A Retrospective Single-Center Case Series of Direct Aspiration Thrombectomy as First-Line Approach in Ischemic Stroke and Review of the Literature

Marius Georg Kaschner, MD,* Christian Rubbert, MD,* Julian Caspers, MD,* Jennifer Karsten,* Bastian Kraus, MD,* John-Ih Lee, MD,† Michael Gliem, MD,† Sebastian Jander, MD,† and Bernd Turowski, MD*

Introduction: The benefit of the direct aspiration thrombectomy (ADAPT) technique for the treatment of ischemic stroke due to large vessel occlusion are challenged after publishing of the ASTER trial that failed to show superiority of ADAPT compared to stent retriever. Aim of the present single-center study was a retrospective evaluation of the ADAPT technique comparing our results with literature. *Material/methods*: We retrospectively analyzed institutional data of stroke procedures in patients with mainstem occlusion of the middle cerebral artery treated between November 2016 and December 2017 with an initial attempt of manual thrombaspiration. Reperfusion rate (thrombolysis in cerebral infarction), procedural times, early clinical outcome and complications were recorded. *Results*: Forty patients were treated by using direct thrombaspiration in middle cerebral artery mainstem occlusion. Median age was 67.5 (±17.8) years (m = 27.5%). Median Baseline National Institutes of Health Stroke Scale score was 12 (IQR 7) preintervention and 3 (IQR 11) postintervention. Twenty-eight (70%) patients received intravenous thrombolysis. Successful recanalization (modified thrombolysis in cerebral infarction ≥ 2b) could be achieved in 85% with direct aspiration alone. Mean time from groin puncture to recanalization was 25.2 ± 14.3 minutes. Embolization to new territories occurred in 1 of 40 (2.5%) cases and symptomatic intracranial hemorrhage in 3 of 40 (7.5%). Nineteen of 40 (47.5%) patients achieved favorable outcome (modified Rankin scale 0-2) at discharge. *Conclusions*: The ADAPT technique presented as a safe and efficient first-line recanalization strategy with good clinical outcome for treatment of acute ischemic stroke resulting from large vessel occlusions in this single-center study and review of the literature. However, the concept of ADAPT as an equivalent first-line approach to stent retriever thrombectomy has to be proven by future randomized studies.

Key Words: Stroke—middle cerebral artery occlusion—aspiration thrombectomy—ADAPT

From the *University Düsseldorf, Medical Faculty, Department of Diagnostic and Interventional Radiology, Moorenstr. 5, D-40225, Düsseldorf, Germany; and †Department of Neurology, Heinrich Heine University Duesseldorf, Medical Faculty, Duesseldorf, Germany.

Received June 3, 2018; revision received September 29, 2018; accepted November 4, 2018.

Compliance with ethical standards:

Funding: No funding was received for this study.

Conflict of interest: The authors declare that they have no conflict of interest.

Ethical approval: All procedures performed in the studies involving human participants were in accordance with the ethical standards of the institutional and/or national research committee and with the 1964 Helsinki Declaration and its later amendments or comparable ethical standards.

Informed consent: Patients were informed about the approach, benefit and risks of the planned procedure in the emergency setting and informed consent was obtained prior to intervention. Consent for retrospective data analysis was waived.

Correspondence to: Marius Kaschner, MD, Department of Neuroradiology, Heinrich Heine University Duesseldorf, Moorenstr.5, 40225 Duesseldorf, Germany. E-mail: marius.kaschner@med.uni-duesseldorf.de.

1052-3057/$ - see front matter

https://doi.org/10.1016/j.jstrokecerebrovasdis.2018.11.004

Introduction

The previous studies using ADAPT (a direct first pass aspiration technique) as first-line approach in large vessel occlusion (LVO) reported promising results regarding to recanalization rate, procedural times and costs.[1-6] The ASTER study is the first published prospective, randomized, multicenter, controlled open-label design with blinded outcome evaluation that compared the direct aspiration thrombectomy to stent retriever technique as first-line approach. The study was powered to show superiority of ADAPT over the stent retriever technique regarding efficacy and adverse events.[7] The study enrolled 381 patients from 8 comprehensive stroke centers in France who presented with acute ischemic stroke in the anterior circulation. Superiority of the ADAPT technique over first-line stent retriever could not be demonstrated. Hence, stent retriever thrombectomy remains first-line technique for treatment of LVO in ischemic stroke. The current study presents the results of a single-center patient collective with acute ischemic stroke resulting from middle cerebral artery (MCA) mainstem occlusion that were treated by the ADAPT technique as first-line approach, and a critical review of the literature.

Material and Methods

Our study was approved by our hospital's institutional review board. Data evaluation was approved by the local ethics committee. From November 2016 to December 2017, n = 125 consecutive patients with anterior circulation ischemic stroke due to M1/M2 occlusion, as diagnosed by computed tomography angiography (CTA) or magnetic resonance tomography, were treated by thrombectomy. We further analyzed all patients, in which an aspiration thrombectomy as first-line approach was conducted (n = 40).

According to the guidelines of the local ethics committee, consent for retrospective data analysis was waived.

