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Clinical and radiographic outcomes after mechanical thrombectomy in medium-vessel posterior cerebral artery occlusions: Subgroup analysis from STAR

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Abstract

Background: Whereas mechanical thrombectomy (MT) has become standard-of-care treatment for patients with salvageable brain tissue after acute stroke caused by large-vessel occlusions, the results of MT in patients with medium-vessel occlusions (MEVOs), particularly in the posterior cerebral artery (PCA), are not well known.

Methods: Using data from the international Stroke Thrombectomy and Aneurysm Registry (STAR), we assessed presenting characteristics and clinical outcomes for patients who underwent MT for primary occlusions in the P2 PCA segment. As a subanalysis, we compared the PCA MeVO outcomes with STAR's anterior circulation MeVO outcomes, namely middle cerebral artery (MCA) M2 and M3 segments.

Results: Of the 9812 patients in STAR, 43 underwent MT for isolated PCA MeVOs. The patients' median age was 69 years (interquartile range 61–79), and 48.8% were female. The median NIH Stroke Scale score was 9 (range 6–17). After recanalization, 67.4% of patients achieved successful recanalization (modified treatment in cerebral infarction score [mTICI] $\geq$ 2b), with a first-pass success rate of 44.2%, and 39.6% achieved a modified Rankin score of 0–2 at 90 days. Nine patients (20.9%) had died by the 90-day follow-up. In comparison with M2 and M3 MeVOs, there were no differences in presenting characteristics among the three groups. Patients with PCA MeVOs were less likely to undergo intra-arterial thrombolysis (4.7% PCA vs. 10.1% M2 vs. 16.2% M3, $p = 0.046$) or to achieve successful recanalization (mTICI $\geq$ 2b, 67.4%, 86.7%, 82.3%, respectively, $p < 0.001$); however, there were no differences in the rates of successful first-pass recanalization (44.2%, 49.8%, 52.3%, respectively, $p = 0.65$).

Conclusions: We describe the STAR experience performing MT in patients with PCA MeVOs. Our analysis supports that successful first-pass recanalization can be achieved in PCA MEVOs at a rate similar to that in MCA MeVOs, although further study and possible innovation may be necessary to improve successful PCA MeVO recanalization rates.

Keywords

Anterior cerebral artery, mechanical thrombectomy, stroke, embolectomy, posterior cerebral artery, distal occlusion, medium-vessel occlusion

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Introduction

The benefits of mechanical thrombectomy (MT) in patients after acute stroke caused by large-vessel occlusion have been established through multiple large-scale clinical trials.[1–5] However, our understanding of MT efficacy and outcomes in stroke patients beyond large-vessel occlusion is less robust and is mostly obtained from retrospective or post hoc studies.[6,7] This is especially true for isolated occlusions in the posterior cerebral arteries (PCAs).[8–13]

Isolated PCA occlusions in the P2 and P3 segments are found in approximately 1.3% of patients after stroke.[14] As a comparison, medium-vessel occlusions (MeVOs) in the middle cerebral artery (MCA), namely the M2 and M3 segments, are found in about 20–30% of all patients after stroke and approximately 25–30% of all patients who undergo MT procedures.[15–18] As a result, more studies have reported the safety and efficacy of MT in MCA MeVOs. Although there is clear correlation between achieving successful reperfusion and favorable outcomes in this group of patients, the available data regarding outcomes after MT in PCA MeVOs are significantly more limited.[7–13,19,20]

In the present study, we sought to assess the safety and efficacy of MT in PCA MeVOs using the Stroke Thrombectomy and Aneurysm Registry (STAR). Additionally, to assess whether MT in PCA MeVO achieves similar results as MT in MCA MeVOs, we compared STAR's PCA MeVO patient outcome data against the outcomes of STAR patients with MCA MeVOs.

Methods

Study design

This retrospective cohort study is reported according to STROBE guidelines,[21] and data capture was approved by the ethical review boards at each institution with a waiver of consent. To capture the PCA MeVO cohort, we reviewed the prospectively maintained STAR database, which includes patients from 35 stroke centers.[22] All acute stroke patients who presented with primary PCA MeVO were identified. Posterior cerebral artery MeVO was defined as patients with a primary occlusive lesion in the P2 segment. Patients with primary P3 occlusive lesions were not included because of a lack of cases. All included patients received MT within 24 h of witnessed symptom onset between January 1, 2016, and July 31, 2022. Follow-up imaging was performed 24 h after MT to determine the presence of hemorrhagic transformation and cerebral edema. As an anterior circulation comparison group, we also captured patients with the same parameters, but who experienced MCA MeVO in the M2 or M3 segments. M2 and M3 were characterized as the second and third major segments of the MCA.[7,18]

