



Reasons for Failed Mechanical Thrombectomy in Posterior Circulation Ischemic Stroke Patients

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Received: 27 May 2020 / Accepted: 6 August 2020 / Published online: 7 September 2020
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Abstract

Background and Purpose To determine reasons for failed recanalization in mechanical thrombectomy (MT) of the posterior circulation.

Methods Retrospective single center analysis of reasons for MT failure in the posterior circulation. Failed MTs were categorized according to the reason for procedure failure in failed vascular access, failed passage of the target vessel occlusion and MT failure after passing the occluded target vessel. Patient characteristics were compared between failed and successful MT.

Results Patients with failed MT (30/218 patients, 13.8%) were categorized into futile vascular access (13/30, 43.3%), abortive passage of the target vessel occlusion (6/30, 20.0%) and MT failure after passing the vessel occlusion (11/30, 36.7%). In 188/218 (86.2%) successful MTs alternative vascular access, local intra-arterial (i.a.) thrombolysis and emergency stent-assisted PTA prevented 65 MT failures. Patients with failed MT showed a higher NIHSS at discharge, a higher pc-ASPECTS in follow-up imaging, a higher mRS 90 days after stroke onset and a high mortality rate of 77.0% (mRS at 90 days, median (IQR): 6 (6–6) vs. 4 (2–6) for successful MT, p -value < 0.001). Co-morbidities and stroke etiology were not different compared to sufficient recanalization with atherosclerotic disease as the leading stroke etiology in both groups.

Conclusion Failure of MT in posterior circulation ischemic stroke patients is associated with a high mortality rate. Reasons for MT failure are diverse with futile vascular access and MT failure after passing the vessel occlusion as the leading causes. Alternative vascular access, local i.a. thrombolysis and stent-assisted PTA can prevent MT failure.

Keywords Rescue strategies · Alternative vascular access · Local thrombolysis · Intracranial stenting · Mortality

Availability of data and material Individual participant data that underlie the results reported in this article (after deidentification) will be available to researchers who provide a methodologically sound proposal. Proposals should be directed to the corresponding author beginning 24 months and ending 48 months following article publication.

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Abbreviations

BA	Basilar artery
LVO	Large vessel occlusion
MT	Mechanical thrombectomy
mRS	Modified Rankin scale
NIHSS	National Institutes of Health Stroke Scale
PCA	Posterior cerebral artery
pc-ASPECTS	Posterior circulation Alberta Stroke Early CT Score
PTA	Percutaneous transluminal angioplasty
rtPA	Recombined tissue plasminogen activator
TOAST	Trial of Org 10172 in Acute Stroke Treatment
VA	Vertebral artery

Key Points

- Mechanical thrombectomy (MT) of the posterior circulation is technically successful in over 85% of this population and associated with a very high mortality rate in cases of MT failure.
- Reasons for MT failure in the posterior circulation are diverse with futile vascular access and failed MT after passage of the target vessel occlusion as leading causes before abortive passage of the target vessel occlusion.
- Alternative vascular access, local i.a. thrombolysis and stent-assisted PTA prevent MT failure in selected patients.

Introduction

Mechanical thrombectomy (MT) has become the state of the art for treating patients with ischemic stroke and large vessel occlusion (LVO) in the anterior circulation since several randomized, multicenter studies emerged in 2015 proved its superiority to intravenous rt-PA alone [1–4]. A successful recanalization of the target vessel occlusion is crucial for a good clinical outcome and with modern thrombectomy techniques, it lies over 80% [5]. Recently, models emerged to classify the considerable minority of failed recanalization for further development of rescue strategies and to increase the MT success rate in the anterior circulation [6, 7]. Failed recanalization attempts are subdivided into interventions with futile vascular access and failed thrombus removal. The second group is further classified as failure to pass the target vessel occlusion and as stent-retriever failure, where the thrombus cannot be removed despite all MT maneuvers. Studies following this approach investigated causes for recanalization failure in MT of the anterior circulation [8] and for stent-retriever-based thrombectomy also focusing on the anterior circulation [9]. Rescue strategies, such as intracranial stenting and

alternative vascular access, are discussed for failed MT of the anterior circulation.

