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Original research

Mechanical thrombectomy in ischemic stroke after cardiovascular procedures: a propensity-matched cohort analysis

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ABSTRACT

Background Stroke after a cardiovascular procedure (CVP) is a devastating complication adversely affecting outcome. Mechanical thrombectomy (MT) has not been investigated systematically in this population.

Objective To carry out a retrospective study in patients undergoing MT for early stroke after CVP, aiming to further characterize this cohort of patients, and to evaluate the efficacy, safety, procedural characteristics, and outcome of MT.

Methods A single-center stroke registry of patients who received MT was analyzed. Baseline and procedural parameters, mortality, functional outcome, recanalization rates, and complications were evaluated. Propensity score matching was carried out, identifying a control cohort with non-periprocedural large vessel occlusion (LVO).

Results Overall 913 patients were included (mean age 73.0 (±13.0) years, 52.5% female, median National Institutes of Health Stroke Scale score 15 (10–19)). Eleven patients with a LVO after a recent (<30 days postoperatively) CVP were identified (n=3 transcatheter aortic valve and n=1 surgical aortic valve replacements (SAVR), n=3 coronary bypass grafting (CABG) surgeries, n=2 SAVR+CABG, and n=2 aortic surgeries). After matching, 8 patients in the CVP group were compared with 16 patients in the matched cohort. Comparable rates of reperfusion were achieved. Time from symptom onset to groin puncture (171.5 min (136.3, 178.3) vs 284.0 min (215.0, 490.5); p=0.039), as well as recanalization (195.0 min (146.0, 201.0) vs 419.0 min (274.0, 613.0); p=0.028) was faster in the CVP group. However, this was not reflected by an improved outcome (modified Rankin Scale score after 90 days: 5.5 (3.3, 6.0) vs 5.0 (4.0, 6.0), mortality after 90 days 50.0% vs 37.5%). Complications did not differ between the groups.

Conclusions Use of MT for LVO stroke in patients after a recent CVP is a safe and efficient treatment in comparison with patients with a non-periprocedural LVO undergoing MT.

WHAT IS ALREADY KNOWN ON THIS TOPIC

⇒ Although mechanical thrombectomy has been used widely for large vessel occlusion stroke, data on its use for stroke after cardiovascular procedures are scarce.

WHAT THIS STUDY ADDS

⇒ We were able to demonstrate that mechanical thrombectomy in patients with stroke after cardiovascular procedures is a safe and efficient treatment method after propensity score matching.

HOW THIS STUDY MIGHT AFFECT RESEARCH, PRACTICE OR POLICY

⇒ Patients with stroke after cardiovascular procedures should be screened for endovascular stroke treatment on an individual basis.

INTRODUCTION

Early stroke after cardiovascular procedures (CVPs), defined as a cerebral vascular event during the first 30 days postoperatively, is a debilitating complication adversely influencing survival and recovery.[1] The incidence of early ischemic stroke after CVP ranges from 0 to 5%, depending on the complexity of the procedure and the investigated patient population.[2] For stand-alone surgical aortic valve replacement (SAVR) the incidence of stroke has been described at 1.5–5%, while a concomitant myocardial revascularization leads to a higher risk of stroke.[2] Even higher rates of stroke have been documented after complex cardiovascular procedures, such as multiple valve surgery.[3] For minimally invasive procedures such as transcatheter aortic valve replacement (TAVR), a continuous improvement of interventional techniques, newer generation valves, and use of TAVR in lower-risk patients has led to a decrease of cerebral complications.[4 5] The etiology of stroke after cardiac procedures is multifactorial since patient-related risk factors, such as older age, prior stroke or cardiac surgery, atrial fibrillation, poor left ventricular function, known carotid or peripheral artery stenosis, as well as procedural aspects, e.g intraoperative cross-clamping time and time on cardiopulmonary bypass, lead to an increased risk of cerebrovascular complications.[2] In TAVR, aortic manipulation due to advancement of guide catheters, manipulation of the calcified aortic valve (including post-dilatation),

and co-morbidities, such as history of atrial fibrillation, stroke or transient ischemic attacks, poor left ventricular function, and smaller aortic valve area, have been identified as risk factor for a CVP-associated stroke.[2 6–8]

Endovascular mechanical thrombectomy (MT) has been shown to reduce death and improve outcome in patients with stroke and large vessel occlusion (LVO), and has therefore been incorporated into guideline recommendations.[9–11] Since the emergence of MT as a valid treatment option for patients with LVO stroke, only a limited number of reports have documented its feasibility as treatment after cardiovascular surgeries, as well as minimally invasive interventions such as TAVR.[12–18]

We therefore conducted a retrospective study in patients undergoing MT for early stroke after CVP, aiming to further characterize this cohort of patients, and to evaluate the efficacy, safety, procedural characteristics, and outcome of MT. Our hypothesis was that MT for patients with LVO after a preceding CVP had a comparable outcome and procedural safety of MT in comparison with a matched cohort of patients undergoing MT for non-periprocedural stroke.