Inclusion Criteria

The study enrolled adults with occlusion of the M1 and M2 branches of the MCA receiving direct aspiration thrombectomy as first-line endovascular treatment; no age limit, no baseline National Institutes of Health Stroke Scale (NIHSS) score limit at admission, and no time limit from symptom onset to treatment were applied to restrict study inclusion. Standardized stroke imaging at our institution included non−contrast-enhanced cranial computed tomography (NECCT), computed tomography perfusion (CTP), and CTA. If time from symptom onset to admission was uncertain, patients were scanned with magnetic resonance imaging (MRI), applying diffusion-weighted imaging (DWI), perfusion weighted imaging (PWI), and fluid-attenuated inversion recovery (FLAIR) image to discern between salvageable and terminally infarcted tissue. Patients who qualified for treatment with intravenous thrombolysis (IVT), received this treatment according to the guidelines of the German Society of Neurology. Extensive early ischemic signs or hemorrhage could be excluded in preinterventional imaging by CT or MRI assessment. There were no ASPECTS treshholds for exclusion from thrombectomy. Eligibility for thrombectomy in patients with acute M1/M2 occlusion, as established in CTA or time-of-flight magnetic resonance tomography, was determined individually for each patient in consensus between neurologists and neurointerventionalists. The decision is primarily based on the infarct-core/penumbra mismatch, estimated procedural risk, probability of recanalization by IVT, contraindication for IVT, comorbidities, and social and medical prestroke conditions. Exclusion criteria were intracranial hemorrhage and occlusion of the cervical carotid artery.

CTP was acquired with 2 adjacent slices of 1 cm thickness angled parallel to the Frankfurt horizontal line at the level of the cella media over 50 seconds with 1 image per second. Perfusion maps including time to maximum (T_{max}), mean transit time, relative cerebral blood volume (rCBV), and relative cerebral blood flow were calculated using singular value decomposition (STROKETOOL-CT, Version 2.0, H.-J. Wittsack, DIS, Frechen, Germany). Perfusion restriction was detected by visual inspection and region of interest (ROI) measurement in the T_{max} map. A difference exceeding 6 seconds in T_{max} values between ischemic and contralateral unaffected hemisphere was suggested as critical ischemia. To differentiate irreversibly infarcted tissue (infarct core) and salvageable ischemic tissue (penumbra), and to estimate collateralization, NECCT and rCBV were used. Tissue showing infarct typical hypoattenuation in NECCT or/and rCBV close to 0 was considered as irreversibly infarcted brain parenchyma that corresponds to the infarct core. Tissue showing significant T_{max} prolongation outside the infarct core was considered as the penumbra. Dynamic contrast-enhanced magnetic resonance PWI was performed with the duration of the gradient-echo sequence about 1 minute and whole brain coverage (4 mm slice thickness). Perfusion maps including time to peak, mean transit time, CBV, and cerebral blood flow. In MR imaging infarct core was distincted from penumbra by DWI/PWI mismatch. DWI affected tissue was considered as infarct core. Tissue showing perfusion deficit in time to peak without DWI alteration was considered as penumbra.

If substantial penumbra was detected on CTP by NECCT/CTP mismatch or MRI by DWI/PWI mismatch analysis, decision for thrombectomy was made. Furthermore, as portions of DWI abnormalities may represent penumbra with the potential of normalization when perfusion is restored, a phenomenon described "DWI reversal," thrombectomy was also performed in cases where DWI affected tissue clearly exceeded FLAIR demarcation (FLAIR/DWI mismatch).[8,9] For all cases, the estimation of substantial penumbra was to the discretion of the interventionalist.

Interventional Procedure

The interventional procedures were performed under analgesia (1-2 g Novaminsulfone as short infusion) and local anesthesia of the groin. General anesthesia was performed in patients with need for endotracheal intubation (Glasgow coma scale < 8) or in case of extreme agitation. Access was performed using a long 8F sheath or additional guiding catheter positioned in the distal internal carotid artery. A .027-in. inner lumen microcatheter was advanced up to (no touch technique) or past the thrombus over a microwire and then an aspiration catheter (5F or 6F SOFIA, MicroVention Inc, Tustin, CA) was advanced to the proximal aspect of the thrombus. In cases of nonelongated or minorelongated arteries, the aspiration catheter could be directly advanced to the site of occlusion without using a microcatheter and microwire. When applied, microcatheter (Neuroslider 21, Acandis, Pforzheim, Germany) and microguidewire were removed and aspiration catheter was directly locked to a 20 mL syringe. Manual aspiration was started and as soon as absence of flow was noted, the resulting vacuum was maintained for at least 60 seconds, before the catheter was slowly retracted under additional aspiration at the guide catheter.[10] If first aspiration attempt failed completely (defined as no extraction of any thrombus material), a rescue maneuver with a stent retriever (APERIO; Acandis, Pforzheim, Germany) under local aspiration through the aspiration catheter (Solumbra technique) was performed immediately. In case of partial clot extraction the aspiration attempt was either (1) repeated up to 3 times, (2) an additional thrombectomy device was used under local aspiration, or (3) the intervention was terminated when residual clot could not be reached without increased risk of procedural complications. The choice of procedure was at the discretion of the interventionalist.