Data collection and clinical outcome assessment

Data collection and use was approved by the Institutional Review Board at each of the included centers, and the

need for informed consent was waived given its minimal-risk design. Collected data included baseline demographics, occlusion of PCA P2 segment, symptom onset-to-groin puncture time, MT technique, procedure time, thrombectomy passes, devices used, rescue therapy used, complications, and final modified Thrombolysis in Cerebral Ischemia (mTICI) scores. Stroke severity on admission was assessed using the National Institutes of Health Stroke Scale (NIHSS). Baseline imaging, recanalization rates, and imaging after procedure completion were reviewed by local investigators at each participating site at the time of recording into the STAR database.

Successful recanalization was defined as a mTICI score of 2b or better. The 90-day modified Rankin scale (mRS) score was used as the primary outcome measure and was recorded during a follow-up visit or a telephone encounter at 90 days (±14 days) after stroke by a stroke neurologist or registered nurse.[23] Favorable outcome was defined as mRS 0–2 at 90 days. Symptomatic intracranial hemorrhage (sICH) was defined as hemorrhage after procedure with an associated decline of ≥4 points in NIHSS.

Statistical analysis

We used descriptive statistics to report patients' demographic and clinical characteristics using median and interquartile range (IQR) for continuous variables and percentages for categorical variables. No missing data were replaced. A binary logistic regression model was used to assess factors associated with favorable 90-day outcomes including age, admission NIHSS, and successful recanalization.[24–27] In a univariate subanalysis, PCA MeVO outcomes were compared against those of M2 and M3 MCA MeVOs. In the PCA MeVO versus MCA MeVO subanalysis, characteristics of each group (P2 vs. M2 vs. M3) were compared using the Wilcoxon rank-sum (Mann–Whitney) test and Chi-square test, where appropriate. All statistical analyses were performed with Stata/MP 17.0 (Stata Corp, College Station, TX), and an alpha of <0.05 was considered statistically significant.

Table 1. Characteristics of thrombectomy patients presenting with PCA MeVO.

Variable	PCA MeVO ($n = 43$)
Age in years, median (IQR)	69 (61–79)
Female sex, *n* (%)	21 (48.8%)
White race, *n* (%)	32 (74.4%)
Admission NIHSS, median (IQR)	9 (6–17)
Comorbidities	
Diabetes mellitus, *n* (%)	16 (37.2%)
Hypertension, *n* (%)	34 (79.1%)
Atrial fibrillation, *n* (%)	13 (30.2%)
Hyperlipidemia, *n* (%)	17 (39.5%)
IV tPA, *n* (%)	21 (48.8%)
Onset-to-groin time in minutes, median (IQR)	285 (214–490)

IQR: interquartile range; NIHSS: National Institute of Health stroke scale; IV tPA: intravenous tissue plasminogen activator; MeVO: medium-vessel occlusion.

Results

A total of 9812 patients treated with MT were included in STAR at the time of the study. Of those, 43 (0.4%) patients underwent MT for PCA MeVO.

Presenting characteristics of patients with PCA MeVO

Nearly half of the patients who underwent MT of the PCA were female (48.8%), the median age was 69 years (IQR 61–79), and 32 patients (74.4%) were white (Table 1). In terms of comorbidities at presentation, 37.2% had diabetes mellitus, 79.1% had hypertension, 30.2% had atrial fibrillation, and 39.5% had hyperlipidemia. The median NIHSS on admission was 9 (6–17), and 21 (48.8%) of the patients received intravenous tissue plasminogen activator (tPA). Most patients ($n = 27$, 62.8%) who presented with PCA MeVO received MT in the early thrombectomy window (≤6 h), and the median onset-to-groin time was 285 min (214–490).

Procedural outcomes of patients with PCA MeVO

The median number of MT passes performed for PCA MeVOs was 2 (IQR 1–3), and the median procedure time was 37 min (Table 2). Aspiration was used first in 22 (51.2%) patients, intra-arterial tPA was seldom used (4.7%), and a stent retriever was used in 27 (62.8%). Successful recanalization was achieved in 29 (67.4%) individuals, the rate of successful first pass was 44.2%, and 4.7% experienced a complication event, with sICH seen in 2.3% of patients. The rate of favorable 90-day outcomes (mRS 0–2) was 39.6%, and the 90-day mortality rate was 20.9%. Multivariate analysis did not demonstrate statistically significant association between age (adjusted odds ratio [AOR] 0.97, 95% confidence interval [CI]

Table 2. Procedural and clinical outcomes of thrombectomy patients presenting with PCA MeVO.

