

CASE SERIES

Thromboaspiration technique as first approach for endovascular treatment of acute ischemic stroke: initial experience at nine Italian stroke centers

D G Romano,¹ S Cioni,¹ S L Vinci,² G Pero,³ C Comelli,⁴ A Comai,⁵ S Peschillo,⁶ D Mardighian,⁷ L Castellan,⁸ F Resta,⁹ M G Piano,³ S Comelli,⁴ L Barletta,⁸ A Puliti,¹ S Leonini,¹ S Bracco¹

¹Department of Neurological Sciences, Division of Diagnostic and Interventional Neuroradiology, University Hospital of Siena, Italy

²Neuroradiology Unit, Department of Radiological Sciences, University of Messina, Messina, Italy

³Neuroradiology Department, Niguarda Ca' Granda Hospital, Milan, Italy

⁴Department of Interventional Radiology and Neuroradiology, S. Giovanni Bosco Emergencies Hospital, Turin, Italy

⁵Department of Radiology, Central Hospital of Bolzano, Italy

⁶Department of Neurology and Psychiatry, Endovascular Neurosurgery/Interventional Neuroradiology, "Sapienza" University of Rome, Rome, Italy

⁷Department of Neuroradiology, Spedali Civili, University of Brescia, Italy

⁸Neuroradiology Unit, San Martino Hospital-IST-IRCCS, Genoa, Italy

⁹Department of Cardiology, University of Bari, Bari, Italy

Correspondence to

Dr Daniele G Romano, Neuroimaging and Neurointerventional Department, Aous Siena, Viale M Bracci 2, Siena 53100, Italy; dr.80@live.it

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ABSTRACT

Background and purpose Aspiration thrombectomy of large vessel occlusions has made a comeback among recanalization techniques thanks to recent advances in catheter technology resulting in faster recanalization and promising clinical results when used either alone or as an adjunct to stent retriever. This multicenter retrospective study reports angiographic data, complications, and clinical outcome in patients treated with aspiration thrombectomy as the first-line option.

Materials and methods We analysed the clinical and procedural data of patients treated from January 2014 to March 2015. Recanalization was assessed according to the Thrombolysis in Cerebral Infarction score. Clinical outcome was evaluated at discharge and after 3 months.

Results Overall, 152 patients (mean age 68 years) were treated. Sites of occlusion were 90.8% anterior circulation (including 16.4% tandem extracranial/intracranial occlusions) and 9.2% basilar artery. In 79 patients administration of intravenous tissue plasminogen activator was attempted. Recanalization of the target vessel was obtained in 115/152 cases (75.6%) whereas direct aspiration alone was successful in 83/152 cases (54.6%) with an average puncture to revascularization time of 44.67 min. Symptomatic intracranial hemorrhage occurred in 7.8% and embolization to new territories in 1.9%. 77 patients (50.6%) had a good outcome at 90-day follow-up: 55/96 in the direct aspiration alone group and 22/56 in the aspiration-stent retriever group.

Conclusions Direct aspiration thrombectomy appears a feasible technique with good revascularization results achieved in more than half the patients. In light of the self-reported data, inhomogeneous patient selection, absence of a core imaging laboratory, and a non-standardized approach, the results should be validated in a larger trial.

INTRODUCTION

Intravenous thrombolysis has been the gold standard in the treatment of patients with acute ischemic stroke (AIS) for many years. Tissue plasminogen activator (tPA) has a narrow time window and appears to be less effective in large arteries and in tandem extracranial/intracranial anterior circulation occlusions where an early and efficient revascularization correlates with better outcomes.^{1 2} Endovascular therapy (EVT) has therefore emerged as a feasible treatment over the years.³⁻⁵

Thromboaspiration has made a comeback among recanalization techniques thanks to recent advances in catheter technology including large-bore and flexible aspiration catheters that reliably navigate the cerebrovascular tree. Compared with other EVT approaches, a direct aspiration first-pass technique (ADAPT technique) for AIS has obtained good recanalization rates allowing faster interventions, lower costs when used either alone or as an adjunct to stent retriever,⁶⁻¹⁴ and promising clinical results, especially when used in internal carotid artery (ICA) occlusions.¹⁵

The aim of this multicenter study is to retrospectively describe revascularization efficacy, duration of the procedure, intra- and post-procedural complications, and early and 90-day clinical outcome in a group of patients who underwent ADAPT as the primary EVT approach, eventually followed by stent retriever thrombectomy, for recanalization of large vessels in the anterior and posterior circulation.