METHODS

Data availability

The data that support the findings of this study are available from the corresponding author on reasonable request.

Cohort description and patient selection

Between June 2015 and December 2020 all consecutive patients aged 18 and older undergoing endovascular treatment for stroke at the University Medical Center Hamburg-Eppendorf were screened for inclusion in this observational cohort study. The CVP group was defined by treatment with MT after a recent (<30 days) cardiovascular procedure, including patients undergoing cardiac surgery using extracorporeal circulation, as well as minimally invasive cardiovascular interventions. The study was carried out according to the protocol of the German Stroke Registry.[19] An ethics vote was obtained from the ethics committee of the Chamber of Physicians, Hamburg, Germany. Written and informed consent was acquired either from the patient directly, or via legal representatives.

Data acquisition

Medical records were analyzed for baseline characteristics including medical history, medication and laboratory values. Procedural data of the cardiovascular intervention, imaging, as well as MT was collected. The prehospital modified Rankin Scale (mRS) score and National Institutes of Health Stroke Scale (NIHSS) values before MT was judged by an experienced neurologist.

Outcome and safety measures

Complete recanalization was defined as Thrombolysis in Cerebral Infarction (TICI) score ≥2b. Clinical outcome parameters included National Institutes of Health Stroke Scale (NIHSS) and modified Rankin Scale (mRS) scores at discharge, as well as the mRS score at 90 days. Functional independence was defined as mRS score ≤2 at 90 days. Peri-interventional complications, such as intracerebral vascular dissection, subarachnoid hemorrhage, clot migration, and symptomatic intracranial hemorrhage, were documented and assessed by a neurointerventionalist.

Statistical analysis

Categorical variables are shown as absolute numbers and percentages. Continuous variables are described by mean±SD or median and the first and third quartile (Q1, Q3). Normally distributed values are shown as mean and SD, otherwise as median and the first and third quartile (Q1, Q3).

We performed propensity score matching using the MatchIt package with a 2:1 ratio without replacement, using the nearest neighbor matching algorithm with a caliper width of 0.25, which has been shown as adequate for estimation of the average treatment effect in our population.[20–22] Propensity scores were calculated using the age, sex, mRS score before admission, NIHSS score on admission, intravenous (IV) thrombolysis, occlusion site and also dyslipidemia, atrial fibrillation, arterial hypertension, and diabetes mellitus. Normally distributed variables were compared using Student's t-test, non-normally distributed variables using the Mann-Whitney U test, and categorical variables using Fisher's exact test.

A two-sided p value of <0.05 was considered statistically significant. All statistical analyses were carried out using R statistical software (version 3.5.2, R Foundation for Statistical Computing, Vienna, Austria).

RESULTS

Baseline and stroke characteristics

A total of 928 patients underwent MT for acute LVO. Of these, 15 (1.6%) did not provide consent and were excluded, leaving 913 patients for current analyses. The mean age of patients was 73.0 (±13.0) years, 52.5% were female, and the median NIHSS score was documented at 15 (10, 19). In total, 11 patients who had an LVO stroke after a recent cardiovascular procedure were identified. The CVP cohort consisted of a heterogeneous collection of cardiovascular procedures: n=3 TAVR (one transfemoral, two transapical) without cardiopulmonary bypass, n=1 stand-alone SAVR, n=2 combined SAVR and coronary bypass grafting procedures, n=3 singular coronary bypass grafting, and n=2 aortic surgeries. Overall, stroke occurred within 7 days after the cardiovascular procedure in 10 patients (90.9%), while one (9.1%) cerebral vascular event occurred on the 14th postoperative day. For detailed description of characteristics see table 1. With regard to the origin of stroke, a clear causality could only be identified in two patients: one patient had an intraventricular thrombus after myocardial infarction (case 5), and one patient had an embolizing infective endocarditis after mechanical AVR which, after MT, was followed by replacement of the infected valve (case 6).