The use of MT for large vessel occlusions of the posterior circulation does not currently have the same level of evidence. Evidence for its safety and efficacy using modern thrombectomy techniques can be derived from smaller studies as well as evidence for a very high mortality rate when MT of the posterior circulation fails [10, 11]. Technically successful recanalization of patients with posterior circulation stroke and MT represents an independent predictor for good functional outcome [12, 13]. Nevertheless, poor outcome despite successful recanalization, so called futile recanalization, occurs more often compared to MT of the anterior circulation [12, 14–16]. The rate of sufficient recanalization is reported to be around 80% and comparable to LVO of the anterior circulation for adjusted patient cohorts [16, 17]. The aim of this study was to investigate outcome and reasons for MT failure in the posterior circulation and determine possible predictors of procedure failure.

Methods

The prospective stroke database of Heidelberg's comprehensive stroke center was searched for all patients with acute ischemic stroke of the posterior circulation and intention to perform MT between March 2009 and April 2019. All cases included were conducted with modern MT techniques at hand starting with the Solitaire AB stent (Medtronic, Dublin, Ireland) in 2009 and continuously modified by adding or exchanging with new material.

Due to the retrospective character of this study written informed consent was waived. There was no age restriction or other patient selection criteria prior to study analysis. All imaging parameters (e.g. pc-ASPECTS, localization of target vessel occlusion, reperfusion result) were obtained defined by the neuroradiologists (neuroradiologist in training and specialist with at least 6 years radiologic experience) of the in-house stroke team and revised for this study by neuroradiologists with 5 and 3 years of training. All clinical parameters were obtained by the neurologists of our in-house stroke team and after discharge (mainly for mRS 90 days) with telephone interviews conducted by mRS/NIHSS certified medical doctors.

Decision Making and Standard Endovascular Procedure for MT of the Posterior Circulation

The consensual decision for MT of the posterior circulation was made by the neurointerventionalist and an experienced neurologist. The decision for MT was based on current stroke guidelines. The MT was performed by an experienced neuroradiologist (at least 5 years of training

in diagnostic and interventional radiology) with the assistance of a second neuroradiologist in training. The standard interventional approach is a femoral access (7F Flexor Shuttle Guiding Sheath 80 cm, Cook, Bloomington, IN, USA), a 5–6F intermediate catheter for access to the dominating or occluded vertebral artery and a microcatheter in a triaxial system for stent-retriever thrombectomy under continuous aspiration or direct aspiration.

The choice of catheters and MT maneuver approach (direct thrombus aspiration as first attempt or stent-retriever thrombectomy in solumbra technique) was made by the interventionalist. The thrombectomy technique is changed when a thrombectomy strategy fails (e.g. from aspiration to stent-retriever thrombectomy). As standard approach up to three different stent-retriever devices are used in our facility with up to three attempts per device before terminating unsuccessful MT. The material mostly used in this cohort is a 5F-Neuron intermediate catheter (2009–2013; Penumbra, Alameda, CA, USA) or 5F/6F-Sofia intermediate catheter (2013 until today; Microvention, Aliso Viejo, CA, USA). All modern stent-retriever models are available in our facility with Solitaire (Medtronic, Boulogne Billancourt, France), Trevo (Stryker, Kalamazoo, MI, USA) and pREset (Phenox, Bochum, Germany) used most commonly for the posterior circulation. The MT of the posterior circulation is performed with the patient under intubation anesthesia. For rescue stenting during MT of persistent basilar artery occlusions a glycoprotein (GP) IIb/IIIa inhibitor is given for 6 h during and after intervention followed by an overlapping loading with double platelet inhibition with aspirin and clopidogrel.

Classification for Reasons of Failed MT

The following classification systems for failed recanalization in MT of the anterior circulation, all cases of failed MT were categorized in one of the following groups.

