ORIGINAL RESEARCH

Larger ACE 68 aspiration catheter increases first-pass efficacy of ADAPT technique

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ABSTRACT

Purpose To report the efficacy of A Direct Aspiration first-Pass Thrombectomy (ADAPT) technique with larger-bore ACE aspiration catheters as first-line treatment for anterior circulation emergent large vessel occlusions (ELVOs), and assess for the presence of a first-pass effect with ADAPT.

Methods We retrospectively reviewed 152 consecutive patients with anterior circulation ELVOs treated with the ADAPT technique as first-line treatment using ACE60, 64, or 68 at our institution. Baseline characteristics, procedural variables, and modified Rankin Scale (mRS) at 90 days were recorded.

Results Fifty-seven patients were treated with ACE60 (37.5%), 35 with ACE64 (23%), and 60 with ACE68 (39.5%). Median groin puncture to reperfusion time was 30 min with ACE60, 26 min with ACE64, and 19.5 min with ACE68. Successful reperfusion after the first ADAPT pass was 33% with ACE60 and 53% with ACE68 (P=0.04). The stent-retriever rescue rate was 26% with ACE60, 3% with ACE64, and 10% with ACE68 (P=0.004). In multivariate logistic regression analysis, use of the ACE68 aspiration catheter was an independent predictor of successful reperfusion after the first ADAPT pass (P=0.016, OR1.67, 95% CI 1.1 to 2.54), and successful reperfusion after the first ADAPT pass was an independent predictor of good clinical outcome at 90 days (P=0.0004, OR6.2, 95% CI 2.27 to 16.8).

Conclusion Use of the larger-bore ACE 68 aspiration catheter was associated with shorter groin puncture to reperfusion time, higher rate of successful reperfusion after the first ADAPT pass, and lower rate of stent-retriever rescue. Further, a first-pass effect was demonstrated in our ADAPT patient cohort.

INTRODUCTION

After landmark randomized controlled trials showed that patients with acute ischemic strokes due to anterior circulation emergent large vessel occlusions (ELVO) had better clinical outcomes when best medical management was followed by mechanical thrombectomy,[1–6] this strategy is now the standard of care in this patient population.[7]

Although there is debate in the neurointerventional community regarding what is the safest and most effective technique for performing mechanical thrombectomy,[8–16] direct aspiration at the face of the thrombus using A Direct Aspiration first-Pass Thrombectomy (ADAPT) technique with a large-bore aspiration catheter such as the ACE 60, 64, or 68 catheters (Penumbra, Alameda, CA, figure 1) has gained increased acceptance as first-line treatment.[17–26] Further, angiographic and clinical outcomes of the ASTER and COMPASS randomized controlled trials showed that the ADAPT technique was equivalent in safety and efficacy to stent-retriever thrombectomy for patients with anterior circulation ELVOs,[15 16] while stent-retrievers can be used as rescue devices when ADAPT only fails to achieve successful reperfusion.[17–31] A recent analysis of the North American Solitaire Acute Stroke Registry showed that achieving successful reperfusion after the first Solitaire thrombectomy device pass was an independent predictor of a good clinical outcome at 90 days, the first-pass effect.[32]

The purpose of this study is to assess the safety and efficacy of the ADAPT technique as first-line treatment for anterior circulation ELVOs with larger-bore ACE aspiration catheters, and to assess for the presence of a first-pass effect with the ADAPT technique.

METHODS

Our study was approved by our hospital's institutional review board and conducted in compliance with the Health Insurance Portability and Accountability Act. We analyzed our prospectively-maintained institutional neurointerventional database to examine the procedural and clinical outcomes in patients with anterior-circulation ELVOs who were treated with mechanical thrombectomy using the ADAPT technique with ACE 60, 64, or 68 as first-line treatment between July 12 2013 and November 30 2017.

Medical record review

We recorded baseline patient and radiological characteristics, procedural variables, periprocedural complications, and clinical outcomes at 90 days in a consecutive cohort of patients with ELVOs treated with mechanical thrombectomy using the ADAPT technique as first-line treatment at our institution during the study period. The patient cohort was divided into three groups according to the ACE aspiration catheter used: ACE 60, 64, or 68.