Variable	PCA MeVO ($n = 43$)
Thrombectomy passes, median (IQR)	2 (1–3)
Aspiration as first approach, *n* (%)	22 (51.2%)
IA tPA used, *n* (%)	2 (4.7%)
Stent retriever used, *n* (%)	27 (62.8%)
Procedure time, median (IQR)	37 (24–59)
Successful recanalization (final mTICI ≥ 2b), *n* (%)	29 (67.4%)
Successful first pass, *n* (%)	19 (44.2%)
Complications, *n* (%)	2 (4.7%)
sICH, *n* (%)	1 (2.3%)
90-day mRS, median (IQR)	3 (1–5)
mRS score 0–2 at 90 days, *n* (%)	17 (39.6%)
Mortality at 90 days, *n* (%)	9 (20.9%)

IQR: interquartile range; IA tPA: intra-arterial tissue plasminogen activator; mTICI: modified Thrombolysis in Cerebral Infarction; sICH: symptomatic intracerebral hemorrhage; mRS: modified Rankin Scale; MeVO: medium vessel occlusion.

0.93–1.02, p = 0.22), presenting NIHSS (AOR 0.93, 95% CI 0.85–1.01, p = 0.09), or successful recanalization (TICI ≥ 2b) (AOR 3.89, 95% CI 0.84–18.01, p = 0.08) as independent predictors of favorable 90-day clinical outcomes.

Comparison of PCA and M2 and M3 MeVO procedural and clinical outcomes

Within the STAR database, MT for primary M2 and M3 occlusion was identified in 1273 (13.0%) patients and 130 (1.3%) patients, respectively. When patients in the PCA MeVO group were compared with patients with M2 and M3 MeVOs, there were no differences in baseline characteristics (Table 3). During the procedure, intra-arterial tPA was less likely to be used in PCA MeVOs compared with M2 and M3 MeVOs (4.7% PCA, 10.1% M2, 16.2% M3, p = 0.046); but no difference was seen in the rate of stent retriever use (62.8%, 63.4%, 63.8% M3, p = 0.99) or aspiration as the first approach (51.2%, 45.3%, 40.8%, p = 0.44) (Table 4).

Successful recanalization (mTICI ≥ 2b) was achieved in only 67.4% of patients in the PCA MeVOs compared with 86.7% in the M2 MeVOs and 82.3% in the M3 MeVOs (p < 0.001); however, no difference was seen in the rate of successful first pass (44.2%, 49.8%, 52.3%, p = 0.65). The rate of complications in each group was similar (4.7%, 7.3%, 8.5%, p = 0.71), and sICH was seen in 2.3% of patients in the PCA group compared with 5.2% in the M2 group and 6.2% in the M3 group (p = 0.62). There was no difference in the rate of favorable 90-day outcome (mRS

Table 3. Comparison of characteristics of thrombectomy patients presenting with PCA, M2, and M3 MeVOs.

Variable	PCA MeVO thrombectomy (*n* = 43)	M2 MeVO thrombectomy (*n* = 1273)	M3 MeVO thrombectomy (*n* = 130)	p-value*
Age in years, median (IQR)	69 (61–79)	72 (62–81)	69 (61–79)	0.24
Female sex, *n* (%)	21 (48.8%)	660 (51.9%)	56 (43.1)	0.15
White race, *n* (%)	32 (74.4%)	842 (66.2%)	94 (72.3%)	0.21
Admission NIHSS, median (IQR)	9 (6–17)	12 (7–17)	11.5 (7–17)	0.09
Comorbidities				
Diabetes mellitus, *n* (%)	16 (37.2%)	344 (27%)	36 (27.7%)	0.34
Hypertension, *n* (%)	34 (79.1%)	913 (71.8%)	97 (74.6%)	0.47
Atrial fibrillation, *n* (%)	13 (30.2%)	488 (38.4%)	37 (28.5%)	0.05
Hyperlipidemia, *n* (%)	17 (39.5%)	533 (41.9%)	59 (45.4%)	0.70
IV tPA, *n* (%)	21 (48.8%)	582 (45.8%)	69 (53.1%)	0.27
Onset-to-groin time in minutes, median (IQR)	285 (214–490)	261 (171–450)	254 (181–469)	0.48

*Calculated using chi-square test for categorical variables and Wilcoxon test for the continuous variables.
IQR: interquartile range; NIHSS: National Institute of Health stroke scale; IV tPA: intravenous tissue plasminogen activator; MeVO: medium vessel occlusion.