Category I: Target Vessel Occlusion not Reached

Ia The intracranial target vessel could not be reached due to difficult aortic anatomy, vessel tortuosity and/or vertebral hypoplasia.

Ib Target occlusion was not reached due to atherosclerotic stenosis/occlusion of the vertebral arteries.

Category II: Target Vessel Occlusion Reached but not Passed

II The intracranial target vessel was reached but could not be passed for any MT maneuver until the end of the procedure.

Category III: Target Vessel Occlusion Reached and Passed

IIIa Target occlusion stayed occluded despite MT maneuvers or vessel lumen reoccluded until the end of the MT.

IIIb After passing the vessel occlusion complications or neurologic deterioration of the patient lead to a termination of the procedure.

pc-ASPECTS and Reperfusion Result—For MT of the Posterior Circulation

The Alberta Stroke Program Early CT Score (ASPECTS) was originally developed as a reliable topographic assessment for early ischemic signs of infarct tissue in the middle cerebral artery territory with predictive value [18]. Later the score was modified for the posterior circulation, the so called pc-ASPECTS [19], which is a powerful predictor for functional outcome when transferred to diffusion-weighted MRI for ischemic lesions in the posterior circulation [20]. We determined the pc-ASPECTS in admission and follow-up imaging. Due to changing imaging protocols during the assessment period of this study and varying clinical settings CT and MR imaging were both evaluated depending on availability.

The reperfusion result after MT was reviewed independently case by case. A persistent occlusion of the target vessel was considered as failed MT (comparable to modified thrombolysis in cerebral infarction score 0–1 in the anterior circulation).

Statistical Analysis

Descriptive group statistics were gathered for patients with either successful or failed MT. Quantitative data were tested for normal distribution using the Shapiro-Wilk normality test and showed that all quantitative data were distributed non-parametrically. Univariate analyses were performed using Wilcoxon rank-sum and χ^2 -tests for nonparametric quantitative variables and categorical variables, as appropriate, to compare all parameters between groups of successful and failed MT. A *p*-value of less than or equal to 0.05 was considered to indicate a significant difference. All statistical analyses were performed by using R version 3.6.0 (Foundation for Statistical Computing, Vienna, Austria).

Results

Overall, 1671 patients underwent MT for acute ischemic stroke in our department between March 2009 and April 2019. Of the patients 218 were treated for ischemic stroke of the posterior circulation. In 30/218 patients (13.8%) the MT

Table 1 Mechanical thrombectomy in the posterior circulation grouped according to reperfusion result

	Failed MT (n = 30)	Successful MT (n = 188)	p-value
Age (years), mean (SD)	71 (13)	73 (14)	0.35513
Male, n (%)	19 (63.3)	110 (58.5)	0.76488
Coronary artery disease, n (%)	9 (34.6)	49 (27)	0.55894
Known atrial fibrillation	13 (50)	71 (39)	0.39278
Arterial hypertension, n (%)	25 (93)	140 (77)	0.10723
Diabetes mellitus II, n (%)	6 (23)	40 (21.9)	1
Hypercholesterinemia, n (%)	12 (46)	62 (34)	0.32446
<i>Stroke-related clinical and imaging aspects</i>			
pmRS, median (IQR)	1 (0–2)	1 (0–2)	0.72645
mRS 90 days after stroke onset, median (IQR)	6 (6–6)	4 (2–6)	0.00029
Mortality, n (%)	23 (77.0)	68 (36.2)	0.001
Initial NIHSS score, median (IQR)	14 (8–27)	22 (10–35)	0.13093
NIHSS at discharge, median (IQR)	34 (11–34)	8 (3–34)	0.00005
Pc-ASPECTS baseline, median (IQR)	8 (7–10)	9 (7–10)	0.63243
Pc-ASPECTS follow-up, median (IQR)	5 (3–7.5)	7 (5–8)	0.03049
Intravenous rtPA, n (%)	13 (43.3)	104 (56)	0.27753
Time of symptom onset known, n (%)	19 (63.3)	131 (69.6)	0.62788
<i>Etiology of stroke</i>			
Large artery atherosclerosis, n (%)	14 (46.7)	62 (33)	0.17548
Cardioembolism, n (%)	10 (33.3)	76 (41)	0.57639
Small vessel occlusion, n (%)	0	0	–
Other determined etiology, n (%)	2 (6.7)	17 (9)	0.92973
Embolic stroke of unknown source, n (%)	4 (13.3)	23 (12.3)	1
Unknown etiology, n (%)	0	15 (8)	0.2224
<i>Procedural aspects</i>			
Time from stroke onset to groin puncture, in minutes, median (IQR)	388 (229–713)	329 (200–615)	0.33534
Procedure time (groin puncture to reperfusion result) in minutes, median (IQR)	139 (50–189)	73 (42–111)	0.10029
<i>Location of occlusion</i>			
V4-segment of VA to proximal BA, n (%)	5 (17)	19 (10)	0.45205
Mid-BA, n (%)	24 (80)	151 (80)	1
Distal BA to PCA, n (%)	5 (9.5)	34 (18)	1
Number of direct aspirations, median (IQR)	0	0	–
Number of stent-retriever thrombectomy under continuous aspiration, mean (SD)	0 (0–3)	1 (1–3)	0.03579
Stent-assisted PTA of VA/BA, n (%)	9 (30)	56 (30)	1