Mechanical thrombectomy exclusion criteria

Institutional exclusion criteria for mechanical thrombectomy were: mild stroke symptoms, defined as an admission National Institutes of Health Stroke Scale (NIHSS)<5; presence of a large completed territorial infarction by non-contrast CT

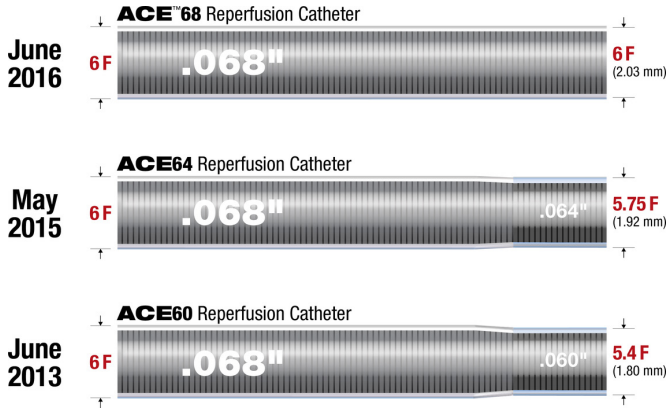

Figure 1 Time of release and specifications of ACE 60, 64 and 68 aspiration catheters (reproduced with permission from Penumbra, Inc.)

(NCCT), defined as an Alberta Stroke Program Early CT Score (ASPECTS)<5; or any intracranial hemorrhage. There was no strict time from last known well (LKW) cut-off for exclusion, as long as the NCCT ASPECTS was ≥5 at presentation.

ADAPT mechanical thrombectomy technique

The mechanical thrombectomy procedure was performed in a biplane neuroangiography suite (Axiom Artis, Siemens, Munich, Germany) by one of four neurointerventional radiologists with 3 to 15 years of experience in neurointervention. The procedure was performed under monitored minimal to moderate conscious sedation with intravenous fentanyl administered by a sedation nurse. In patients requiring intubation prior to mechanical thrombectomy for airway protection, the procedure was performed under a propofol infusion administered by a sedation nurse.

Through a short 8F femoral sheath, a long sheath was advanced to the cervical vasculature (NeuronMax088, Penumbra) using a Simmons Select catheter (Penumbra). Then, a coaxial assembly comprising a large-bore aspiration catheter (ACE 60, 64, or 68, Penumbra) and either a Velocity microcatheter (used with ACE 60 or 64, Penumbra) or 3Max catheter (used with ACE 68, Penumbra) over a 0.016 inch microwire (double-angle Headliner, Microvention/Terumo, Aliso Viejo, CA) was introduced through the long sheath. The aspiration catheter was advanced up to the face of the thrombus over the Velocity or 3Max, which were subsequently removed. The aspiration tubing was connected directly to the hub of the aspiration catheter, and the Penumbra aspiration pump was turned on. After 30–90 s, the aspiration catheter was slowly withdrawn under continuous aspiration until there was free bloodflow in the tubing. Then, the tubing was disconnected from the hub of the aspiration catheter, and the catheter was aspirated with a syringe to remove any residual thrombus fragments. If there was no free bloodflow in the tubing during aspiration catheter withdrawal, then the catheter was slowly removed from the patient under continuous aspiration from the pump and the NeuronMax088 was aspirated with a syringe to remove any residual thrombus fragments. This was repeated until successful reperfusion (TICI 2b-3) was achieved. If four ADAPT passes failed to achieve incremental reperfusion, then stent-retriever rescue was employed.

ACE 60 was used from the beginning to the end of the study period, ACE 64 from May 2015 until June 2016, and ACE 68 from June 2016 to the end of the study period. Presently, ACE 68 is used for internal carotid artery (ICA), M1 and proximal M2 segment occlusions, and ACE 60 is used for distal M2 and select proximal M3 segment occlusions.

Image analysis

Two experienced neurointerventionalists reviewed: pre-treatment NCCTs to determine the baseline ASPECTS; treatment angiograms to determine thrombus location and post-thrombectomy Thrombolysis In Cerebral Infarction (TICI) score; follow-up NCCTs to determine the presence and type of intracranial hemorrhage; and pre-treatment CT angiograms, treatment angiograms, and/or post-treatment MR angiograms to determine the degree of cervical vascular tortuosity in the common carotid artery and ICA proximal to the ELVO using the methodology described by Faggioli et al.[33] Severe vascular tortuosity proximal to the ELVO was defined as ≥360 degrees in the combined common carotid artery and ICA tortuosity score. Differences in image interpretation were resolved by consensus.