Before propensity score matching, in the control cohort without CVP, NIHSS score at stroke recognition was 15 (10, 19). In comparison to the non-matched control cohort significantly more patients in the CVP cohort had diabetes mellitus (16.1% vs 45.5%; p=0.028) and dyslipidemia (11.5% vs 63.6%; p<0.001), while further baseline parameters did not differ significantly (table 2). With regard to the occluded vessel, no statistically significant differences were noted, although a numerically higher amount of posterior circulation strokes was registered within the CVP group (36.4% in comparison with 13.2% in the non-matched control cohort; p=0.367 for location of occlusion overall). The use of concomitant IV thrombolysis next to MT was markedly higher in the non-matched control cohort with 506 (57.0%) patients receiving peri-interventional thrombolytic therapy, which was the case in only one patient (9.1%) in the CVP group (p=0.004). Baseline characteristics of CVP subgroups according to the use of cardiopulmonary bypass (surgical vs interventional cohort) are displayed in online supplemental table S1.

Table 1 Individual patient characteristics of patients with stroke due to large vessel occlusion after cardiovascular procedures

Case	Cardiovascular procedure	Indication	Emergency	CPB time	POD of stroke	Symptoms
1	tfTAVR	AS	No	–	0	Aphasia and right-sided hemiplegia
2	taTAVR	AS	No	–	0	Aphasia and left-sided hemiplegia
3	taTAVR	AS	No	–	0	Left-sided hemiplegia
4	SAVR+CABG	AS+CAD	No	75	6	Dysarthria and left-sided hemiplegia
5	SAVR+CABG	AS+CAD	Yes (STEMI)	224	14	Left-sided hemiparesis of upper extremity
6	SAVR	AS (bicuspid valve, IE)	Yes (cardiogenic shock)	105	7	Left-sided hemiparesis
7	CABG	CAD	No	131	1	Aphasia
8	CABG	CAD	Yes (NSTEMI, CPR)	75	1	Vigilance impairment
9	CABG	CAD	No	106	1	Right-sided hemiplegia
10	Arch and ascending aorta replacement	Aneurysm of ascending aorta	No	144	1	Aphasia and right-sided hemiplegia
11	Partial arch and ascending aorta replacement	Aneurysm of ascending aorta	No	148	0	Vigilance impairment

AS, aortic stenosis; CABG, coronary artery bypass grafting; CAD, coronary artery disease; CPB, cardiopulmonary bypass; CPR, cardiopulmonary resuscitation; IE, infectious endocarditis; NSTEMI, non-ST-segment elevation myocardial infarction; POD, postoperative day; SAVR, surgical aortic valve replacement; STEMI, ST-segment elevation myocardial infarction; taTAVR, transapical transcatheter aortic valve replacement; tfTAVR, transfemoral transcatheter aortic valve replacement.

Interventional characteristics, outcome, and complications after propensity score matching

After propensity score matching, 16 patients without CVP were matched with eight patients with a CVP, leading to an equal distribution of baseline characteristics and comorbidities.

Significantly faster times from symptom onset to groin puncture were found in the CVP group (CVP vs matched control cohort: 171.5 min (136.3, 178.3) vs 284.0 min (215.0, 490.5); p=0.039), as well as time from symptom onset to recanalization (CVP vs matched control cohort: 195.0 min (146.0, 201.0) vs 419.0 min (274.0, 613.0); p=0.028).

Successful recanalization (TICI ≥2b) could be achieved in six out of eight patients (75.0%) of the CVP cohort, which was comparable to the matched cohort (14 out of 16 patients (87.5%)). An equal number of retrieval attempts were registered across both groups (CVP vs matched control cohort: 2 (1, 2) vs 2 (1, 2); p=0.819).