BA basilar artery, IQR interquartile range, mRS modified Rankin Scale, NIHSS National Institute of Health Stroke Scale, PCA posterior cerebral artery, pc-ASPECTS posterior-circulation Alberta Stroke Program Early CT Score, PTA percutaneous transluminal angioplasty, rtPA recombinant tissue Plasminogen Activator, SD standard deviation, VA vertebral artery

failed and 188/218 patients (86.2%) showed a sufficient recanalization result after MT. The locations of the target vessel occlusion, which involved the basilar artery in all cases (intracranial vertebral artery to proximal basilar artery, mid-basilar artery occlusion or distal basilar artery to posterior cerebral artery occlusion) were represented equally in the groups of sufficient and failed MT (Table 1). There was no tendency towards a higher success rate in more recent years while the overall number of MTs performed gradually increased.

Patient Characteristics Primary Analysis

Baseline characteristics and demographics in comparison to failed MT and successful MT are shown in Table 1. There was no significant difference for the stroke-related comorbidities coronary artery disease, diabetes, known atrial fibrillation, arterial hypertension or hypercholesterinemia. The most frequently determined stroke etiology according to the Trial of Org 10172 in Acute Stroke Treatment (TOAST) classification were large artery atherosclerosis

(TOAST 1, failed MT: 46.7%, successful MT: 33.0%) and cardioembolism (TOAST 2, failed MT: 33.3%, successful MT: 41.0%) with no statistical difference between the two groups (p -value: 0.175 and 0.576, respectively). Stent-assisted PTA was performed in 30.0% of successful (56 patients) and 30.0% of failed (9 patients) MTs, the patients neurological deficit (per NIHSS) and handicap (per mRS) were different with a higher NIHSS at discharge for patients with failed MT (median (IQR) failed MT 34 (11–34); successful MT 2/3 8 (3–34), p -value <0.001), a higher mortality rate after failed MT ($n=23/30$, 77%) and a higher mRS 90 days after stroke onset (median (IQR) failed MT 6 (6–6), successful MT 4 (2–6), p -value <0.001). Also, the pc-ASPECTS in the follow-up imaging (CT or MRI, 1–3 days after MT) was significantly lower after failed MT (median IQR failed MT 5, 3–7.5, successful MT 7, 5–8). In both groups, a stent-assisted percutaneous transluminal angioplasty (PTA) was performed in 30.0% of the cases during the MT.