In cases where intracranial hemorrhage was present in the post-thrombectomy NCCT within 24 hours of treatment, consensus with a vascular neurologist independent of the procedure was reached to determine if the hemorrhage was symptomatic, defined as an increase in NIHSS ≥4 from the last-recorded pre-thrombectomy NIHSS.[16]

Clinical outcomes

A modified Rankin Scale (mRS) at 30 and 90 days post-thrombectomy was obtained during routine clinical follow-up visits performed by one of two nurse practitioners independent of the procedure and certified in the mRS. If the patient was unable to return to the clinic for a follow-up visit, an mRS was obtained using a validated phone interview questionnaire.[34] A good clinical outcome was defined as functional independence, mRS 0–2, at the time of the 90-day follow-up.

Statistical analysis

Statistical analysis was performed utilizing the MedCalc 11.1 software package (MedCalc Software, Mariakerke, Belgium). Univariate analyses were performed using Student's t-test for continuous variables and Fisher's exact or Chi-square tests for categorical variables. Multivariate logistic regression analyses were performed to identify independent predictors of: overall successful reperfusion; successful reperfusion with ADAPT only; successful reperfusion after the first ADAPT pass; and good clinical outcome at 90 days (mRS 0–2). Receiver operating characteristic analysis was performed to identify optimal thresholds for continuous variables that were identified to be independent predictors. P≤0.05 was considered statistically significant.

RESULTS

From July 12 2013 until November 30 2017, 220 patients with acute ischemic strokes due to an ELVO underwent mechanical thrombectomy at our institution. Among these patients, 15 were enrolled in a mechanical thrombectomy randomized controlled trial (7.1%), four were enrolled in an investigational thrombectomy device clinical trial (1.8%), 10 had a posterior-circulation ELVO (4.5%), 10 had an extracranial anterior-circulation ELVO (4.5%), nine were treated with the 3Max or 4Max aspiration catheters for distal intracranial occlusions (4.1%), and 20 were treated with a stent-retriever as first-line treatment (9.1%).

Hence, 152 patients with intracranial anterior-circulation ELVOs were treated using the ADAPT technique with ACE 60, 64, or 68 as first-line treatment during the study period at our institution, comprising this study's cohort. The aspiration catheter utilized was an ACE 60 in 57 cases (37.5%), ACE 64 in 35 cases (23%), and ACE 68 in 60 cases (39.5%). Mean lengths of stay were 3 days in the neurological intensive care unit and 6.9

Table 1 Baseline clinical and radiological patient characteristics

	All patients, n=152 (%)	ACE 60, n=57 (%)	ACE 64, n=35 (%)	ACE 68, n=60 (%)	P values
Mean age, years	68.1	67.4	68.7	68.3	0.65*/0.71†
Sex					0.051
Female	70 (46)	21 (37)	22 (63)	27 (45)	
Male	82 (54)	36 (63)	13 (37)	33 (55)	
Atrial fibrillation	61 (40)	22 (39)	12 (35)	27 (45)	0.56
Diabetes mellitus	32 (21)	12 (21)	8 (23)	12 (20)	0.95
Hypertension	93 (61)	34 (60)	21 (60)	38 (63)	0.91
Mean NIHSS	18.5	18.2	18.8	18.4	0.6*/0.62†
IV-tPA administration	81 (53)	31 (54)	18 (51)	32 (53)	0.96
Mean baseline NCCT ASPECTS	9	9.3	8.7	8.9	0.015*/0.08†
Thrombus location					
ICA	43 (28)	14 (25)	11 (31)	18 (30)	0.72
MCA M1	78 (51)	25 (44)	20 (57)	33 (55)	0.36
MCA M2	26 (17)	14 (25)	3 (9)	9 (15)	0.12
MCA M3	5 (3)	4 (7)	1 (3)	0	0.1
Left side	86 (57)	31 (54)	17 (49)	38 (63)	0.34
Tandem ICA origin occlusion	22 (15)	8 (14)	7 (20)	7 (12)	0.5
Mean cervical tortuosity, degrees	244.9	255.8	263.6	223.8	0.81*/0.28†
Severe,≥360°	41 (27)	19 (33)	10 (29)	12 (20)	0.26
Mean time LKW to groin puncture, min	262	224.1	302.3	274.4	0.028*/ 0.11†