Table 2 Baseline characteristics of the original and propensity-matched cohort

	Before propensity score matching			After propensity score matching		
Baseline characteristics	**Control cohort (n=902)**	**CVP cohort (n=11)**	**P value**	**Control cohort (n=16)**	**CVP cohort (n=8)**	**P value**
Age in years (mean±SD)	73.0±13.0	70.9±15.7	0.601	66.9±16.5	68.5±18.1	0.834
Female (%)	473 (52.4)	6 (54.5)	1.000	13 (81.3)	4 (50.0)	0.266
Arterial hypertension (%)	597 (67.2)	10 (90.9)	0.178	12 (75.0)	7 (87.5)	0.859
Diabetes mellitus (%)	143 (16.1)	5 (45.5)	0.028	6 (37.5)	3 (37.5)	1.000
Hyperlipoproteinemia (%)	102 (11.5)	7 (63.6)	0.001	6 (37.5)	4 (50.0)	0.884
Atrial fibrillation (%)	293 (33.0)	3 (27.3)	0.939	4 (25.0)	3 (37.5)	0.874
Stroke characteristics						
Prestroke mRS score (median; Q1, Q3)	0.0 (0.0, 1.0)	0.0 (0.0, 0.0)	0.418	0.0 (0.0, 0.3)	0.0 (0.0, 0.3)	0.968
NIHSS score at onset (median; Q1, Q3)	15 (10, 19)	20 (14, 27)	0.079	16.0 (12.8, 20.0)	16.5 (11.5, 26.5)	1.000
ASPECTS (median; Q1, Q3)	8.0 (6.0, 9.0)	7.0 (5.0, 8.0)	0.317	7.00 (3.5, 7.0)	6.0 (5.0, 8.5)	0.474
Intravenous tPA (%)	506 (57.0)	1 (9.1)	0.004	2 (12.5)	1 (12.5)	1.000
Location of occlusion						
Tandem occlusion (%)	39 (4.6)	1 (9.1)		1 (6.2)	1 (12.5)	
ICA (%)	42 (4.9)	1 (9.1)		3 (18.8)	1 (12.5)	
M1 proximal (%)	227 (26.5)	3 (27.3)		6 (37.5)	3 (37.5)	
M1 distal (%)	158 (18.5)	1 (9.1)		0 (0.0)	1 (12.5)	
M2 (%)	135 (15.8)	1 (9.1)		1 (6.2)	0 (0.0)	
Posterior circulation (%)	113 (13.2)	4 (36.4)		5 (31.3)	2 (25.0)	

Categorical variables are shown as absolute numbers and percentages. Continuous variables are described by mean±SD or median and the first and third quartile (Q1, Q3). Percentages are given for patients with the full availability of the investigated variable.
ASPECTS, Alberta Stroke Programme Early CT Score; CVP, cardiovascular procedure; ICA, intracranial carotid artery; M1, first segment of middle cerebral artery; M2, second segment of middle cerebral artery; mRS, modified Rankin Scale; NIHSS, National Institutes of Health Stroke Scale; tPA, tissue plasminogen activator.

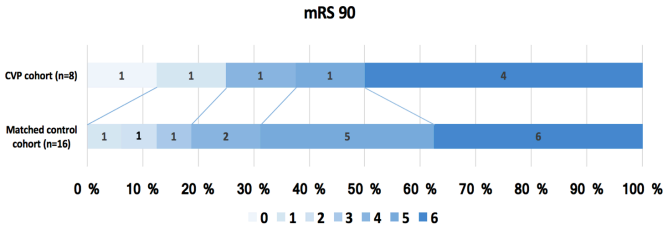

Figure 1 Ordinal modified Rankin scale (mRS) after 90-day follow-up (mRS 90). Cohort undergoing a cardiovascular procedure (CVP) versus the matched control cohort (n = 8, 2:1 propensity score matched patients).

Faster recanalization times were, however, not reflected by an improved outcome since the mRS score at 90 days did not differ significantly between groups after propensity score matching (CVP vs matched control cohort: 5.5 (3.3, 6.0) vs 5.0 (4.0, 6.0), p=1.0). In figure 1 an overview of mRS distribution after 90 days of follow-up is provided. Overall, four out of eight (50%) patients from the CVP subgroup died within the first 90 days, whereas six out of 16 (37.5%) died in the matched control (p=0.884). Outcome measures within the CVP subgroups are displayed in online supplemental table S1.

With regard to peri-interventional complications, no vasospasm, subarachnoid bleeding or thrombus migration were registered in the CVP group. Symptomatic intracerebral hemorrhage occurred in two patients from the CVP cohort which was not statistically different from the matched control cohort (CVP vs matched control cohort: 2 (28.6%) vs 0 (0.0%), p=0.152). Detailed results for procedural characteristics, outcome, and peri-interventional complications are displayed in table 3.

DISCUSSION

In the present study, we investigated the outcome of MT in patients with LVO stroke after a recent CVP. We found comparable efficacy, outcome, and safety profiles of MT in patients with a preceding CVP in comparison with a matched cohort of patients undergoing MT for non-periprocedural stroke. While time from symptom onset to groin puncture and time from symptom onset to reperfusion were significantly faster in patients with recent CVP, no difference in outcome was observed.