Table 4. Procedural and clinical outcomes of thrombectomy patients presenting with PCA, M2, and M3 MeVOs.

Variable	PCA MeVO thrombectomy (*n* = 43)	M2 MeVO thrombectomy (*n* = 1273)	M3 MeVO thrombectomy (*n* = 130)	p-value*
Thrombectomy passes, median (IQR)	2 (1–3)	1 (1–2)	1 (1–2)	0.25
IA tPA used, *n* (%)	2 (4.7%)	129 (10.1%)	21 (16.2%)	**0.046**
Aspiration as first approach, *n* (%)	22 (51.2%)	576 (45.3%)	53 (40.8%)	0.44
Stent retriever used, *n* (%)	27 (62.8%)	807 (63.4%)	83 (63.8%)	0.99
Procedure time, median (IQR)	37 (24–59)	37 (22–61)	31 (20–53)	0.19
Successful recanalization (final mTICI ≥ 2b), *n* (%)	29 (67.4%)	1103 (86.7%)	107 (82.3%)	**<0.001**
Successful first pass, *n* (%)	19 (44.2%)	633 (49.8%)	68 (52.3%)	0.65
Complications, *n* (%)	2 (4.7%)	93 (7.3%)	11 (8.5%)	0.71
sICH, n (%)	1 (2.3%)	66 (5.2%)	8 (6.2%)	0.62
90-day mRS, median (IQR)	3 (1–5)	3 (1–5)	3 (1–4.5)	0.69
mRS score 0–2 at 90 days, *n* (%)	17 (39.6%)	574 (45.1%)	54 (41.5%)	0.59
Mortality at 90 days, *n* (%)	9 (20.9%)	250 (19.7%)	21 (16.2%)	0.61

Calculated using chi-square test for categorical variables and Wilcoxon test for the continuous variables.
Bold indicates significance.
IQR: interquartile range; IA tPA: intra-arterial tissue plasminogen activator; mTICI: modified Thrombolysis in Cerebral Infarction; sICH: symptomatic intracerebral hemorrhage; mRS: modified Rankin Scale; MeVO: medium vessel occlusion.

0–2) in the PCA MeVOs (39.6%) compared with the M2 MeVOs (45.1%) and the M3 MeVOs (41.5%) ($p = 0.59$). In addition, there was no difference in 90-day mortality rate (20.9% PCA) compared with the M2 (19.7%) and M3 (16.2%) MeVOs ($p = 0.61$).

Discussion

Efficacy and safety of MT in PCA MeVOs

Limited data are available regarding the benefits of MT in patients with MeVOs, particularly in more distal posterior vasculature such as the PCA. In this large multicenter study, we report the STAR experience performing MT for PCA MeVOs, with our primary outcome being a favorable clinical outcome at 90 days (mRS 0–2). In the MT procedures, 67.4% of patients with PCA MeVOs achieved successful recanalization, including 44.2% who achieved recanalization on first pass, and minimal procedural complications were reported (4.7%). Our results demonstrated that at 90-day follow-up, 39.6% of patients had achieved a good clinical outcome, and 20.9% of patients had died.

The STAR experience performing MT for PCA MeVOs contributes to the accumulating evidence exploring the feasibility and efficacy of MT in distal PCA segments. Recent landmark works suggesting similar relatively positive results include the Endovascular Versus Medical Management of Posterior Cerebral Artery Occlusion Stroke (PLATO)[28] and Thrombectomy for Primary Distal Posterior Cerebral Artery Occlusion Stroke (TOPMOST)[8] studies. In the PLATO study of 1023 patients with PCA occlusions, Nguyen et al.[28] demonstrated that endovascular thrombectomy was associated with similar 90-day mRS outcomes, higher likelihood of a decrease in NIHSS score (by ≥ 2 points) at discharge, and better odds of an excellent outcome and complete vision recovery compared with medical management. The nonrandomized, retrospective TOPMOST study[8] propensity matched patients with PCA occlusions (in P2 and P3 segments) managed with pharmacotherapy against those treated with MT and found that patients with MT-treated PCA occlusions recorded a nonsignificant -1.5 mean NIHSS score change compared with occlusions managed with standard medical treatments ($p = 0.06$). However, among patients with higher NIHSS scores on admission (defined as ≥ 10), MT was associated with a significantly better reduction in NIHSS, with -5.6 mean difference in NIHSS score, than with medical management ($p = 0.04$). Other retrospective reports have found similar effects of MT over traditional medical management approaches.[11] From these reports, and in conjunction with the results of the present study, the feasibility and efficacy of MT for P2/P3 occlusions have been demonstrated, although randomized controlled trials will be necessary to confirm these findings.

