, relevant risk factors, and stroke parameters (including eTICI as ordinal variable for the reperfusion outcome).

aHR indicates adjusted hazard ratio; ASPECTS, Alberta Stroke Program Early Computed Tomography Score; CI, confidence interval; CRP, C-reactive protein; eTICI, expanded treatment in cerebral infarction; IVT, intravenous thrombolysis; LKW, last known well; NIHSS, National Institutes of Health Stroke Scale; SVS, susceptibility vessel sign. P interaction indicates P-value for corresponding interaction terms.



eFigure III - Follow-up time and establishment of follow-up groups

Patients treated with mechanical thrombectomy between January 2010 and December 2018 and with available SVS status were included. Surviving patients were contacted for long-term follow-up by telephone interview between August 2019 and July 2020. Because of the heterogeneous follow-up times, three follow-up groups of approximately equal size were established (1.2–3 years, 3–5 years, 5–9.5 years) to guarantee statistical power (see Methods).



eFigure IV – Association between long-term poor functional outcome (defined as mRS 3–6) and demographics, relevant risk factors and stroke parameters in the multivariate logistic regression model

This figure summarizes the association between long-term poor functional outcome and demographics, relevant risk factors, and stroke parameters. Adjusted odds ratios (aOR) and 95% confidence intervals are reported. Absence of SVS, diabetes mellitus, low ASPECTS and older age at admission were associated with poor long-term functional outcome. Interaction analyses (* and **) did not identify any substantial influence of the diabetes mellitus and active cancer on the association between absence of SVS and long-term poor functional outcome. Successful reperfusion was omitted from interaction analyses because of collinearity. ASPECTS indicates Alberta Stroke Program Early Computed Tomography Score; CRP, C-reactive protein; IVT, intravenous thrombolysis; LKW, last known well; N.A., not applicable; NIHSS, National Institutes of Health Stroke Scale; SVS, susceptibility vessel sign.



eFigure V – Association between long-term poor functional outcome (defined as mRS 3–6) with eTICI

This analysis included demographics, relevant risk factors and stroke parameters (including eTICI as ordinal variable for the reperfusion outcome) in the multivariate logistic regression model.

aOR indicates adjusted odds ratio; ASPECTS, Alberta Stroke Program Early Computed Tomography Score; CI, confidence interval; CRP, C-reactive protein; eTICI, expanded treatment in cerebral infarction; IVT, intravenous thrombolysis; LKW, last known well; NIHSS, National Institutes of Health Stroke Scale; SVS, susceptibility vessel sign.



eFigure VI – Association between long-term poor functional outcome (defined as mRS 3–6) and other covariates in the different follow-up groups

This sensitivity analysis of the different follow-up groups (described in eFigure III) included demographics, relevant risk factors and stroke parameters in the multivariate logistic regression model. The number of patients included in the multivariate analysis in each group is indicated in parenthesis.

aOR indicates adjusted odds ratio; ASPECTS, Alberta Stroke Program Early Computed Tomography Score; CI, confidence interval; CRP, C-reactive protein; IVT, intravenous thrombolysis; LKW, last known well; NIHSS, National Institutes of Health Stroke Scale and SVS, susceptibility vessel sign.