In the literature, multiple etiologies and risk factors for acute LVO have been reported after cardiac procedures, such as new onset atrial fibrillation, previous stroke or further vascular disease, congestive heart disease, cross-clamping time during cardiopulmonary bypass, and complexity of the surgical intervention.[2] Within our cohort, a most likely causal pathology was identified in only two patients. In stroke patients without a recent CVP, embolic stroke of undetermined source reportedly accounts for 25–40% of ischemic strokes.[23] Therefore, a multifactorial origin seems to be the most likely cause, which makes recommending a single preventive measure difficult.

We were able to document significantly faster revascularization times within the CVP cohort, presumably because these patients were already hospitalized. While shorter time to revascularization has been shown to be associated with an improved outcome in anterior circulation stroke, this was not observed in our study.[24] In recent literature, only one other single-center cohort compared reperfusion times between postoperative and non-postoperative patients, and neither time from symptom onset to imaging, nor time from symptom onset to reperfusion differed between the matched groups.[13]

Table 3 Procedural characteristics and outcome of the original and propensity-matched cohort

	Before propensity score matching			After propensity score matching		
Procedural characteristics	Control cohort (n=902)	CVP cohort (n=11)	P value	Control cohort (n=16)	CVP cohort (n=8)	P value
Onset to groin puncture, min (median; Q1, Q3)	230.0 (152.5, 311.5)	125.0 (100.0, 173.0)	0.007	284.0 (215.0, 490.5)	171.5 (136.3, 178.3)	0.039
Groin puncture to final TICI, min (median; Q1, Q3)	42.0 (27.0, 65.5)	45.0 (27.3, 66.3)	0.989	45.0 (25.5, 55.0)	40.0 (25.8, 65.5)	0.969
Onset to final TICI, min (median; Q1, Q3)	278.0 (202.0, 354.8)	177.0 (145.5, 198.0)	0.003	419.0 (274.0, 613.0)	195.0 (146.0, 201.0)	0.028
Median number of passes (median; Q1, Q3)	2 (1, 3)	2 (1, 3)	0.205	2 (1, 2.3)	2.0 (1, 2)	0.819
Recanalization TICI (%)						
2a	73 (8.6)	1 (9.1)		1 (6.2)	0 (0.0)	
2b	302 (35.4)	1 (9.1)		7 (43.8)	1 (12.5)	
3	367 (43.0)	6 (54.5)		7 (43.8)	5 (62.5)	
Complications						
Clot migration (%)	17 (1.9)	0 (0.0)		0 (0.0)	0 (0.0)	
SAB (%)	13 (1.4)	0 (0.0)		0 (0.0)	0 (0.0)	
Vasospasm (%)	22 (2.4)	0 (0.0)		0 (0.0)	0 (0.0)	
Dissection/perforation (%)	22 (2.4)	0 (0.0)		0 (0.0)	0 (0.0)	
sICH (%)	66 (7.3)	2 (22.2)	0.292	0 (0.0)	2 (28.6)	0.152
Outcome						
mRS score at 90 days (median; Q1, Q3)	4.0 (2.0, 6.0)	5.0 (3.50, 6.0)	0.274	5.00 (4.0, 6.0)	5.50 (3.3, 6.0)	1.000
Mortality at 90 days (%)	209 (26.5)	5 (45.5)	0.285	6 (37.5)	4 (50.0)	0.884
Good outcome (%)	244 (30.9)	2 (18.2)	0.561	2 (12.5)	2 (25.5)	0.846

Categorical variables are shown as absolute numbers and percentages. Continuous variables are described by mean±SD or median and the first and third quartile (Q1, Q3). Good outcome is defined as mRS score at 90 days ≤2. Percentages are given for patients with the full availability of the investigated variable.
CVP, cardiovascular procedure; mRS, modified Rankin Scale; SAB, subarachnoid bleeding; sICH, symptomatic intracranial hemorrhage; TICI, Thrombolysis in Cerebral Infarction.

Since the advent of MT in the treatment of stroke with LVO, the feasibility and outcome of endovascular interventions in patients with a recent cardiovascular procedure has been investigated in only a few retrospective studies. A recent single-center analysis investigated the incidence of stroke in patients after cardiothoracic surgery and the treatment used. Overall, six patients underwent MT for LVO, and in four patients successful reperfusion (TICI ≥2b) was achieved.[14] In a case-matched control study investigating perioperative strokes (25 patients overall, 68% after cardiovascular procedures including endovascular treatments) Premat and colleagues showed that MT was safe and provided a comparable reperfusion rate to a matched control group with non-perioperative strokes also treated by MT.[13]

We confirmed these findings in our cohort, which represents one of the largest series of MT after recent CVP; since MT achieved similar reperfusion rates in comparison with the non-matched as well as matched control cohort. Given that patients admitted for cardiovascular surgeries and interventions commonly display more comorbidities (such as dyslipidemia and diabetes mellitus) and concomitant vascular disease, a comparable reperfusion rate of MT in this patient cohort is encouraging.