MATERIALS AND METHODS

We performed a multicenter retrospective data collection through the Italian Registry of ThromboAspiration (RITA) website to find all patients who received ADAPT between January 2014 and March 2015 from nine medical centers in Italy.

Patient selection, imaging and clinical assessment

Inclusion criteria were (1) age ≥ 18 years, (2) large artery occlusion in the anterior or posterior circulation, (3) a time window of < 8 h for anterior circulation and 24 h for posterior circulation occlusion, (4) no intracerebral hemorrhage (ICH), (5) an ASPECTS score of ≥ 5 at baseline CT, and (6) no or poor neurologic response to tPA administration or contraindications to tPA.

All patients underwent unenhanced CT to exclude hemorrhage and assess the ASPECTS score and CT angiography to detect large vessel occlusions. In 26 patients the diagnostic investigation also included magnetic resonance diffusion-weighted imaging (MR DWI) and FLAIR imaging. In case of uncertain onset of the symptoms (ie, wake-up stroke), patients were considered eligible for EVT when salvageable brain parenchyma was

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Ischemic stroke

depicted by perfusion CT or DWI-FLAIR mismatch. All patients were evaluated by a stroke-dedicated neurologist and an interventional neuroradiologist before proceeding to EVT. All angiographic images were re-evaluated after the procedure and the Thrombolysis In Cerebral Infarction (TICI) score was applied. Procedural timings were obtained from the angiographic records. Technical success was defined as recanalization of the target vessel according to TICI score $\geq 2b$. The NIH Stroke Scale (NIHSS) score at admission and discharge and the modified Rankin Scale (mRS) score after 90 days of follow-up were assessed by the same stroke-dedicated neurologist. A good outcome was defined as an mRS score ≤ 2 at 90 days. Mortality was defined as death occurring within 90 days of initial presentation. Intra- and post-procedural complications including symptomatic (NIHSS score worsening by ≥ 4 points at clinical examination) and asymptomatic ICH were recorded. Before treatment informed consent was obtained from the patient (if conscious) or a legal representative.

Technique

The ADAPT technique has been previously described by many authors.^{6–12} Briefly, a large guide catheter was advanced into the ICA as distally as possible to reach the cervical or proximal petrous segment of the ICA. In the posterior circulation the catheter was navigated into the vertebral artery with larger size and positioned as distally as possible in order to avoid arterial dissection. An aspiration catheter of caliber to fit in the vessel was selected for each case (distal ICA, proximal middle cerebral artery or basilar occlusions). Four types of catheters were used: 5MAX ACE (Penumbra, Alameda, California, USA), 5MAX (Penumbra), Navien 058 (Covidien, Irvine, California, USA), or Sofia 0.55 (MicroVention, Tustine, California, USA). The catheter was advanced in front of the thrombus, coaxially over a microwire and a microcatheter, then aspiration was applied either manually with a 20 or 60 mL syringe or through a Penumbra aspiration pump, depending on the operator experience. As soon as the absence of flow was noted within the aspiration system, the catheter was slowly advanced to ensure solid engagement with the thrombus. Aspiration was left for approximately 1 min. When no flow through the system was found, the catheter was withdrawn. When aspiration alone did not result in successful revascularization, a stent retriever was added through the large-bore catheter. The choice of aspiration catheter and number of attempts was up to the primary operator.