*P-value for the difference between ACE 60 and ACE 64 using Student's t-test.
†P-value for the difference between ACE 60 and ACE 68 using Student's t-test.
ASPECTS, Alberta Stroke Program Early CT Score; CT, computed tomography; ICA, internal carotid artery; IV-tPA, intravenous tissue plasminogen activator; LKW, last known well; min: minutes; MCA, middle cerebral artery; N, number of patients; NIHSS, National Institutes of Health Stroke; NCCT, non-contrast computed tomography CT.

days in the hospital. Thirty-eight patients were discharged home (25%), 66 to a rehabilitation facility (43.4%), 23 to a skilled nursing facility (15.1%), and 25 expired during the hospitalization (16.4%). At 90 days, a good clinical outcome, mRS 0–2, was achieved in 70 patients (46.1%), while 27 patients had mRS 3 (17.8%), 22 mRS 4–5 (14.5%), and 33 expired (21.7%).

Table 1 summarizes the baseline clinical and radiological patient characteristics in our cohort. Compared with patients treated with ACE 60, those treated with ACE 64 had significantly longer LKW to groin puncture times (P=0.028) and lower baseline NCCT ASPECTS (P=0.015). There were no other significant differences in baseline clinical and radiological characteristics between patients treated with the three different ACE aspiration catheters in our cohort.

Efficacy of the ADAPT technique with larger-bore ACE aspiration catheters

Table 2 summarizes the procedural variables in our cohort. Mean groin puncture to reperfusion time was significantly longer in ACE 60 cases (44.4 min) compared with ACE 64 (30.2 minutes, P=0.02) and ACE 68 cases (27.7 min, P=0.003). The rate of

Table 2 Efficacy of the ADAPT technique with larger-bore ACE aspiration catheters

	All cases, n=152 (%)	ACE 60, n=57 (%)	ACE 64, n=35 (%)	ACE 68, n=60 (%)	P values
Mean time puncture to reperfusion, minutes	34.5	44.4	30.2	27.7	**0.02***/**0.003†**
Median time puncture to reperfusion, minutes	24	30	26	19.5	n/a
Mean number of ADAPT passes	2.3	2.3	2.5	2	0.6*/0.8†
Median number of ADAPT passes	2	2	2	1	n/a
Overall successful reperfusion‡	137 (90)	50 (88)	32 (91)	55 (92)	0.74
Successful reperfusion‡ using ADAPT only	122 (80)	38 (67)	31 (89)	53 (88)	**0.005**
Successful reperfusion‡ after first ADAPT pass	64 (42)	19 (33)	13 (37)	32 (53)	0.07/**0.04**§
Stent-retriever rescue	22 (14.5)	15 (26)	1 (3)	6 (10)	**0.004**
Mean number of ADAPT passes before stent-retriever rescue	3.3	2.6	3	5	0.8*/**0.029†**
Successful reperfusion‡ after stent-retriever rescue	15 (68)	12 (80)	1 (100)	2 (33)	0.09

*Pvalue for the difference between ACE 60 and ACE 64 using Student's t-test.
†P-value for the difference between ACE 60 and ACE 68 using Student's t-test.
‡Defined as thrombolysis in cerebral ischemia 2b, 2c, or 3.
§P value for the difference between ACE 60 and ACE 68 using Chi-square test. n/a: not applicable.

successful reperfusion using ADAPT only was significantly lower with ACE 60 (67%) than with ACE 64 (89%) or ACE 68 (88%, P=0.005). Further, the rate of successful reperfusion after the first ADAPT pass was significantly higher with ACE 68 (53%) than ACE 60 (33%, P=0.04). The rate of stent-retriever rescue was significantly higher with ACE 60 (26%) than with ACE 64 (3%) or ACE 68 (10%, P=0.004). Notably, successful reperfusion after the first ADAPT pass was achieved in 23 of the 33 patients with M1 occlusions treated with ACE 68 in our cohort (70%).

Interplay between the ADAPT technique learning curve and its efficacy with larger-bore ACE aspiration catheters

Compared with early ACE 60 cases (performed up to December 31 2014, n=24), late ACE 60 cases (performed from January 1 2015 onwards, n=33) exhibited trends toward shorter mean groin puncture to reperfusion time (39.4 min vs 51.3 min, P=0.1), higher rate of successful reperfusion after the first ADAPT pass (42% vs 21%, P=0.08) and higher rate of successful reperfusion using ADAPT only (76% vs 54%, P=0.08), as well as a significantly lower rate of stent-retriever rescue (15% vs 42%, P=0.03).