Imaging and procedural data collection: time from symptom onset to stroke imaging, to groin puncture, and to recanalization were captured. The location of the occlusion and thrombus length were assessed on CT or MR angiographic images. Collateral supply of the occluded MCA territory from preinterventional CTA scans was scored based on collateral grading system of Tan et al on a scale of 0-3.[11] Devices and medication used during the interventional procedures, duration, and intraprocedural complications were evaluated from the treatment protocols. Angiographic outcome was graded by the modified thrombolysis in cerebral infarction (TICI) scale.[12] Pretreatment cerebral infarction, according to the Alberta Stroke Program Early CT score (ASPECTS) was assessed by cardiovascular computed tomography or MRI. Post-treatment ASPECTS and symptomatic intracerebral hemorrhage, according to the European Cooperative Acute Stroke Study classification, were assessed by follow-up cardiovascular computed tomography imaging that was routinely performed 6-24 hours after treatment.[13]

Statistical Analysis

Statistical analysis was performed using R version 3.4.3. R is a programming language widely used for data analysis. Stroke severity as measured by NIHSS, clinical outcome according to modified Rankin Scale (mRS), and ASPECTS between admission and discharge were compared by means of Mann-Whitney U tests. The Mann-Whitney U test is a nonparametric test of the null hypothesis, which allows 2 groups, conditions, or treatments to be compared without making the assumption that the values are normally distributed. A paired test was conducted, since the values were compared in the same patient at the time of admission and discharge. Results were considered statistically significant at a level of $P < .05$.

Results

Patients

Forty patients with M1/M2 segment occlusion were identified who underwent an endovascular therapy by the ADAPT technique as first revascularization attempt between November 2016 and December 2017. Twenty-eight patients (70%) received intravenous tissue plasminogen activator (IVT) prior to endovascular procedure. Mean age of the patients was 67.5 years (SD 17.8), 72.5% were women. Median baseline NIHSS was 12, and median pretreatment mRS was 4. Baseline median ASPECTS was 10 and median collateral score was 3 (Table 1).

Technical Success

An overall final revascularization result of (TICI ≥ 2b) was achieved in all 40 cases. The ADAPT technique with aspiration alone was successful in 85% (34/40) of cases; the remaining 6 (15%) cases required stent retriever thrombectomy to reach TICI 2b/3 recanalization. TICI3 revascularization rate was 52.9% (18/34) with the ADAPT technique alone and 66.7% (4/6) in ADAPT cases with adjunctive use of a stent retriever (Table 1). In 80% (32/40) primary site of occlusion was located in the M1 segment and 20% (8/40) of cases involved the M2 segment. Overall mean time to final recanalization proceeding from femoral access to final revascularization was 25.2 minutes (SD ± 14.3) over all cases and 20.7 minutes (SD ± 8.4) for the ADAPT technique alone cases. In those cases where an adjunctive stent retriever was required time to final recanalization increased significantly to 50.6 minutes (SD ± 15.2, $P = .005$). Median of overall aspiration attempts was 1 in the whole sample, 1 in the ADAPT alone, and 2 in the ADAPT rescue group. In the 34 cases where successful recanalization was achieved by ADAPT as stand-alone technique we found red thrombus material, in the 6 cases with rescue stentretriever treatment hard white fragment clots were extracted.

Table 1. *Baseline data, angiographical results, clinical outcome, and complications*

	All (n = 40)	Aspiration alone (n = 34)	Aspiration + stent retriever (n = 6)
Age (mean, ±SD)	67.5 ± 17.8	65.7 ± 17.8	79 ± 15.1
Sex (n)	m = 11, w = 29	M = 11, w = 23	W = 6
CTA-collateral score (0-3), median	3	3	3
IVT n(%)	28(70)	22(64.7)	6(100)
Onset to groin puncture (min., mean SD±)	202.5 ± 161.6	215.9 ± 171	142 ± 78.2
Time from groin puncture to final recanalization (min., mean ± SD)	25.2 ± 14.3	20.7 ± 8.4	50.6 ± 15.2
TICI 2b n(%)	11(27.5)	9(26.5)	2(33.4)
TICI 2c n(%)	7(17.5)	7(20.6)	0(0)
TICI 3 n(%)	22(55)	18(52.9)	4 (66.6)
ASPECTS premedian, (IQR)	10 (1)	10 (.75)	10 (1.5)
ASPECTS postmedian, (IQR)	8 (2.25)	8 (2)	9 (2.75)
NIHSS premedian, (IQR)	12 (7)	12 (7)	12 (3.75)
NIHSS postmedian, (IQR)	3 (11)	2 (8.25)	12 (8.25)
mRS premedian, (IQR)	4 (1)	4 (1)	5 (1)
mRS postmedian, (IQR)	3 (3)	2 (3)	4 (.75)
mRS ≤ 2 post n(%)	19 (47.5)	19(55.8)	0(0)
Emboli to new territories n(%)	1(2.5)	0(0)	1(17.1)
sICH n(%)	3(7.5)	2(5.8)	1(16.7)
Mortality n(%)	1(2.5)	1(2.9)	0(0)

Abbreviations: CTA, CT angiography; IVT, intravenous thrombolysis; mRS, modified Rankin scale; NIHSS, National Institutes of Health Stroke Scale; sICH, symptomatic intracranial hemorrhage; TICI, thrombolysis in cerebral infarction.