Statistical analysis

The Shapiro–Wilk test was used to perform data distribution analysis. Continuous study parameters were compared between patients using the Student t test for normally distributed data or the Mann–Whitney U test for non-normally or ordinal distributed data. All statistical analyses were performed using commercially available software (SPSS V.21.0.0.0; IBM); significance was set at $\alpha=0.05$.

RESULTS

Patient demographics and procedural data

Between January 2014 and March 2015, 152 patients (66 women (44%) and 86 men (56%)) of mean age 68 years (range 29–84) were admitted to nine Italian institutions for AIS and underwent EVT with ADAPT. Sites of occlusion were the anterior circulation in 138 patients (90.8%) (ICA terminus in 40 (17 right, 23 left), middle cerebral artery M1 segment in 73 (39 right, 34 left), and tandem extracranial/intracranial occlusions in 25 (9 right, 16 left)). In the posterior circulation (14/152, 9.2%), occlusions were located at the basilar artery.

Before EVT, tPA administration was attempted in 79 patients. The mean ASPECTS score at diagnosis was 8.1 (range 5–10) and the mean NIHSS score at baseline was 19 (range 5–35). There was no statistically significant difference in terms of baseline features or site of occlusion between patients treated with aspiration alone and those treated with an additional stent retriever (table 1). General anesthesia was performed in 102 patients. The remaining 50 patients had mild sedation or no anesthesia. The average time from symptom onset to groin puncture was 227 min (range 27–1331). Recanalization of the target vessel was obtained in 115/152 cases (75.6%), as shown in table 2. The primary ADAPT revascularization catheter was 5MAX in 59 cases, 5MAX ACE in 90 cases, Navien 058 in 1 case, and Sofia 0.55 in 2 cases.

The ADAPT technique was successful in achieving revascularization of the occluded vessel in 83/152 cases (54.6%) with a median of 1.9 aspiration attempts (range 1–6). The difference between patients treated with aspiration alone and those treated with aspiration and a stent retriever was statistically significant in terms of TICI $\geq 2b$. Manual aspiration was used in 63 cases (40/63 TICI $\geq 2b$) and a Penumbra aspiration pump in 89 cases (43/89 TICI $\geq 2b$). Most of the cases in the ADAPT alone group (96 cases) were successful when the occlusion was located at the level of the M1 segment (TICI $\geq 2b$ in 43/47; 91.5%). In 13 more cases with ADAPT alone in whom the thromboaspiration

Table 1 Baseline characteristics of patients

	All (n=152)	Aspiration alone (n=96)	Aspiration+stent retriever (n=56)	p Value
Age, mean (range)	68 (29–84)	68 (29–84)	68 (33–84)	0.64
Male sex, n (%)	86 (56.6)	56 (58.3)	30 (53.6)	0.57
ASPECTS, mean	8.1	8.16	7.61	0.08
NIHSS baseline, mean (range)	19 (5–35)	19.24 (6–35)	18.21 (5–30)	0.3
Anterior circulation, n (%)	113 (74.3)	69 (71.8)	44 (78.5)	
Anterior circulation NIHSS, mean	18.9	19.1	18.54	0.58
Posterior circulation, n (%)	14 (9.2)	11 (1.4)	3 (5.3)	
Posterior circulation NIHSS, mean	20.4	21.5	18	0.55
Tandem occlusions, n (%)	25 (16.4)	17 (17.7)	8 (14.2)	
Tandem occlusions NIHSS, mean	17.4	18.7	16.6	0.42
Tissue plasminogen activator (n)	77	49	28	0.903

NIHSS, NIH Stroke Scale.

