Case series

Mechanical thrombectomy in medium vessel occlusions using the novel aspiration Q catheters: an international multicenter experience

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ABSTRACT

Background Medium vessel occlusions (MeVOs) comprise a large proportion of all stroke events. We performed a multicenter study of MIVI Q catheters, a novel design that optimizes suction forces without an increase in lumen diameter, for the treatment of MeVOs, aiming to evaluate its efficacy and safety.

Methods Databases of two US and two UK centers were retrospectively reviewed for MeVO patients (M2-M3, anterior cerebral artery (ACA), or posterior cerebral artery (PCA)) treated with Q catheters. Outcomes were assessed as successful recanalization (modified Thrombolysis in Cerebral Infarction (mTICI) score ≥2b), first pass effect (FPE), and modified FPE (mFPE) as single pass achieving mTICI ≥2c and mTICI≥2b, respectively, and 90 day modified Rankin Scale (mRS) score.

Results 69 patients were included (median age 71 years, IQR 56–82.5; 52.2% men). Median National Institutes of Health Stroke Scale (NIHSS) score at admission was 14, and Alberta Stroke Program Early CT Score (ASPECTS) was 9. Primary (without large vessel occlusion (LVO)) and secondary (with LVO) MeVOs represented 47.8% and 52.2% of cases, respectively. Q catheters used were Q3 (47.8%), Q4 (33.3%), Q5 (10.1%), and Q6 (8.7%). mTICI≥2b was achieved in 92.8% of patients, with FPE in 47.8%, and mFPE in 68.1%. Two (2.9%) intraprocedural complications (symptomatic intracranial hemorrhage) occurred. 50% (27/54) achieved an mRS score of ≤2 at the 90 day follow-up. The median NIHSS at admission was significantly higher in secondary than in primary MeVOs (19.5 vs 12, P=0.009). The rate of mRS ≤2 at 90 days was significantly higher in primary than in secondary MeVOs (77.3% vs 31.3%, P=0.002).

Conclusions Treatment of MeVO patients with Q catheters resulted in optimal angiographic and clinical outcomes. Although angiographic results were similar between primary and secondary MeVOs, the former had less severe presenting NIHSS and better outcomes at 90 days than the latter.

WHAT IS ALREADY KNOWN ON THIS TOPIC

⇒ Currently, aspiration first is considered non-inferior to stent retriever based mechanical thrombectomy for large vessel occlusion stroke.
⇒ Linear tubing design of most aspiration catheters makes the suction force dependent on a large diameter to effectively retrieve clots, a limiting factor in the treatment of medium vessel occlusions (MeVOs).
⇒ Distal arteries in which MeVOs occur have a smaller caliber and can be more tortuous, increasing the risk of catheterization failure, dissection, and vessel perforation if navigation with large bore catheters is performed for clot retrieval.

WHAT THIS STUDY ADDS

⇒ In this international multicenter study, novel Q catheters for patients with MeVOs were used for mechanical thrombectomy.
⇒ Primary and secondary MeVOs were evenly distributed, each comprising nearly half of the cohort.
⇒ The catheters were highly effective in achieving recanalization, including first pass ones, without major complications.

HOW THIS STUDY MIGHT AFFECT RESEARCH, PRACTICE OR POLICY

⇒ The findings of this study have the potential to affect how MeVOs are treated with novel devices leading to low symptomatic intracranial hemorrhage rates and major complications.

INTRODUCTION

Mechanical thrombectomy (MT) became the gold standard treatment for anterior circulation large vessel occlusion (LVO) after the results of multiple randomized clinical trials.[1] Modern stent retrievers played a major role in this paradigm shift in stroke care due to their high efficiency in achieving successful recanalization (>70%).[2 3] Later, large bore distal aspiration catheters with improved navigability gained popularity with many defending the use of the Aspiration Direct First Pass Technique (ADAPT).[4] Currently, aspiration first is considered non-inferior to stent retriever based MT for LVO.[5 6] However, the linear tubing design of most aspiration catheters makes the suction force dependent on a large diameter to effectively retrieve clots.[7] While this is not an issue when treating LVO, it is

a limiting factor in the treatment of medium vessel occlusions (MeVOs), which represent the next frontier in endovascular management of acute ischemic stroke. Distal arteries in which MeVOs occur have a smaller caliber and can be more tortuous, increasing the risk of catheterization failure, dissection, and vessel perforation if navigation with large-bore catheters is performed for clot retrieval.[8]

The Q aspiration catheter (MIVI Neuroscience Inc, Minnesota USA) has a novel design that replaces the proximal three quarters of the catheter with a 104 cm long, 0.020 inch stainless steel pusher wire. This allows the 8 F guide lumen to be utilized for aspiration and has been reported to augment aspiration flow rates by up to 240%.[7] In the current study, we report an international multicenter experience on the use of Q catheters for treatment of MeVOs, aiming to evaluate the effectiveness and safety of these devices.