Data concerning the outcome of MT in patients with LVO after a recent CVP are scarce. In the cohort from Premat and colleagues, a good clinical outcome (defined as mRS score ≤2) in the postoperative MT group (33.3% vs control 56.5%; p=0.055) was rare, and mortality at 3 months was significantly higher (33.3% vs control 4.2%; p=0.002) in comparison with the matched control group. In our study, while overall mortality after 90 days of follow-up was higher in the CVP group, this finding was not statistically significant.

The HERMES collaboration, in which results from five randomized trials investigating the efficacy of MT were pooled, an mRS score of ≤2 in 46.0% of patients in the thrombectomy group was registered, while 15.3% of patients died.[25] In contrast, the outcome in our cohort was considerably worse, even though faster recanalization times were achieved. This might be due to differences in baseline characteristics, such as older age, a higher cardiovascular risk factor burden, less concomitant stroke treatment (such as IV fibrinolysis), and worse initial neurological status in our CVP cohort in comparison with the results from the HERMES collective. It can only be assumed that the patients in the CVP cohort display an even broader profile of risk factors and multimorbidity leading to the comparatively worse outcome. Furthermore, due to the low incidence, and in some cases restrictive inclusion and exclusion criteria, patients with LVO stroke after a recent CVP will not have accounted for a large proportion of patients included within the landmark trials investigating MT in stroke. However, propensity score matching from a large real-life cohort, adjusting for potentially confounding baseline factors such as diabetes mellitus, which have been shown to be associated with an adverse outcome, allowed an adequate group of matched controls to be selected, as shown by the patient characteristics in table 2.[26 27]

In addition, the HERMES collaboration only included patients with anterior circulation stroke, while in our cohort 36.4% of affected vessels were in the posterior circulation. It has recently been shown that posterior circulation strokes (ie, basilar artery occlusions) are associated with an adverse outcome (as measured by the mRS), even in cases of successfully achieved perfusion.[28 29] The worse outcome in the CVP cohort, as only 18.2% of the patients achieved a mRS score of ≤2, might therefore be due to the numerically higher proportion of posterior circulation strokes. However, results for the outcome of posterior circulation strokes are inconsistent.[30] Therefore, the use of different radiological parameters should be evaluated to predict the outcome after thrombectomy.[31]

More recently, a study including 72 639 patients after TAVR investigated management patterns of postoperative strokes in this cohort. Overall, in 1135 cases (1.6%) TAVR was complicated by stroke. In the MT group 22.0% died during the hospital stay compared with a 7.7% and 13.0% mortality rate in the conservative and IV thrombolysis group, respectively. The authors concluded that the increased mortality rates in the IV thrombolysis and MT group in comparison with conservative treatment were due to a more severe form of stroke, leading to an inherently increased risk of an adverse outcome.[32] Our data concerning functional outcome as well as mortality should therefore be interpreted bearing in mind the severity of the stroke present, individual patient characteristics such as comorbidities, as well as the affected vessel.

Regarding transferability of our findings to the typical patients who were included in the ground-breaking MT trials, a recent analysis published from the German Stroke Registry (GSR), where our cohort represents a large portion of the total study cohort, investigated the eligibility for inclusion in these large randomized clinical trials (namely, SWIFT-PRIME, MR CLEAN, ESCAPE, DAWN, and DEFUSE-3). Briefly, within the GSR population only a relatively small proportion of patients met all inclusion criteria, ranging from 3% (DEFUSE-3 criteria) to 35% (MR CLEAN criteria).[33] Similar findings were also reported from our single-center cohort.[34] Although inclusion criteria were not fulfilled by a large portion of included patients, the studied population represents a 'real-life' MT cohort with direct correlation to everyday clinical practice.

While rates of symptomatic intracerebral hemorrhage were numerically higher within the CVP group, it was especially encouraging to document no further relevant complications, such as vasospasm, subarachnoid bleeding, or clot migration, demonstrating that MT can be attempted in patients with CVP with comparable safety profile. However, with only two complications the generalizability of this finding is limited, due to low statistical power.