Table 2 Procedural timing, revascularization results, complications, and clinical outcome

	All (n=152)	Aspiration alone (n=96)	Aspiration+stent retriever (n=56)	p Value
PTR, mean (range)	57.8 (15–170)	44.67 (15–150)	80.41 (25–170)	<0.001
Anterior circulation PTR, mean	55.22	40.62	77.45	<0.001
Posterior circulation PTR, mean	60.7	42.72	126.66	<0.001
Tandem occlusions PTR, mean	67.11	60.94	79.44	0.086
TICI $\geq 2b$, mean (%)	115 (75.6)	83 (83.3)	32 (53.57)	<0.001
sICH, n (%)	12 (7.8)	4 (4.1)	8 (14.2)	0.026
ENT, n (%)	3 (1.9)	2 (2.1)	1 (1.8)	
90-day mRS ≤ 2 , mean (%)	77 (50.6)	55 (57)	22 (40.1)	0.026
90-day mortality, n (%)	12 (7.8)	6 (6.2)	6 (10.7)	0.32

ENT, embolization to new territories; mRS, modified Rankin Scale; PTR, time from groin puncture to revascularization (min); sICH, symptomatic intracranial hemorrhage; TICI, Thrombolysis In Cerebral Infarction.

technique failed, no other treatments were attempted for the following reasons: time from symptom onset >8 h in 6 cases, challenging navigation of vascular anatomy in 4 cases, cardiac arrest during procedure in 2 cases, and vertebral artery dissection in 1 case. In the remaining 56/152 cases a stent retriever was added to complete recanalization. The average puncture-to-revascularization (PTR) time was 44.67 min (range 15–150) in the thromboaspiration ADAPT group and 80.41 min (range 25–170) in the combined aspiration-stent retriever group. There was a significant difference between the two groups with regard to PTR, favoring the direct aspiration alone subgroup (44.67 min vs 80.41 min), both for anterior (40.6 min vs 77 min) and posterior (43 min vs 126 min) circulation (table 2).

There were three (1.9%) cases of embolization to a new territory (ENT), two as a complication of the ADAPT technique and solved by stent retriever and one at the end of the combined aspiration-stent retriever procedure. One device-related complication was encountered—namely, a hypoplastic vertebral artery dissection during EVT of basilar artery occlusion. No significant vasospasm, dissection, or endothelial lesion of the intracranial vessels was caused by the aspiration catheters.

Clinical outcomes

The mean NIHSS score at discharge was 8.5 (range 1–36). Seventy-seven patients (50.6%) had a good outcome (mRS ≤ 2) at 90-day follow-up. In the 96 cases where ADAPT alone was used, 55 patients achieved mRS ≤ 2 . In the 56 cases where ADAPT required a stent retriever, 22 patients achieved mRS ≤ 2 . Hemorrhagic events occurred in 17/152 cases (11.1%), 5 asymptomatic and 12 symptomatic.

We could not find significant differences between the groups regarding the rate of clinical outcome, although there was a higher rate of patients with mRS ≤ 2 in the ADAPT alone group (57% vs 40%) (table 2). Overall mortality was 12/152 (7.9%); 3/12 patients died from unrelated causes.

DISCUSSION

For intracranial large vessel occlusion in AIS, a high degree of revascularization in the minimal amount of time predicts improved outcomes.^{16–17} Nonetheless, recanalization rates of ICA occlusions by tPA are only 4–8% and are associated with a risk of ICH.¹⁸

To improve the low recanalization rate of tPA, mechanical thrombectomy has been developed using two main methods: physical grasping and removal of thrombi with retrieval devices, and aspiration of occlusive thrombi with suction devices.¹⁹

In 2015 larger multicenter randomized controlled trials used stent retrievers as devices for thrombectomy, proving their better rates of recanalization, smaller residual territory of stroke on follow-up brain imaging, and better clinical outcomes compared with best medical therapy and other endovascular techniques.^{3–5} Briefly, the TICI recanalization rates and mRS ≤ 2 at 90 days were reported to be 58.7% and 32.6% in the MR CLEAN trial, 76% and 71% in the EXTEND-IA trial, and 69% and 53% in the ESCAPE trial.^{3–5}