Failed Mechanical Thrombectomy

Category I In 12/30 cases (40.0%) of failed MT, an unsuccessful vascular access was the reason for procedure failure. Atherosclerotic stenosis or occlusion of the vertebral arteries was the cause in seven cases (category Ia). Anatomically difficult access with aortic or vertebral artery elongations was the cause in five cases (category Ib). In overall 7/218 MTs of the posterior circulation an alternative vascular access was performed after the standard femoral access failed. Four times a brachial/radial access followed after a failed femoral access. This led to three successful MTs and one failed MT. A retrograde access through a posterior communicating artery was performed two times for local, intra-arterial rtPA application ensuing one successful MT. One time the vertebral artery was directly accessed in the V2 segment through a dominant ascending cervical artery and a successful MT followed.

Category II In 7/30 cases (23.3%) the target vessel occlusion could not be passed with a probable underlying atherosclerotic occlusion stated by the interventionalist in five of these cases. Local intra-arterial (i.a.) thrombolysis (rtPA) was performed in 13/218 cases. Four times a persisting basilar artery occlusion was treated with i.a. rtPA with two successful recanalization results. Six times i.a. rtPA and an additional stent-assisted PTA was performed. Three times an embolic vessel occlusion (PCA and SUCA) that occurred after recanalization of the basilar artery were targeted.

Category III In 11/30 cases (36.7%), the MT failed after passing the occluded vessel. In three of these cases, the

vessel stayed occluded or the vessel lumen reoccluded despite MT maneuvers (category IIIa). An emergency stent-assisted PTA was conducted if possible in these scenarios. Stenting of the V4 segment of the vertebral artery and/or the basilar artery was performed in 65/218 cases of MT in the posterior circulation. In 9/65 cases MT failed comprising three device malfunctions (i.e. stent kinking) and six cases where the stent implantation did not lead to a restoration of the target vessel volume.

In five cases, intraprocedural complications (two cases of vessel perforation and three cases of stent kinking or failed stent unfolding) or the patient's deteriorating clinical status during the MT led to a termination of the intervention (category III B).

Discussion

In this single center analysis we showed that futile vascular access due to atherosclerotic disease or anatomic difficulties ($n=12/30$ patients, 40.0%) and MT failure after passing the target vessel occlusion ($n=11/30$ patients, 37.0%) are the leading causes for failed recanalization in posterior circulation MT, followed by abortive passage of the thrombus ($n=7/30$ patients, 23.0%).

Patients with MT failure showed a higher mRS 90 days after stroke onset with a high mortality rate of 77.0% and a very high NIHSS at discharge as well as a lower pc-ASPECTS in follow-up imaging. No specific target vessel occlusion side, which involved the basilar artery in all cases in this cohort, was associated with a higher risk of MT failure. Corresponding to studies of the anterior circulation, further investigation is needed to identify probable associations of thrombus length or texture and MT failure [21, 22]. Overall, a sufficient recanalization result for stroke patients and MT of the posterior circulation was achieved in 86.2%, which is comparable to the 90.3% and 84.5% success rate of MT in basilar artery occlusions published by Meinel et al. and Sun et al., respectively, and underlines the notion that success rates for MT in the posterior circulation are comparable to the anterior circulation [16, 23].

Likewise, reasons for MT failure are diverse compared to studies on MT failure in anterior circulation ischemic stroke patients with a similar tendency towards a futile vascular access and failed MT after passing the target vessel occlusion as the leading categories. Futile vascular access is a common reason for MT failure in the anterior and posterior circulations, which highlights the necessity to discuss alternative vascular access routes in MT as a rescue strategy. In individual cases of this cohort an alternative access led to a successful target vessel recanalization. These alternative accesses comprised brachial/radial accesses, retrograde access through a dominant posterior communicating artery

and access from a dominant ascending cervical artery to the vertebral artery's V3/4 segment. An unsuccessful passage of the target vessel occlusion as reason for a failed MT could only be witnessed in a few cases and was seldom successfully treated with a local intra-arterial lysis (rtPA) [8, 9]. Also, MT failure after passing the target vessel occlusion seems to be equally relevant in anterior and posterior circulation MT; however, this scenario is linked to different reasons in the posterior circulation. In the anterior circulation remaining target vessel occlusion after trying different stent-retriever devices, the so-called true stent-retriever failure, is the main reasons for MT failure after passing the target vessel occlusion. Stent-assisted PTA during MT is discussed as possible rescue strategy but remains an exception to the rule so far [8].