Limitations

Strengths of the present study are the recruitment of all thrombectomies carried out for LVO at a tertiary center over a timespan of 6 years, enabling comparison of patients with a LVO after a recent CVP with a matched cohort of non-periprocedural MT patients. Representing a single-center retrospective analysis, typical limitations apply. We only analyzed patients who underwent MT, and results might be different for LVO stroke after exclusive IV thrombolysis, or conservative therapy. Also, a comparison with patients undergoing cardiovascular procedures without a postoperative stroke is missing. While all patients included within the CVP cohort had a cardiovascular disease manifestation, with five different operative and interventional procedures and three different cardiovascular disease entities (aortic stenosis, coronary artery disease, and thoracic aortic aneurysm) being included, the heterogeneity of our study limits the transferability to other procedures and cohorts. Also, with 11 patients with postoperative stroke after cardiovascular procedures only a small number of cases are available, although this cohort represents one of the largest consecutive series to date.

CONCLUSION

Use of MT in LVO stroke in patients with a preceding CVP is associated with high mortality rates, even though time from symptom onset to recanalization was significantly faster than in the control cohort. After propensity score matching, similar rates of mortality, achieved functional status, as well as efficacy and safety were found in comparison with patients without a CVP. Therefore, use of an endovascular treatment in patients with LVO stroke after CVP should be discussed on a case--case basis.

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Contributors BB and FF conceptualized the study, performed data analyses, wrote the manuscript, and are the guarantors of the study; BB, N.-OG, MR, MSc, and FF performed data preparation. GT, JF, and FF composed the cohort. KZ, JF, and GT supervised the clinical aspects of the study. MSe, FJB, PC, SB, JF, LC, HR, CW, and FF supervised the work. All authors critically reviewed the manuscript and approved the final version.