Compared with late ACE 60 cases, ACE 68 cases exhibited significantly lower mean groin puncture to reperfusion time (27.7 min vs 39.4 min, P= 0.02) trends toward higher rate of successful reperfusion after the first ADAPT pass (53% vs 42%, P=0.2) and higher rate of successful reperfusion using ADAPT only (88% vs 76%, P=0.1), and a lower rate of stent-retriever rescue (10% vs 15%, P=0.5).

Complications of the ADAPT technique with larger-bore ACE aspiration catheters

Table 3 summarizes the complications in our cohort. The rate of embolus to new territory was slightly higher with ACE 60 (5.3%) than with ACE 64 (2.9%) and ACE 68 (1.7%). The overall rate of intracranial vascular injury was slightly higher with ACE 64 (5.7%) and ACE 68 (5%) than with ACE 60 (1.8%). Nevertheless, none of these differences were statistically significant.

Both cases of intracranial vascular injury with ACE 64 occurred while advancing the aspiration catheter past the ophthalmic artery over a Velocity microcatheter. The vessel perforation with ACE 68 occurred during the second ADAPT pass while advancing the aspiration catheter over a 3Max catheter to the M1 segment in a nonagenarian patient with an ICA terminus occlusion. The intracranial dissection with ACE 68 occurred while advancing the aspiration catheter past the ophthalmic artery over a 3Max catheter and resolved without clinical sequelae after 1 month of dual antiplatelet therapy. The inadvertent broad-based M1 segment aneurysm perforation occurred with a Synchro 14 microwire (Stryker Neurovascular, Fremont, CA) while attempting to advance a Velocity microcatheter past a tenacious M1 segment thrombus for stent-retriever rescue after five failed ADAPT passes with ACE 68 (the broad-based M1 segment aneurysm had initially been mistaken for the stump of an M2 branch).

The rate of SICH was slightly higher with ACE 64 (5.7%) and ACE 68 (6.7%) than with ACE 60 (1.8%), although these differences were not statistically significant. Of note, the rate of all SICH and subarachnoid SICH after stent-retriever rescue was significantly higher in ACE 64 and ACE 68 cases than in ACE 60 cases (table 3).

Predictors of successful reperfusion

There were no independent predictors of overall successful reperfusion in our cohort. Independent predictors of successful reperfusion with ADAPT only were ACE aspiration catheter used (P=0.0016, OR 2.44, 95% CI 1.40 to 4.26), and thrombus location (P=0.048, OR 1.82, 95% CI 1.00 to 3.3). Independent predictors of successful reperfusion after the first ADAPT pass were thrombus location (P=0.013, OR 1.88, 95% CI 1.14 to 3.1), and ACE aspiration catheter used (P=0.016, OR 1.67, 95% CI 1.1 to 2.54). The logistic regression model controlled for patient age, sex, intravenous tPA administration, history of atrial fibrillation, hypertension, diabetes mellitus, presence of a tandem ICA origin occlusion, and degree of cervical tortuosity (table 4).

Predictors of a good clinical outcome at 90 Days (mRS 0–2)

Independent predictors of a good clinical outcome at 90 days were successful reperfusion after the first ADAPT pass (P=0.0004, OR 6.2, 95% CI 2.27 to 16.8), NIHSS (P=0.0076, OR 0.89, 95% CI 0.82 to 0.97), and history of hypertension

Table 3 Complications of the ADAPT technique with larger-bore ACE aspiration catheters