METHODS

Study population

The databases of endovascular interventions for acute ischemic stroke at four centers (two in the US and two in the UK) were retrospectively searched. The MeVO definition used for this study was occlusion of M2-M3, anterior cerebral artery (ACA), or posterior cerebral artery (PCA), and categorized as primary (without proximal LVO) or secondary (proximal LVO with a subsequent distal occlusion after recanalization attempt). M2 segments were defined as vessels beyond the first bifurcation (or trifurcation) of the insular segment of M1. Dominant M2 segments were included in the study as long as they had an occlusion. Therefore, we included all patients aged ≥18 years with primary or secondary MeVOs treated with a Q catheter.

Data extraction

Variables extracted were age, sex, comorbidities, National Institutes of Health Stroke Scale (NIHSS) score, Alberta Stroke Program Early CT Score (ASPECTS) and posterior ASPECTS, procedural details (access site, other devices used, and Q catheter size), complications, and angiographic and clinical outcomes. Angiographic outcomes were based on the modified Thrombolysis in Cerebral Infarction (mTICI) scale, with successful recanalization defined as mTICI ≥2b. The modified Rankin Scale (mRS) was used to assess prestroke functionality and clinical outcomes at 90 days. Functional independence was defined as mRS ≤2. First pass effect (FPE) and modified FPE (mFPE) were defined as single pass with Q catheter in the distal occlusion achieving mTICI ≥2c and mTICI ≥2b, respectively. Postprocedural hemorrhages were evaluated based on the Heidelberg classification, with symptomatic intracranial hemorrhage (sICH) defined as parenchymal hematoma type 2 with an increase of ≥4 points in NIHSS.[9]

RESULTS

Baseline characteristics

Sixty-nine patients were included. Median age was 71 years (IQR 56–82.5) and 36 patients (52.2%) were women. Comorbidities were hypertension in 28 patients (40.6%), atrial fibrillation in 27 (39.1%), diabetes in 52 (75.4%), hyperlipidemia in 16 (23.2%), and coronary artery disease in 20 (29.4%). Sixty-five patients (94.2%) had a prestroke mRS score of ≤2 (table 1). Median NIHSS score at admission was 14 (IQR 8.5–23) and median ASPECTS was 9 (IQR 8–9). Intravenous alteplase was administered to 30 (43.5%) patients.

Table 1 Summary of baseline characteristics, procedural details, and outcomes of patients

Variable	Value
Age (years) (mean (SD))	68.8 (15.2)
Women	36 (52.2)
Prestroke functional independence	65 (94.2)
Diabetes	52 (75.4)
Hypertension	28 (40.6)
Hyperlipidemia	16 (23.2)
Atrial fibrillation	27 (39.1)
Coronary artery disease	20 (29)
Median NIHSS	15 (8–23)
Median ASPECTS	9 (8–9)
Time from last known well to puncture (min) (median (IQR))	327 (190–549)
Time from puncture to recanalization (min) (median (IQR))	45 (33–72)
MeVO type	
Primary	33 (47.8)
Secondary	36 (52.2)
MeVO location	
ACA	9 (13)
M2-M3	57 (82.6)
PCA	3 (4.3)
Access site	
Femoral	64 (92.8)
Radial	5 (7.2)
Use of balloon guide catheter	5 (7.2)
No of Q catheter passes	
1	50 (72.5)
2	10 (14.5)
≥3	9 (13)
Final mTICI	
0	2 (2.9)
1	1 (1.4)
2a	2 (2.9)
2b	23 (33.3)
2c	14 (20.3)
3	27 (39.1)
mFPE	48 (69.6)
FPE	34 (49.3)
Any ICH	9 (13)
sICH	2 (2.9)
90 day functional independence	27 (50)

Values are n (%) unless otherwise stated.
ACA, anterior cerebral artery; ASPECTS, Alberta Stroke Program Early CT Score; FPE, first pass effect; ICH, intracranial hemorrhage; MeVO, medium vessel occlusion; mFPE, modified first pass effect; mTICI, modified Thrombolysis in Cerebral Infarction; NIHSS, National Institutes of Health Stroke Scale; PCA, posterior cerebral artery; sICH, symptomatic intracranial hemorrhage; TICI, Thrombolysis in Cerebral Infarction.