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REFERENCES

1 McDonagh DL, Berger M, Mathew JP, *et al*. Neurological complications of cardiac surgery. *Lancet Neurol* 2014;13:490–502.
2 Devgun JK, Gul S, Mohananey D, *et al*. Cerebrovascular events after cardiovascular procedures: risk factors, recognition, and prevention strategies. *J Am Coll Cardiol* 2018;71:1910–20.
3 Bucerius J, Gummert JF, Borger MA, *et al*. Stroke after cardiac surgery: a risk factor analysis of 16,184 consecutive adult patients. *Ann Thorac Surg* 2003;75:472–8.
4 Leon MB, Smith CR, Mack M, *et al*. Transcatheter aortic-valve implantation for aortic stenosis in patients who cannot undergo surgery. *N Engl J Med Overseas Ed* 2010;363:1597–607.
5 Leon MB, Smith CR, Mack MJ, *et al*. Transcatheter or surgical aortic-valve replacement in intermediate-risk patients. *N Engl J Med Overseas Ed* 2016;374:1609–20.
6 Amat-Santos IJ, Rodés-Cabau J, Urena M, *et al*. Incidence, predictive factors, and prognostic value of new-onset atrial fibrillation following transcatheter aortic valve implantation. *J Am Coll Cardiol* 2012;59:178–88.
7 Miller DC, Blackstone EH, Mack MJ, *et al*. Transcatheter (TAVR) versus surgical (AVR) aortic valve replacement: occurrence, hazard, risk factors, and consequences of neurologic events in the partner trial. *J Thorac Cardiovasc Surg* 2012;143:e13:832–43.
8 Tay ELW, Gurvitch R, Wijesinghe N, *et al*. A high-risk period for cerebrovascular events exists after transcatheter aortic valve implantation. *JACC Cardiovasc Interv* 2011;4:1290–7.
9 Powers WJ, Rabinstein AA, Ackerson T, *et al*. 2018 guidelines for the early management of patients with acute ischemic stroke: a guideline for healthcare professionals from the American heart Association/American stroke association. *Stroke* 2018;49:e46–99.
10 Turc G, Bhogal P, Fischer U, *et al*. European Stroke Organisation (ESO)- European Society for Minimally Invasive Neurological Therapy (ESMINT) guidelines on mechanical thrombectomy in acute ischemic stroke. *J Neurointerv Surg* 2019;11:535–8.
11 Rajkumar CA, Ganesananthan S, Ahmad Y, *et al*. Mechanical thrombectomy with Retrievable stents and aspiration catheters for acute ischaemic stroke: a meta-analysis of randomised controlled trials. *EuroIntervention* 2022;17:e1425–34.
12 Kashani HH, Mosienko L, Grocott BB, *et al*. Postcardiac surgery acute stroke therapies: a systematic review. *J Cardiothor Vasc Anesth* 2020;34:2349–54.
13 Premat K, Clovet O, Frasca Polara G, *et al*. Mechanical thrombectomy in perioperative strokes. *Stroke* 2017;48:3149–51.
14 Sheriff F, Hirsch J, Shelton K, *et al*. Large-vessel occlusion stroke after cardiothoracic surgery: expanding time windows offer new salvage opportunities. *J Thorac Cardiovasc Surg* 2019;158:186–96.
15 Wilkinson DA, Koduri S, Anand SK, *et al*. Mechanical thrombectomy improves outcome for large vessel occlusion stroke after cardiac surgery. *J Stroke Cerebrovasc Dis* 2021;30:105851.
16 Madeira M, Martins C, Koukoulis G, *et al*. Mechanical thrombectomy for stroke after cardiac surgery. *J Card Surg* 2016;31:517–20.
17 Haider AS, Garg P, Watson IT, *et al*. Mechanical thrombectomy for acute ischemic stroke after cardiac surgery. *Cureus* 2017;9:e1150.
18 Thomas MC, Delgado Almandoz JE, Todd AJ, *et al*. A case of right middle cerebral artery 'tendonectomy' following mitral valve replacement surgery. *J Neurointerv Surg* 2017;9:e35.
19 Alegiani AC, Dorn F, Herzberg M, *et al*. Systematic evaluation of stroke thrombectomy in clinical practice: the German Stroke Registry endovascular treatment. *Int J Stroke* 2019;14:372–80.
20 Brookhart MA, Schneeweiss S, Rothman KJ, *et al*. Variable selection for propensity score models. *Am J Epidemiol* 2006;163:1149–56.
21 Ho DE, Imai K, King G, *et al*. MatchIt: nonparametric preprocessing for parametric causal inference. *J Stat Softw* 2011;42.
22 McDonald JS, Brinjikji W, Rabinstein AA, *et al*. Conscious sedation versus general anaesthesia during mechanical thrombectomy for stroke: a propensity score analysis. *J Neurointerv Surg* 2015;7:789–94.
23 Mark IT, Nasr DM, Huston J, *et al*. Embolic stroke of undetermined source and carotid intraplaque hemorrhage: asystemic review and meta-analysis. *Clin Neuroradiol* 2021;31:307–13.
24 Jahan R, Saver JL, Schwamm LH, *et al*. Association between time to treatment with endovascular reperfusion therapy and outcomes in patients with acute ischemic stroke treated in clinical practice. *JAMA* 2019;322:252–63.
25 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.
26 Lu G-D, Ren Z-Q, Zhang J-X, *et al*. Effects of diabetes mellitus and admission glucose in patients receiving mechanical thrombectomy: a systematic review and meta-analysis. *Neurocrit Care* 2018;29:426–34.
27 Borggrefe J, Glück B, Maus V, *et al*. Clinical outcome after mechanical thrombectomy in patients with diabetes with major ischemic stroke of the anterior circulation. *World Neurosurg* 2018;120:e212–20.
28 Meinel TR, Kaesmacher J, Chaloulos-Iakovidis P, *et al*. Mechanical thrombectomy for basilar artery occlusion: efficacy, outcomes, and futile recanalization in comparison with the anterior circulation. *J Neurointerv Surg* 2019;11:1174–80.
29 Vavrova J, Koznar B, Peisker T, *et al*. Long-term outcomes of thrombectomy for acute ischaemic stroke by occluded artery and stroke aetiology: a PRAGUE-16 substudy. *EuroIntervention* 2021;17:e169–77.
30 Wollenweber FA, Tiedt S, Alegiani A, *et al*. Functional outcome following stroke thrombectomy in clinical practice. *Stroke* 2019;50:2500–6.

31 Jing M, Yeo JYP, Holmin S, *et al*. Preprocedural Imaging: areview of different radiological factors affecting the outcome of thrombectomy. *Clin Neuroradiol* 2022;32:13–24.
32 Alkhouli M, Alqahtani F, Hartsell Harris A, *et al*. Management patterns and outcomes of acute ischemic stroke complicating transcatheter aortic valve replacement. *Stroke* 2021;52:e94–6.
33 Leischner H, Brekenfeld C, Meyer L, *et al*. Study criteria applied to real life-multicenter analysis of stroke patients undergoing endovascular treatment in clinical practice. *J Am Heart Assoc* 2021;10:e017919.
34 Deb-Chatterji M, Pinnschmidt H, Flottmann F, *et al*. Stroke patients treated by thrombectomy in real life differ from cohorts of the clinical trials: a prospective observational study. *BMC Neurol* 2020;20:81.