Clinical Outcome, Follow-up Imaging and Complications

The post-treatment median NIHSS improved significantly from 12 (at admission) to 3 at discharge ($P < .005$). Median mRS improved from 4 to 3 ($P < .05$). The post-treatment median mRS in the ADAPT alone group was statistically significantly lower compared to patients with stent retriever rescue treatment (2 versus 4, $P < .05$). Forty-seven percent of patients achieved a mRS score of 0-2 at discharge. In the cases where ADAPT alone was successful, 55.8% of patients achieved a mRS score of 0-2. In the cases with stent retriever rescue treatment no patient (0/6) achieved mRS 0-2, 33.3% (2/6) resulted in mRS 5, 33.3% (2/6) in mRS 4, and 16.7% (1/6) resulted in mRS 3. Median pretreatment ASPECTS was 10 in both groups. Median ASPECTS after treatment was 8 in the ADAPT alone cases and 9 in cases with rescue stent retriever maneuver without statistically significance between the groups ($P > .05$). Differences in pre- to post-treatment median ASPECTS shift were significant in the overall and ADAPT alone group (10 versus 8; $P < .05$). Overall mortality was 2.5% (1/40) with a mortality rate of 2.9% (1/35) in the ADAPT alone group and 0% in the ADAPT rescue group. Postprocedure symptomatic intracerebral hemorrhage occurred in 3 cases (7.5%), 2/34 (5.8%) in the ADAPT alone and 1/6 (16.7%) in the ADAPT and stent retriever group. Embolization to new territories occurred in 1 patient (2.5%, 1/40) who received ADAPT plus rescue stent retriever (Table 1).

Discussion

ADAPT or contact aspiration technique has gained growing popularity as it is thought to achieve revascularization safely, quickly and with a small amount of material resources. [5,14,16,10] There are numerous single-center reports suggesting the aspiration approach to be less traumatic in vessel wall damage and consecutive symptomatic hemorrhages.[1,3] Nonrandomized retrospective trials comparing direct aspiration to stent retriever thrombectomy have reported increased successful recanalization rates when using ADAPT as first-line approach.[4,15,16]

The results of our single-center trial are in line with the good results of the preceded observational studies. Our overall rates of 100% (40/40) successful recanalization (TICI2b, 27.5%; TICI2c/3, 72.5%) and 85% (34/40) successful recanalization (TICI 2b;26.5%, TICI 2c/3; 73.5%) when ADAPT used alone were high compared to results of recently published studies (Table 2).[1,3,5-7,10,14,15,17,18] Rates of rescue stent retriever use were comparable in our study group (15%). In all cases of necessary stent retriever maneuvers in addition to ADAPT hard fragment clots were the reason of vessel occlusion, which hints to a possible limitation of the ADAPT technique. The percentage of patients with mRS 0-2 at discharge were comparable to data in recently published studies (47% versus 46%-50.6%).[3,10,14] Our overall rate of symptomatic intracranial hemorrhage of 7.5% is in line with data from other ADAPT studies.[14,15] Embolization to new territories was

comparable to the reported rates in the literature (2.5% versus 2%-6%).[1,3,7,10,14] There was no significant difference between the median ASPECT score in the ADAPT group compared to the ADAPT+rescue group (8 versus 9) post-treatment, but postinterventional median mRS was significantly lower in the ADAPT group compared to the ADAPT+rescue group. Even if the results from literature and our own are encouraging there is a paucity of randomized trials for efficacy of ADAPT as first-line approach in LVO stroke and most of the nonrandomized trials are biased by group definition.

The currently published ASTER-trial is the first randomized comparative trial that has studied the aspiration technique versus the stent retriever thrombectomy as first-line strategy in LVO in acute ischemic stroke but the results indicated that there was no difference between the 2 techniques.[7]

The ASTER trial was designed to demonstrate superiority of aspiration as first-line therapy over stent retriever in achieving the primary end point of successful recanalization (TICI2b/3) at the end of angiography after all endovascular treatment. The study failed to achieve this result with a recanalization rate below the expected level of 15% increased successful recanalization rates by the aspiration attempt. Even if revascularization rate is a major early indicator of treatment success, clinical outcome such as the 90-day mRS score is more relevant. Clinical outcome with a 90-day mRS 0-2 was comparable between the 2 groups but ASTER also failed to demonstrate equivalence or noninferiority in clinical outcome because it was not designed to prove these aspects and hence underpowered. Numerous single-center studies suggest aspiration to be less traumatic regarding vessel damage, which may be because of aspiration thrombectomy having less of a shearing effect, that is why many interventionalists may favor this approach in the first place. The safety profile at the ASTER trial was equal for both treatment strategies with comparable rates of procedure-related adverse events (16.2% aspiration versus 15.9% stent retriever). Thus, ASTER also failed to confirm a potential safety superiority.