Although these accumulating data are encouraging, it is clear that endovascular treatment of PCA MeVOs with current techniques and technologies is challenging, as evidenced by the 67.4% successful recanalization rate encountered in our study. Furthermore, it is unknown whether existing technologies for MT are less ideal for PCA MeVOs occlusions compared with more proximal occlusions in the posterior circulation or anterior circulation MeVOs. The deliberate optimization of posterior MeVO thrombectomy technologies and techniques to enable successful recanalization is likely critical for good patient outcomes in the long term. Our data hint that if the rate of successful recanalization could be raised with PCA-specific technology, the odds of good patient outcome (mRS 0–2) would be improved, but this could not be confirmed with the relatively low number of patients in our series.

This study also raises the issue of outcomes metric selection in patients with PCA occlusions. Many published PCA thrombectomy analyses, including the present study, utilize the NIHSS. This is less than ideal considering the NIHSS is known to underestimate the clinical severity of posterior circulation strokes.[29] Instead, future analyses and prospective databases may benefit from using the posterior NIHSS (POST-NIHSS)[29] or Adam's Scale of Posterior Stroke[30] scales when recording posterior circulation infarct data because these validated tools are designed to more objectively assess the severity of posterior circulation strokes.

Comparison of PCA MeVOs with MCA MeVOs

As a limited subanalysis to compare MT outcomes for anterior and posterior MeVOs, we compared patients in our PCA cohort against those with M2 and M3 occlusions captured within STAR. Our results suggest that the patients in the PCA MeVO cohort may have experienced stroke severity similar to that of the patients in the M2 and M3 MeVO groups and that 90-day clinical outcomes in PCA MeVOs were comparable with those in the M2 and M3 MeVOs, despite their having lower rates of successful recanalization. Notably, the rate of sICH in the PCA MeVOs was not higher than previously reported for MT in landmark clinical trials,[4] and the rates of sICH and complications did not significantly differ in patients among the 3 MT groups. This could be argued as further evidence for the relative safety of MT in distal PCA MeVOs. Although the successful recanalization rate in PCA MeVOs was worse (67.4% PCA vs. 86.7% M2 and 82.3% M3), it warrants notice that the median number of passes was similar across these groups. The reason for this is unclear; however, these findings may reflect that the PCA patients were more likely than M2/M3 MeVOs to have intracranial atherosclerotic disease as the occlusion etiology. Alternatively, there could be hesitancy among neurointerventionalists to perform multiple thrombectomy attempts in posterior locations because of the greater potential harm of procedural complications.

Limitations

The present study carries limitations inherent to its retrospective and observational design. Most notably, direct analysis of patients with isolated distal occlusions in the

PCA treated via medical management was not possible given our study design. Additionally, our reporting of only 43 PCA MeVO cases portends statistical power limitations, which was potentially observed in our multivariate results with a likely Type II error.

We acknowledge that using M2 and M3 MT groups as a comparison to assess MT efficacy is challenging, given the substantive differences in the anatomy of the tissue affected (e.g., presenting symptoms, NIHSS metrics, regions of brain affected). However, considering these anterior circulation locations have support from large-scale clinical trial subgroup analyses,[8–13,19,20,31] we believe this comparison has value. Finally, this was a multicenter study; therefore, management and procedural protocols were likely heterogeneous.

Conclusion

The STAR experience suggests that MT of isolated PCA MeVOs may be relatively safe and efficacious. A comparison with anterior circulation M2 and M3 MeVOs may suggest that improved techniques for PCA MeVOs are necessary for better patient outcomes. Also, the literature would likely benefit from future studies reporting PCA MeVO outcomes after MT using validated posterior circulation scales or grading systems. Finally, randomized controlled studies are still required to provide improved evidence for the efficacy of MT on clinical outcomes in PCA MeVOs.

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Authors' contribution

All authors contributed significantly to the preparation of this paper.

Data availability

The data are available from the corresponding author upon reasonable request.

Declaration of conflicting interests

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Ethical approval and informed consent

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