The thromboaspiration technique (also called ADAPT, manual aspiration thrombectomy (MAT) or forced suction thrombectomy) combines modern aspiration and retrieval technology. It is being increasingly used to achieve revascularization in AIS^{6–12} with reliable and cost-effective results.⁹ Its philosophy builds on the concept of ‘starting simple’ (with a large-bore, atraumatic, and easy trackable catheter) and then adding complex tools (a stent retriever) if needed.⁹ Technically, any stent retriever can be introduced easily through the reperfusion catheters and the system has proved to be sufficiently versatile to treat even more resistant clots;¹⁰ moreover, distal aspiration can be performed during stent retrieval as a combination technique, previously called ‘Solumbra’.²⁰ The reperfusion catheters extract the clot with a negative pressure applied from the Penumbra pump system or a syringe connected to the proximal hub of the catheter. A recent basic science study²¹ comparing stent retriever mechanical thrombectomy techniques with direct aspiration concluded that the latter significantly increases the risk of fragmentation of smaller soft elastic clots. In our experience, ADAPT had a low rate of ENT (1.9%) and a single aspiration attempt resulted in extraction of the occlusive embolus en bloc in 35% of cases, but unfortunately the size and histopathological features of the clots were not recorded.

Without any procedure through the clot, the ADAPT technique has a low risk of perforation of intracranial vessels. ADAPT is therefore safe to treat occlusions involving the top of the basilar artery where hemorrhagic complications may result from perforation of small arteries.²²

More recently, high performance catheters designed to remove large clots have been introduced to the market (eg, Penumbra ACE 64 and Sofia PLUS) to optimize pushability and supple navigation. In our study two types of catheters (5MAX and 5MAX ACE) were used in the majority of cases. Their main characteristics are the easy navigability in intracranial arterial vessels and the distal large inner diameters. All these systems produce a different aspiration force on the clot; an *in vitro* study by Hu and Stiefel²³ showed that the Penumbra 5MAX ACE catheter had the greatest aspiration rate with the greatest

tip force. In our population, patients in the subgroup treated with aspiration alone with the 5MAX ACE catheter (0.060 inner diameter) obtained a TICI $\geq 2b$ revascularization rate of 92.7% compared with the original 5MAX catheter (0.054 inner diameter) (77.2%), confirming the improved aspiration performance of a larger bore catheter.

In a recent retrospective series of 98 patients by Turk *et al*,⁶ ADAPT with 5MAX ACE has been reported to achieve final TICI $\geq 2b$ rates of 95% when stent retrievers are introduced and 78% following direct aspiration. Considering the revascularization rates in our total population and in three recently published non-randomized retrospective studies (table 3), we found that TICI $\geq 2b$ results were comparatively low in comparison with final revascularization rates (75.6%) but good when thromboaspiration was used primarily alone (83.3%). The reason for the relatively low number of successfully recanalized patients may be the heterogeneous population and the variable operator experience. Notably, our final results on the revascularization rate are in line with non-randomized retrospective NASA registry studies using a stent retriever as the first-line approach (75.6% vs 72.5%).²⁴

Tandem extracranial/intracranial anterior circulation occlusions independently predict a poor outcome after intravenous thrombolysis.¹ Unlike other ADAPT studies,^{6 10} we treated a high rate of tandem occlusions (16.4%). In our series, intracranial occlusions in tandem lesions were treated with ADAPT alone in 18/25 cases and ADAPT associated with stent retriever in 7/25 cases (table 1). In 11/25 patients, cervical ICA artery stenting was performed, in four cases in association with angioplasty; in two more patients angioplasty alone was performed. In our series we achieved mRS ≥ 2 in 56% of patients, which is in line with outcome rates reported in previous studies.^{25 26}

Our study confirms that ADAPT enables a short procedure. Turk *et al*⁶ reported an average time from groin puncture to final revascularization of 37 min and Kowoll *et al*¹⁰ reported 41 min. We found an average PTR of 57.8 min (44.87 min when using thromboaspiration alone) compared with 77 min reported in the NASA registry²⁴ (table 3). Recanalization times in the randomized studies EXTEND-IA and ESCAPE were 31 and 43 min, respectively. Not surprisingly, the high rate of tandem occlusions in our series led to a prolonged procedure time until recanalization. In addition, a longer time for revascularization (average PTR 80.41 min) in the thromboaspiration

plus stent retriever group is explained by the fact that thromboaspiration alone was attempted for a mean of 1.9 attempts and failed; hence, it could also possibly explain the lower mRS ≥ 2 in this subgroup as longer revascularization times lead to a poorer outcome.