The problem of comparing aspiration and the stent retriever technique is the lack of randomized trials for aspiration thrombectomy. The only randomized trial in this analysis using ADAPT as first-line technique was ASTER that demonstrated high revascularization rates with rates of good functional outcome (mRS 0-2) of 45%. In THERAPY, an international, multicenter, prospective, randomized trial comparing aspiration thrombectomy after intravenous alteplase administration with intravenous alteplase alone, high revascularization rates (TICI2b/c) of 70% were achieved but the rate of 38% with 90-day good functional outcome was relatively low. Moreover, the study was underpowered, because it has been terminated early and failed to show significant results.[19]

A patient-level meta-analysis of 5 randomized trials (MR CLEAN, ESCAPE, REVASCAT, SWIFT PRIME, and an EXTEND IA) that used predominantly stent retrievers for first-line revascularization approach revealed an overall good clinical outcome rate of 46%, but a rate of mRS less than or equal to 2 up to 60% in SWIFT-PRIME and 71% mRS less than or equal to 2 in EXTEND IA could be achieved (Fig 1).[5,7,19-28] At last the heterogeneity in the ADAPT meta-analysis limits the comparability to the stent-retriever technique. Theoretically ADAPT might lower the risk of embolic complications, because passage of the thrombus before aspiration is not necessary and the thrombus is frequently extracted en bloc. However, an in-vitro study has found that more angiographically not visible emboli occur with the ADAPT technique, than with stent retriever. This higher number of microemboli in soft elastic clots might be the reason for the poor rate of favorable functional outcome.[29] The frequency of small distal emboli following recanalization is unknown, and it is unclear whether the risk of small distal embolization differs between recanalization techniques in vivo.

At this point in time, the question if aspiration is equivalent to stent retriever as first-line approach to clot removal is unresolved while uncertainty about clinical effectiveness of the technique remains. On the other hand results of a current meta-analysis indicate that ADAPT might be an effective first-line approach in the treatment of LVO. Wei et al conducted a meta-analysis of 16 studies that used ADAPT as first-line approach and 5 studies that limited endovascular procedures to aspiration thrombectomy only. The reported rate of 90-day mRS less than or equal to 2 in the 16 ADAPT studies was 52.7% (95% confidence interval, 48.0%-57.4%).[16] Moreover, the results from the COMPASS trial, that ought to be published soon, have been presented at the International Stroke Conference (ISC; 24-26 January, Los Angeles, CA) and revealed noninferiority of ADAPT as first-line thrombectomy therapy for acute ischemic stroke with regard to functional outcomes when compared to the stent-retriever-first approach.[30] The major limitation of our study is the relatively small sample size that might be the reason for the relatively high revascularization success. Further, the use of ADAPT technique was at the discretion of the interventionalist, which might have created a selection bias. For example, in very tortuous and complex vessel anatomy the interventionalist may have chosen to use a stent retriever as a first-line therapy, instead of escalating from ADAPT to stent retriever therapy. The detectable significance level of the Mann-Whitney U test is not expected to suffer from the sample size of n = 40.

At last the question arises, if any of the thrombectomy methods are superior to others. Choosing a method for a specific patient depends on a number of different variables, for example vessel anatomy, operator experience, or, as our results show, clot composition. The ADAPT method alone might be more promising in short, soft,

Table 2. *An overview of published studies on thrombectomy using the ADAPT technique as first-line approach*

Study	First-line technique	Number patients/ cases	NIHSS	TICI2b-3 n (%)	ADAPT+ Resc, n (%)	Onset to groin puncture, min.	Time groin puncture-recanalization, min.	90-day mRS≤2, (%)	sICH, n (%)	ENT, n (%)	Mortality, n (%)
Turk 2014 (ADAPT-FAST)[5]	ADAPT	All: 100 ADAPT alone: 78	All: median 17 ADAPT alone: NA	All: 95/100 (95) ADAPT alone: 78/100 (78)	22/100 (22)	All: mean 507 ADAPT alone: NA	All: mean 36.6 ADAPT alone: mean 31.6	All: 32/81 (39.5) ADAPT alone: 37/78 (47.4)	0	0	All: 15/77 (19.5) ADAPT alone: 11/78 (14.1)
Jankowitz 2015[10]	ADAPT	All: 112 ADAPT alone: 66	All: median 17 ADAPT alone: NA	All: 97/112 (87) ADAPT alone: 66/112 (59)	46/112 (41.1)	All: median 267 ADAPT alone: NA	All: median 70 ADAPT alone: NA	All: 52/112 (46.4) ADAPT alone: NA	All: 7/112 (6.2) ADAPT alone: NA	All: 4/112 (3.5) ADAPT alone: 2/66 (3)	All: 35/112 (31.3) ADAPT alone: NA
Romano 2016[14]	ADAPT	All: 152 ADAPT alone: 96	All: mean 19.0 ADAPT alone: mean 19.2	All: 115/152 (75.6) ADAPT alone: 83/152 (54.6)	56/152 (36.8)	All: mean 227 ADAPT alone: NA	All: mean 57.8 ADAPT: mean 44.7	All: 77/152 (50.6) ADAPT: 55/96 (57.3)	All: 12/152 (7.8) ADAPT alone: 4/96 (4.1)	All: 3/152 (1.9) ADAPT alone: 2/96 (2.1)	All: 12/152 (7.8) ADAPT alone: 6/96 (6.2)
Kowoll 2016[3]	ADAPT	All: 54 ADAPT alone: 30	All: median 15 ADAPT alone: mean 14	All: 50/54 (93%) ADPAT alone: 30/54 (55.5)	24/54 (44.4)	All: median 179 ADAPT alone: median 174	All: mean 41 ADAPT alone: median 30	All: 25/54 (46.3)$^{+}$ ADAPT alone: 16/30 (53.3)	All: 2/54 (3.7) ADAPT alone: 1/30 (3)	All: 3/54 (6) ADAPT alone: 2/30 (7)	All: 6/54 (11.1) ADAPT alone: 1/30 (3)
Vargas 2016[17]	ADAPT	All: 191 ADAPT alone: 146	All: mean 15.4 ADAPT alone: mean 15.3	All: 180/191 (94.2) ADAPT alone: 145/191 (75.9)	45/191 (23.6)	All: mean 468.3 ADAPT alone: mean 483.9	All: mean 37.3 ADAPT alone: mean 30.1	All: 98/181 (54.1) ADPAT alone: 79/137 (57.7)	All: 13/191 (6.8) ADAPT alone: NA	0	All: 27/181 (14.9) ADAPT alone: 19/137 (13.9)
Blanc 2017[1]	ADAPT	All: 347 ADAPT alone: 209	All: median 17 ADAPT alone: NA	All: 288/347 (83) ADAPT alone: 193/347 (55.6)	138/347 (39.7)	All: Median 255 ADAPT alone: NA	All: NA ADAPT alone: median 37	All: 144/323 (44.5) ADAPT alone: NA	All: 10/347 (2.9) ADAPT alone: NA	All: 22/347 (6.3) ADAPT alone: NA	All: 73/323 (22.6) ADAPT alone: NA