In the posterior circulation, however, emergency stent-assisted PTA is already performed in a great number of MTs (65/218 MTs in this cohort) preventing many cases of MT failure but also failing itself in 14% (9/65 cases). The implementation of intracranial stent-assisted PTA during MT of the posterior circulation therefore often seems inevitable but also represents an existing source of peril. Therefore, to improve the success rate and safety of MT in the posterior circulation overall, devices for stent-assisted PTA need further improvement. Although patient comorbidities and stroke etiology were not different between the two groups of successful and failed MT in the posterior circulation, the high rate of large vessel atherosclerosis as stroke etiology in both groups (33.0% and 46.7% for successful and failed MT, respectively) reflects a high significance of atherosclerosis for posterior circulation stroke patients. Arguably, detecting and treating atherosclerotic stenosis of the basilar artery before ischemic stroke for patients at risk can be seen as primary prevention. Primary stenting for high-grade basilar artery stenosis is proven to be successfully performed in cases of refractory medical treatment [24, 25]. Risk stratification for these patients is currently not available. Strengthening strategies to prevent MT failure of the posterior circulation represents in many cases the only option to decrease the high mortality rate of failed MT of basilar artery occlusions. The majority of patients with failed MT in this cohort were comatose on discharge to another hospital or medical facility, or had died before discharge. Thus, palliative or rehabilitative concepts can seemingly only contribute to a better outcome in selected patients.

Limitations

This single center retrospective study with a substantial patient cohort (30 failed MT in 218 patients for MT of the posterior circulation) can serve as a first approach for investigating reasons of failed MT in the posterior circulation. Future prospective studies should focus on investigat-

ing important issues that remain unclear, such as the management and implementation of stent-assisted PTA in failed MT of the posterior circulation, to further improve therapeutic options in these patients. Although this study cohort did not show a decrease of MT failure or complications over the years in the wake of increasing MT cases overall, the growing experience with MT for anterior and posterior circulation target vessel occlusions as standard intervention in modern endovascular stroke treatment can influence the findings.

Conclusion

Mechanical thrombectomy of the posterior circulation is successful in the majority of patients but shows a high mortality rate if recanalization fails. Reasons for MT failure are diverse, with futile vascular access and MT failure after passing the target vessel occlusion as leading causes. Alternative vascular access, local i.a. thrombolysis and stent-assisted PTA can prevent MT failure. Further investigation and device innovation are necessary to improve the success rate of MT particularly regarding the frequently performed emergency stent-assisted PTA.

Funding This research was performed with departmental funding only and received no specific grant from any funding agency in the public, commercial, or not-for-profit sectors.

Funding Open Access funding provided by Projekt DEAL.

Compliance with ethical guidelines

Conflict of interest C.S. Weyland, U. Neuberger, A. Potreck, J.A.R. Pfaff, S. Nagel and S. Schönerberger declare that they have no competing interests. M. Bendszus: activities related to the present article: disclosed no relevant relationships. Activities not related to the present article: grants and personal fees from Bayer, Codman, Guerbet, Medtronic and Novartis; grants from the German Research Council (DFG), European Union, Hopp Foundation, Siemens, and Stryker; personal fees from BBraun, Böhlinger Ingelheim, Roche, Teva, and Vascular Dynamics. Other relationships: disclosed no relevant relationships. M.A. Möhlenbruch: unrelated: board membership: Codman; consultancy: Medtronic, MicroVention, Stryker; Grants/Grants Pending: Balt*, MicroVention*; payment for lectures: Medtronic, MicroVention, Stryker. *Money paid to the institution.

Ethical standards This study was approved by the local ethics committee (Ethikkommission der Universität Heidelberg). Informed consent was waived due to the retrospective nature of this study. The study was conducted following the STROBE criteria.

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