Procedural information

Access site was the femoral artery in 64 patients (92.8%) and the radial artery in 5 patients (7.2%). Thirty-three patients (47.8%) had primary MeVOs and 36 patients (52.2%) had secondary MeVOs. The occlusion locations of the primary MeVOs are listed in table 1. The proximal occlusion location in secondary MeVOs was the internal carotid artery (ICA) in 8 patients (22.2%), M1 in 25 patients (69.5%), and the basilar artery in 3 patients (8.3%). A different device was used in an

attempt to recanalize the MeVO in six patients (8.7%). Q catheter sizes used were the Q3 in 33 patients (47.8%), Q4 in 23 patients (33.3%), Q5 in 7 patients (10.1%), and Q6 in 6 patients (8.7%). Balloon guide catheters were used in only five (7.2%) cases. Successful recanalization (mTICI ≥2b) was achieved in 64 patients (92.8%). FPE was achieved in 34 patients (49.3%) and mFPE in 48 patients (69.6%). Only two (2.9%) intraprocedural complications occurred: one severe vasospasm and one ICA dissection caused by an exchange wire.

Postoperative and follow-up clinical outcomes

Postprocedure ICH of any type was observed in nine patients (13%). sICH occurred in two patients (2.9%). Follow-up at 90 days was available for 54 patients, of whom 27 (50%) achieved an mRS score of ≤2. Nine patients (13%) died by 90 days.

Primary versus secondary medium vessel occlusions

Primary and secondary MeVOs were not significantly different regarding age, comorbidities, prestroke functional independence, ASPECTS, intravenous alteplase administration, access site, number of passes, use of balloon guide catheters, final mTICI, FPE, mFPE, any ICH, sICH, and mortality at 90 days (table 2). Median NIHSS at presentation was significantly higher in secondary than in primary MeVOs (19 vs 12, P=0.009). Secondary MeVOs had a significantly (P=0.01) higher rate of ACA (3% vs 22.2%) and PCA (0% vs 8.3%) occlusions, and lower rate of M2-M3 (69.4% vs 97%) occlusions than primary MeVOs. The rate of mRS ≤2 at 90 days was significantly higher in primary than in secondary MeVOs (77.3% vs 31.3%, P=0.002) (table 2). For failed thrombectomy cases, additional devices used included Catch Mini, Sofia, and Embotrap. Primary devices used for secondary MEVO cases included Sofia 6F intermediate catheter, Solitaire Stentretriever, Embotrap, Vecta 74, and Q6 MIVI catheter. The Q6 MIVI catheter was used as the primary device in only five cases for secondary MEVO cases (table 3).

Predictors of functional independence

Univariate regression models for prediction of functional independence at 90 days were built for all variables. Secondary MeVOs (OR 0.13, 95% CI 0.03 to 0.46, P=0.002), NIHSS (OR 0.85, 95% CI 0.77 to 0.93, p<0.003), and time from puncture to recanalization (OR 0.96, 95% CI 0.93 to 0.99, P=0.024) significantly predicted reduced odds of functional independence at 90 days. A multivariate logistic regression model was then built with these three variables, and time from puncture to recanalization (OR 0.95, 95% CI 0.92 to 0.98) and NIHSS (OR 0.76, 95% CI 0.62 to 0.094, P=0.011) independently predicted reduced odds of functional independence at 90 days. Twenty-one patients (38.9%) in the mFPE group achieved good functional outcome at 90 days versus 15 (27.8%) in the FPE group. This difference was found to be statistically non-significant (P=0.221)

DISCUSSION

We have reported an international multicenter experience of MT using the novel Q catheters for patients with MeVOs. Primary and secondary MeVOs were evenly distributed, each comprising nearly half of the cohort. The catheters were highly effective in achieving recanalization, including first pass ones, without major complications. Overall, our patients achieved a high rate of functional outcome at 90 days. However, we found that primary MeVOs presented with lower severity and achieved better outcomes than secondary ones. Furthermore, secondary

Table 2 Comparison of baseline characteristics, procedure details, and outcomes between primary and secondary medium vessel occlusions