Study	First-line technique	Number cases/ patients ADAPT	NIHSS	TICI2b-3 n (%)	ADAPT+ Resc, n (%)	Onset to groin puncture, min.	Time groin puncture-recanalization, min.	90d mRS≤2, n (%)	sICH overall, n (%)	ENT, n (%)	Mortality, n (%)
Turk 2015[6]	ADAPT versus SRLA versus PS	ADAPT all: 64 ADAPT alone:NA	ADAPT: median 16.5 ADAPT alone: NA	ADAPT all: 61/64 (95.3) ADAPT alone: 50/64 (78.1)	NA	ADAPT all: NA ADAPT alone: NA	ADAPT all: mean 37.1 ADAPT alone: NA	ADAPT all: 28/60 (46.7) ADAPT alone: (54.6)§	ADAPT all: NA ADAPT alone: NA	ADAPT all: NA ADAPT alone: NA	ADAPT all: NA ADAPT alone: NA
Lapergue 2017 (ASTER)[7]	ADAPT versus SR	ADAPT all: 192 ADAPT alone: 129	ADAPT all: mean 16.3 ADAPT alone: NA	ADAPT all: 164/192 (85.4) ADAPT alone: 121/ 192 (63)	63/192 (32.8)	ADAPT all: median 217 ADAPT alone: NA	ADAPT all: median 38 ADAPT alone: NA	ADAPT all: 82/181 (45.3) ADAPT alone: NA	ADAPT all: 10/188 (5.3) ADAPT alone: NA	ADAPT all: 7/192 (3.7) ADAPT alone: NA	ADAPT all: 35/181 (19.3) ADAPT alone: NA
Delgado Almandoz 2017[18]	ADAPT versus Solumbra	ADAPT all: 45 ADAPT alone: 32	ADAPT all: mean 19.2 ADAPT alone: NA	ADAPT all: 40/45 (89) ADAPT alone: NA	13/45 (28.9)	ADAPT all: mean 224 ADAPT alone: NA	ADAPT all: mean 50 ADAPT alone: NA	ADAPT all: 25/45 (55.6) ADAPT alone: NA	ADAPT all: 1/45 (2.2) ADAPT alone: NA	ADAPT all: 2/45 (4.4) ADAPT alone: NA	ADAPT all: 8/45 (17.8) ADAPT alone: NA
Stapleton 2018[15]	ADAPT versus SR	ADAPT all: 47 ADAPT alone: 27	ADAPT all: mean 16.5 ADAPT alone: mean 16.7	ADAPT all: 39/47 (83) ADAPT alone: 22/47 (46.8)	20/47 (42.5)	ADAPT all: mean 241.9 ADAPT alone: mean 219.3	ADAPT all: mean 54.0 ADAPT alone: mean 41.8	ADAPT all: 23/47 (48.9) ADAPT alone: 14/27 (51.9)	ADAPT all: 6/47 (12.8) ADAPT alone: 1/27 (3.7)	ADAPT all: NA ADAPT alone: NA	ADAPT all: 6/47 (12.8) ADAPT alone: 1/27 (3.7)
Present study 2018	ADAPT	All: 40 ADAPT alone: 34	All: median 12 ADAPT alone: median 12	All: 40/40 (100) ADAPT alone: 34/40 (85)	6/40 (15)	All: mean 202.5 ADAPT alone: mean 215.9	All: mean 25.2 ADAPT alone: mean 20.7	All: 19/40 (47.5)† ADAPT alone: 19/34 (55.8)†	All: 3/40 (7.5) ADAPT alone: 2/34 (5.8)	All: 1/40 (2.5) ADAPT alone: 0/34 (0)	All: 1/40 (2.5) ADAPT alone: 1/34 (2.9)
*Total: Weighted average ratios**	*ADAPT all ADAPT alone*	1344 847		ADAPT all: *86.9%* ADAPT alone: *63.7%*	*33%*			ADAPT all: *47.3%* ADAPT alone: *54.6%*	ADAPT all: *5%* ADAPT alone*: 4.2%*	ADAPT all: *3.2%* ADAPT alone: *1.4%*	ADAPT all: *18.1%* ADAPT alone: *9.8%*