Regarding clinical outcome, we found a favorable outcome at 90-day follow-up in 50.6% of cases, which is outstanding compared with results published to date^{6 10 12} (table 3). It can be improved by more homogeneous patient selection and a standardized technique. Another limitation in our study is the fact that preoperative perfusion weighted imaging was not performed in all patients; in fact, it has been shown that evaluating the extent of salvageable brain tissue and the degree of collateral blood supply may better stratify the population and identify patients who could preferentially benefit from EVT.⁵

The mortality rate was lower than previous studies of the thromboaspiration technique (7.9% compared with 31% MAT and 23% ADAPT, as shown in table 3). The symptomatic hemorrhagic complication (sICH) rate in our study was 7.9%, worse than ADAPT FAST (table 3) but in line with the cut-off value of 12% stipulated as standard of practice by the international multisociety guidelines of 2013⁸ and better than reported in most stent retriever studies (table 3). Notably, 6/12 cases of sICH occurred in tandem occlusions. The increased risk of hemorrhagic complications may be justified by the intravenous antiplatelet therapy administered during and after extracranial carotid artery stenting in the six abovementioned patients. A reperfusion syndrome to a vascular territory subjected to long-term hypoperfusion may also play a role. Nonetheless, three of the six patients with sICH had a favorable clinical outcome.

CONCLUSIONS

Among endovascular techniques for large vessel occlusions, ADAPT appears a feasible technique resulting in faster revascularization time and lower cost when it works at the first attempt. The present study reports a good revascularization outcome in more than half of the patients when used alone.

Given the lack of a standardized approach, our data cannot be compared in terms of outcome and procedure times with recent large randomized trials using stent retrievers as a first-line option. Other limitations are the retrospective design of the study, the inhomogeneous selection of the patients, and the absence of an imaging core laboratory.

Table 3 Revascularization and clinical outcome compared with MAT¹² and ADAPT⁶ trials using primary aspiration thrombectomy and NASA²⁴ using stent retriever thrombectomy

	RITA (n=152)	MAT (n=112)	ADAPT (n=100)	NASA (n=354)
Age	68	66	66.3	67.3
Site (%)	M1 (48), ICAT (26.3), B (9.2), T (16.4)	M1 (62), M2 (8), ICAT (19), B (11), T (18)	M1 (43), M2 (18), ICA (9), ICAT (14), B (5), T (11)	M1 (56), ICAT (23), B (10.2)
NIHSS baseline	19.7	17	17	18.1
Extra device, %	36.8	41	22	—
PTR	57.8	70	37	77
TICI $\geq 2b$, %	75.6	86.6	95	72.5
ENT, %	1.9	3.5	0	—
sICH, %	7.9	6.2	0	9.9
90-day mRS ≤ 2 , %	50.6	46.1	40	42
90-day mortality, %	7.9	31	23	30.2

ADAPT, a direct aspiration first pass technique; B, basilar artery; ENT, embolization to new territories; ICA, internal carotid artery; ICAT, terminus internal carotid artery; MAT, manual aspiration thrombectomy; M1, M2, middle cerebral artery; mRS, modified Rankin Scale; P1, posterior cerebral artery; PTR, time from groin puncture to revascularization (min); sICH, symptomatic intracranial hemorrhage; T, tandem occlusions; TICI, Thrombolysis In Cerebral Infarction.

Future development of ADAPT should aim for improved patient selection (on the basis of stroke etiology, perfusion weighted imaging, time to treatment, and thrombus features) and standardization of the endovascular approach in order to shorten the procedural time and to limit complications and costs.

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Contributors All authors contributed to the work presented through study design, manuscript composition and critical review.

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