	All cases, n=152 (%)	ACE 60, n=57 (%)	ACE 64, n=35 (%)	ACE 68, n=60 (%)	P values
Embolus to new territory	5 (3.3)	3 (5.3)	1 (2.9)	1 (1.7)	0.5
Intracranial vascular injury	6 (3.9)	1 (1.8)	2 (5.7)	3 (5)	0.5
Vessel perforation	3 (2)	1 (1.8)	1 (2.9)	1 (1.7)	0.9
Aneurysm perforation	1 (0.7)	0	0	1 (1.7)	0.5
Intracranial dissection	1 (0.7)	0	0	1 (1.7)	0.9
Carotid-cavernous fistula	1 (0.7)	0	1 (2.9)	0	0.2
SICH	7 (4.6)	1 (1.8)	2 (5.7)	4 (6.7)	0.4
Intraparenchymal	3 (2)	1 (1.8)	0	2 (3.3)	0.5
Subarachnoid	4 (2.6)	0	2 (5.7)	2 (3.3)	0.23
	All SR rescue cases, n=22 (%)	**SR rescue after ACE 60, n=15 (%)**	**SR rescue after ACE 64, n=1 (%)**	**SR rescue after ACE 68, n=6 (%)**	**P values**
SICH after stent-retriever rescue	3 (13.6)	0	1 (100)	2 (33.3)	**0.005**
Intraparenchymal	1 (4.5)	0	0	1 (16.7)	0.25
Subarachnoid	2 (9.1)	0	1 (100)	1 (16.7)	**0.003**

SICH:symptomatic intracranial hemorrhage, SR: stent-retriever.

Table 4 Independent predictors of successful reperfusion

	Patients with successful reperfusion after first ADAPT pass (%)	Patients with successful reperfusion with ADAPT only (%)	P values*
ACE catheter used			0.016/0.0016
ACE 60, n=57	19 (33)	38 (67)	
ACE 64, n=35	13 (37)	31 (89)	
ACE 68, n=60	32 (53)	53 (88)	
Thrombus location			0.013/0.048
ICA, n=43	5 (12)	27 (63)	
MCA M1, n=78	47 (60)	70 (90)	
MCA M2, n=26	11 (42)	23 (88)	
MCA M3, n=5	1 (20)	2 (40)	

*P value from multivariate logistic regression analysis for successful reperfusion after first ADAPT pass/successful reperfusion with ADAPT only.
ICA, internal carotid artery; MCA, middle cerebral artery.

(P=0.026, OR 0.34, 95% CI 0.13 to 0.88). The logistic regression model controlled for patient age, sex, NCCT ASPECTS, intravenous tPA administration, history of atrial fibrillation, hypertension, diabetes mellitus, thrombus location, presence of a tandem ICA origin occlusion, degree of cervical tortuosity, ACE catheter used, need for stent-retriever rescue, overall successful reperfusion, successful reperfusion with ADAPT only, time from onset to reperfusion, and presence of SICH (table 5). Receiver operating characteristic analysis identified an NIHSS ≤21 as an optimal cut-off for the prediction of a good clinical outcome at 90 days (area under the curve 0.64, 95% CI 0.56 to 0.72, P=0.0014).

DISCUSSION

Our cohort's overall rates of: successful reperfusion, 90%; SICH, 4.6%; embolus to uninvolved territory, 3.3%; and good clinical outcome at 90 days, 46%, are within the range of the landmark randomized controlled trials,[1–6] and similar to the ADAPT arms in the ASTER and COMPASS randomized controlled trials.[15 16] In addition, angiographic and clinical results of the ASTER and COMPASS trials showed that the ADAPT technique was equivalent in safety and efficacy to stent-retriever thrombectomy for patients with anterior circulation ELVOs.[15 16] Thus, the ADAPT technique is a safe and effective alternative to stent-retriever thrombectomy for this patient population and represents a valuable option for neurointerventionalists. Further, stent-retriever rescue can easily be utilized when ADAPT fails to achieve successful reperfusion.

Refinements to the ADAPT technique over the course of the study such as connecting the tubing directly to the hub of the aspiration catheter, prolonging the time of clot engagement with aspiration turned on in successive ADAPT passes, and retracting the aspiration catheter slowly and gently, as well as development of a more powerful aspiration pump, may have had an effect on the efficacy of the ADAPT technique in our cohort. While it may not be feasible to completely parse the differences in efficacy related to operator experience, aspiration pump power and aspiration catheter diameter, although we evidenced increased efficacy of the ADAPT technique in late ACE 60 cases compared with early ACE 60 cases, there was further improvement in its efficacy with the use of ACE 68 in our cohort.

Overall, our findings suggest that the newer, larger-bore ACE 68 aspiration catheter may lead to improved efficacy of the ADAPT technique. The distal internal diameters of the ACE 60 and 68 are 1.8 mm and 2 mm, respectively. Since aspiration force is proportional to the square of the catheter diameter, the ACE 68 generates 25% more aspiration force than the ACE 60 catheter, which may explain its increased efficacy. Furthermore, while ACE 60 has 12 transition zones, ACE 68 has 16 transition zones and a new coil winding geometry, which are designed to increase the pushability and trackability of ACE 68 and minimize ovalization around bends.