Abbreviations: ADAPT alone, ADAPT without adjunctive thrombectomy techniques; ADAPT + Resc, ADAPT with stent retriever rescue; ENT, embolization to new territories; mRS, modified Rankin scale; NIHSS, National Institutes of Health Stroke Scale; PS, traditional penumbra system; SR, stent retriever; SLRA; stent retriever with local aspiration; sICH, symptomatic intracerebral hemorrhage;TICI, thrombolysis in cerebral infarction; § = number of patients is not available.

*Average ratios weighted to number of patients.

†mRS at discharge.

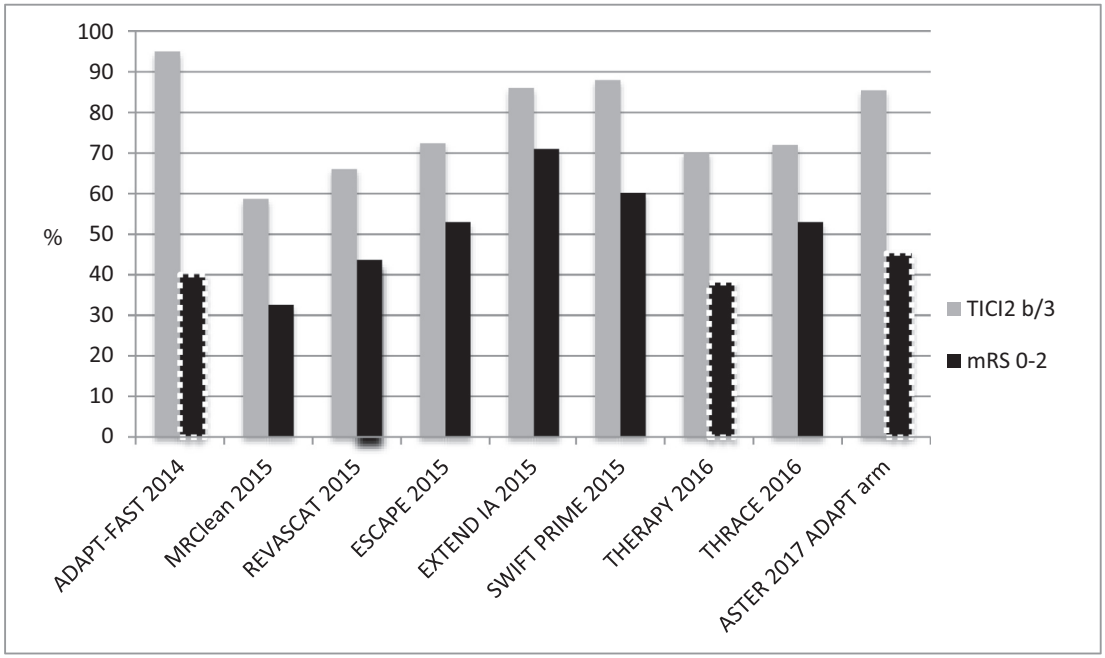

Figure 1. *Summary of major stent retriever and aspiration thrombectomy trials. White-dashed bar graphs represent mRS in trials with ADAPT as first-line revascularization approach. Abbreviations: ADAPT, direct aspiration thrombectomy; mRS, modified Rankin scale.*

elastic clots which can be completely aspirated into large-bore catheters. In longer soft-elastic thrombus, an additional proximal flow-arrest might reduce thrombus fragmentation and microembolies. In contrast, hard, clots are often too rigid to be completely aspirated and may shear of the catheter tip when maneuvering the thrombus along narrow bends or when retracting the aspiration catheter into the sheath or guiding catheter. In such a case, a local aspiration technique in combination with a stent retriever may be the more suitable method, for example the SAVE technique.[31] At this point in time, there are no randomized controlled trials available evaluating the outcome of different stent retriever techniques.

The present series continues to show that the ADAPT technique is very competitive as a first-line treatment modality despite the fact that the randomized study (ie, ASTER) did not show any differences between aspiration and stent retriever thrombectomy. In this context and in regard to this apparent dissonance, it is conceivable that different techniques for different circumstances is probably the most realistic future of thrombectomy.

Conclusions

The existing evidence of ADAPT as a first-line approach may not reach the level of Class IA, but it is increasingly available and our study adds to that body of knowledge. Results from the COMPASS trial, which ought to be published soon, may provide more definitive evidence, that aspiration thrombectomy may be considered as an equally effective therapy when compared to stent retrievers. Choosing the thrombectomy method suitable for a respective patient depends on a number of different variables and further randomized trials may define subgroups of patients, in which a single method or a combination of methods may be more suitable than other approaches.