Variable	Primary (n=33)	Secondary (n=36)	P value
Age (years) (mean (SD))	70.8 (13.7)	67 (16.4)	0.298
Women	14 (42.4)	22 (31.1)	0.151
Prestroke functional independence	32 (97)	33 (91.7)	0.615
Diabetes	8 (24.2)	9 (25)	1
Hypertension	21 (63.6)	20 (55.6)	0.625
Hyperlipidemia	9 (27.3)	7 (19.4)	0.570
Atrial fibrillation	16 (48.5)	11 (30.6)	0.146
Coronary artery disease	6 (18.8)	14 (38.9)	0.109
Median NIHSS	12 (7–18)	19 (12–24)	0.009
Median ASPECTS	9 (8–9)	9 (7–9)	0.656
Intravenous alteplase administration	14 (42.4)	16 (44.4)	0.865
Time from last known well to puncture (min) (median (IQR))	338 (165–540)	300.5 (217–735)	0.825
Time from puncture to recanalization (min) (median (IQR))	37 (26–49)	66 (39–109)	0.006
Proximal occlusion location	NA		NA
ICA		8 (11.6)	
M1		25 (36.2)	
Basilar		3 (4.3)	
MeVO location			0.01
ACA	1 (3)	8 (22.2)	
M2-M3	32 (97)	25 (69.4)	
PCA	0 (0)	3 (8.3)	
Access site			1
Femoral	31 (93.9)	33 (91.7)	
Radial	2 (6.1)	3 (8.3)	
Use of balloon guide catheter	2 (6.1)	3 (8.3)	1
No of Q catheter passes			0.107
1	25 (75.8)	25 (69.4)	
2	2 (6.1)	8 (22.2)	
≥3	6 (18.2)	3 (8.3)	
Final mTICI			0.323
0	1 (3)	1 (2.8)	
1	0 (0)	1 (2.8)	
2a	2 (6.1)	0 (0)	
2b	11 (33.3)	12 (33.3)	
2c	4 (12.1)	10 (27.8)	
3	15 (45.5)	12 (33.3)	
mFPE	23 (69.7)	25 (69.4)	1
FPE	16 (48.5)	18 (50)	1

Continued

Table 2 Continued

Variable	Primary (n=33)	Secondary (n=36)	P value
Any ICH	3 (9.1)	6 (16.7)	0.481
sICH	1 (3)	1 (2.8)	1
Mortality at 90 days	1 (4.5)	8 (25)	0.07
90 day functional independence	17 (77.3)	10 (31.3)	0.002

Value are n (%) unless otherwise stated.
ACA, anterior cerebral artery; ASPECTS, Alberta Stroke Program Early CT Score; FPE, first pass effect; ICA, internal carotid artery; ICH, intracranial hemorrhage; MeVO, medium vessel occlusion; mFPE, modified first pass effect; mTICI, modified Thrombolysis in Cerebral Infarction; NA, not applicable; NIHSS, National Institutes of Health Stroke Scale; PCA, posterior cerebral artery; sICH, symptomatic intracranial hemorrhage.

MeVOs and higher stroke severity were found to be independent predictors of worst outcomes. The current study is the largest series of patients treated with the novel Q catheters.

Aspiration thrombectomy has been demonstrated to have similar efficacy and safety to stent retriever based thrombectomy for LVO in multiple studies and is currently accepted as non-inferior.[4 5] Moreover, the aspiration first strategy has been proposed to have financial advantages over stent retriever first.[10] Comparisons of aspiration versus stent retriever first in MeVOs have been less extensively performed. In a subanalysis of the Treatment for Primary Medium Vessel Occlusion Stroke (TOPMOST) study evaluating 141 patients with primary isolated P2 and P3 occlusions, the investigators reported that aspiration first and stent retriever first strategies had similar rates of FPE (aspiration 53.7% vs stent retriever 44%, P=0.297) and mRS score was 0–1 at 90-days (aspiration 60.5% vs stent retriever 68.6%, P=0.4).[11] Barchetti *et al* performed a meta-analysis of 494 patients, with a distal occlusion definition similar to ours (A2-A3, M2-M3, P1-P2), comparing ADAPT versus 0.017 microcatheter compatible stent retrievers.[12] The authors found comparable recanalization rates, but lower functional independence and higher mortality rate in stent retriever patients.[12]