The average number of ADAPT passes prior to stent-retriever rescue in our cohort was significantly higher with ACE 68 (five passes) than with ACE 60 (2.6 passes, P=0.03), which was influenced by our increased experience with the ADAPT technique by the time the ACE 68 catheter became available. While this may have influenced the difference in rates of successful reperfusion using ADAPT only and stent-retriever rescue between ACE 60 and ACE 68 in our cohort, it did not affect this study's overarching results regarding the higher rate of successful reperfusion after the first ADAPT pass with ACE 68, and, importantly, the demonstration of a first-pass effect with ADAPT.

Compared with ACE 60, we evidenced slightly increased rates of intracranial vascular injury with the use of the larger-bore ACE 64 and 68 aspiration catheters, especially with the use of the Velocity microcatheter to advance the aspiration catheter past the ophthalmic artery and in extremely elderly patients. Hence, use of the 3Max catheter with the larger-bore ACE aspiration catheters in order to minimize the 'lip' as it crosses the origin of the ophthalmic artery would be prudent, as well as being cognizant of the degree of force applied to the aspiration catheter to reach the M1 segment in extremely elderly patients. Further, stent-retriever rescue after ADAPT with the ACE 68 catheter was associated with low rates of successful recanalization (33%) and high rates of SICH (33%). This trade-off should be taken into account by operators when considering stent-retriever rescue after several failed ADAPT passes with ACE 68.

Similar to the results of Zaidat et al with the Solitaire stent-retriever,[32] we found that achieving successful reperfusion after the first ADAPT pass was a strong independent predictor of a good clinical outcome at 90 days in our cohort – the first-pass effect. While Zaidat et al found that the use of a balloon guide catheter and non-ICA terminus thrombus location were independent predictors of first-pass reperfusion with the Solitaire stent-retriever,[32] in our cohort the use of the ACE 68 aspiration catheter and M1 thrombus

Table 5 Independent predictors of a good clinical outcome at 90 days (mRS 0–2)

	Patients with good clinical outcome (%)	P values*
Successful reperfusion after first ADAPT pass		0.0004
Yes, n=64	41 (64)	
No, n=88	29 (33)	
NIHSS ≤21		0.0076
Yes, n=104	57 (55)	
No, n=48	13 (27)	
History of hypertension		0.026
No, n=59	34 (58)	
Yes, n=93	36 (39)	

*P value from multivariate logistic regression analysis.
mRS, modified Rankin Scale; NIHSS, National Institutes of Health Stroke Scale.

location were independent predictors of successful reperfusion after the first ADAPT pass. Notably, successful reperfusion after the first ADAPT pass was achieved in 70% of M1 segment occlusions treated with ACE 68 in our cohort. These findings are important because not only has the first-pass effect now been demonstrated in two independent large ELVO patient cohorts treated with two different mechanical thrombectomy techniques, but also because the rate of successful reperfusion after the first thrombectomy device pass could be used as an objective metric by which to compare the efficacy of different thrombectomy devices in future studies.

Our study's limitations are the modest sample size, retrospective design, and lack of external adjudication of angiographic findings and clinical outcomes.

CONCLUSION

The use of the ACE 68 aspiration catheter led to shorter groin puncture to reperfusion time, a higher rate of successful reperfusion after the first ADAPT pass, and a lower rate of stent-retriever rescue in our cohort. Further, a first-pass effect was demonstrated in our cohort of patients with anterior circulation ELVOs treated with the ADAPT technique.

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Contributors JEDA: Design of the work; acquisition, analysis, and interpretation of the data for the work; drafting of the work; final approval of the version to be published; and accountable for all aspects of the work. YK, ANW, MLY: Design of the work; acquisition, analysis, and interpretation of the data for the work; critical revision of the work for important intellectual content; final approval of the version to be published; and accountable for all aspects of the work. RMT, JLF, MM:Acquisition and analysis of the data for the work; critical revision of the work for important intellectual content; final approval of the version to be published; and accountable for all aspects of the work. JMS, AMM, PR: Acquisition of the data for the work; critical revision of the work for important intellectual content; final approval of the version to be published; and accountable for all aspects of the work.

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