Suction force in aspiration thrombectomy depends on the area in contact with the clot surface. Therefore, higher suction forces are expected with larger bore catheters. However, the diameters of such catheters are not compatible with smaller caliber vessels, such as the ACA, PCA, and M2-M3. In these locations, either smaller bore catheters or stent retriever have to be used, which have diminished odds of recanalization and increased cost of treatment, respectively. The design of Q catheters eliminates the proximal part of the catheter and replaces it with a wire, allowing a larger inner diameter guide to be connected, while the tip remains small, maximizing suction force in distal vessels.[7] No direct comparisons have been performed between standard aspiration catheters compatible with smaller caliber of distal occlusions versus the Q catheter design. In the literature, the meta-analysis of Barchetti *et al* reported 2b–3 recanalization rates in distal occlusions of approximately 80%, in which most studies used standard aspiration catheters.[12] Nevertheless, details such as number of passes and use of adjunctive techniques prior to final recanalization grade in case of failure of aspiration are important for better comparison. In our study, the rate of 92.8% successful recanalization was achieved without the use of adjunctive techniques after the Q catheter was attempted. In a study by Vargas *et al* evaluating ADAPT using 5MAX, 4MAX, and 3MAX catheters in distal occlusions, the rate of 2b–3 recanalization was 77.1% in aspiration alone without further adjunctive techniques.[13] In their study, however, no breakdown of primary and secondary MeVOs was performed.

Table 3 Dimensions of the Q aspiration catheter

Device	Distal ID (mm (inches))	Proximal ID (mm (inches))	Distal OD (mm (inches))	Proximal OD (mm (inches))	Catheter usable length
Q3 (3 F)	0.91 (0.036)	1.45 (0.057)	1.22 (0.048)	2.24 (0.088)	143
Q4 (4 F)	1.09 (0.043)	1.45 (0.057)	1.40 (0.055)	2.24 (0.088)	130
Q5 (5 F)	1.45 (0.057)	1.45 (0.057)	1.83 (0.072)	2.24 (0.088)	125
Q6 (6 F)	1.75 (0.069)	1.75 (0.069)	2.13 (0.084)	2.24 (0.088)	125

(mm (inches))
ID, inner diameter; OD, outer diameter.

In addition to reporting a large experience with the novel Q catheters, our study also provided information for the scarce literature on primary and secondary MeVOs. Goyal *et al* reported that secondary MeVOs can occur due to spontaneous clot fragmentation, thrombolytic drug induced fragmentation (eg, post-intravenous alteplase administration), or mechanical induced fragmentation (eg, during clot retrieval attempts in mechanical thrombectomy).[14] Given that in the context of our study and other series of MeVOs treated with MT it is often not possible to determine the mechanism of secondary MeVOs, we categorized as secondary any MeVO with a proximal LVO. Importantly, our study supports a few assumptions described in the literature about secondary MeVOs.[8 14] For example, we found that secondary MeVOs had greater severity based on NIHSS at admission, longer time to recanalization, and worse outcomes at 90 days. Conversely, it would make sense for secondary MeVOs to have more extensive infarctions, as previously described for MeVOs with discrepant infarct, but we did not observe worse ASPECTS in secondary MeVO patients.[15] It has been speculated that secondary MeVOs could have a higher risk of hemorrhagic conversions when treated, but we observed similar rates for any ICH and sICH in our primary and secondary MeVO patients.[14] Moreover, the hypothesis that secondary MeVOs could be more fragile and prone to further fragmentation on treatment was also not observed in our study, as the rates of recanalization were similar between primary and secondary occlusions.[14] Interestingly, secondary MeVO status did not independently predict worse outcomes when built in the multivariable regression model along with time from puncture to recanalization and NIHSS. This may be a suggestion that even primary MeVOs can have poor outcomes if time to recanalization is delayed, therefore highlighting the importance of efficient thrombectomy devices to achieve first pass recanalization in these patients.

Our study had limitations. This was a retrospective observational study with a limited population of interest. Different management protocols may have been followed across the institutions, which were from two different countries, therefore limiting technical consistency. Although much evidence exists regarding the potential benefit of balloon guide catheters in LVO strokes, only 7.2% of our cases were performed using these. This does not provide enough evidence to draw any conclusions. Also, since four different centers contributed to data for this study, varying operator preference led to dismal use. Furthermore, patients were treated by highly experienced operators at all centers, reducing the generalizability of our findings. The results of this study must be approached with caution.

CONCLUSIONS

Treatment of acute ischemic stroke patients with MeVOs using the novel Q catheters resulted in high rates of successful

recanalization, mFPE and FPE, low complication rates, and high rates of functional independence at 90 days. Secondary MeVOs were found to have worse severity at presentation and worse outcomes at 90 days. Finally, only worse severity and longer time from puncture to recanalization were predictors of poor outcomes in the overall cohort.

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