References

1. Blanc R, Redjem H, Bartolini B, et al. Predictors of the Aspiration Component Success of a Direct Aspiration First Pass Technique (ADAPT) for the endovascular treatment of stroke reperfusion strategy in anterior circulation acute stroke. Stroke 2017;48:1588-1593.
2. Kabbasch C, Möhlenbruch M, Stampfl S, et al. First-line lesional aspiration in acute stroke thrombectomy using a novel intermediate catheter: initial experiences with the SOFIA. Interv Neuroradiol 2016;22:333-339.
3. Kowoll A, Weber A, Mpotsaris A, et al. Direct aspiration first pass technique for the treatment of acute ischemic stroke: initial experience at a European stroke center. J Neurointerv Surg 2016;8:230-234.
4. Lapergue B, Blanc R, Guedin P, et al. A direct aspiration, first pass technique (ADAPT) versus stent retrievers for acute stroke therapy: an observational comparative study. AJNR Am J Neuroradiol 2016;37:1860-1865.
5. Turk AS, Frei D, Fiorella D, et al. ADAPT FAST study: a direct aspiration first pass technique for acute stroke thrombectomy. J Neurointerv Surg 2014;6:260-264.
6. Turk AS, Turner R, Spiotta A, et al. Comparison of endovascular treatment approaches for acute ischemic stroke: cost effectiveness, technical success, and clinical outcomes. J Neurointerv Surg 2015;7:666-670.
7. Lapergue B, Blanc R, Gory B, et al. Effect of endovascular contact aspiration vs stent retriever on revascularization in patients with acute ischemic stroke and large vessel occlusion: the ASTER Randomized Clinical Trial. JAMA 2017;318:443-452.

8. Loh PS, Butcher KS, Parsons MW, et al. Apparent diffusion coefficient thresholds do not predict the response to acute stroke thrombolysis. Stroke 2005;36:2626.
9. Kidwell CS, Saver JL, Mattiello J, et al. Thrombolytic reversal of acute human cerebral ischemic injury shown by diffusion/perfusion magnetic resonance imaging. Ann Neurol 2000;47:462.
10. Jankowitz B, Aghaebrahim A, Zirra A, et al. Manual aspiration thrombectomy: adjunctive endovascular recanalization technique in acute stroke interventions. Stroke 2012;43:1408-1411.
11. Tan IYL, Demchuk AM, Hopyan J, et al. CT angiography clot burden score and collateral score: correlation with clinical and radiologic outcomes in acute middle cerebral artery infarct. AJNR Am J Neuroradiol 2009;30:525-531.
12. Goyal M, Fargen KM, Turk AS, et al. 2C or not 2C: defining an improved revascularization grading scale and the need standardization of angiography outcomes in stroke trials. J Neurointerv Surg 2014;6:83-86.
13. Fiorelli M, Bastianello S, von Kummer R, et al. Hemorrhagic transformation within 36 hours of a cerebral infarct: relationships with early clinical deterioration and 3-month outcome in the European Cooperative Acute Stroke Study I (ECASS I) cohort. Stroke 1999;30:2280-2284. 1999.
14. Romano DG, Cioni S, Vinci SL, et al. Thromboaspiration technique as first approach for endovascular treatment of acute ischemic stroke: initial experience at nine Italian stroke centers. J Neurointerv Surg 2017;9:6-10.
15. Stapleton J, Leslie-Mazwi TM, Torok CM, et al. A direct aspiration first-pass technique vs stentriever thrombectomy in emergent large vessel intracranial occlusions. J Neurosurg 2018;128:567-574.
16. Wei D, Mascitelli JR, Nistal DA, et al. The use and utility of aspiration thrombectomy in acute ischemic stroke: a systematic review and meta-analysis. AJNR Am J Neuroradiol 2017;38:1978-1983.
17. Vargas J, Spiotta A, Fargen K, et al. Long term experience using the ADAPT technique for the treatment of acute ischemic stroke. J NeuroInterv Surg 2017;9:437-441.
18. Delgado Almandoz JE, Kayan Y, et al. Comparison of clinical outcomes in patients with acute ischemic strokes treated with mechanical thrombectomy using either Solumbra or ADAPT techniques. J NeuroInterv Surg 2016;8:1123-1128.
19. Mocco J, Zaidat OO, Rüdiger von Kummer R, et al. Aspiration thrombectomy after intravenous alteplase versus intravenous alteplase alone. Stroke 2016;47:2331-2338.
20. Zaidat OO, Castonguay AC, Gupta R, et al. North American Solitaire Stent Retriever Acute Stroke registry: post-marketing revascularization and clinical outcome results. J NeuroInterv Surg 2014;6:584-588.
21. Pereira VM, Gralla J, Davalos A, et al. Prospective, multicenter, single-arm study of mechanical thrombectomy using solitaire flow restoration in acute ischemic stroke. Stroke 2013;44:2802-2807.
22. Berkhemer OA, Fransen PS, Beumer D, et al. A randomized trial of intraarterial treatment for acute ischemic stroke. N Engl J Med 2015;372:11-20.
23. Jovin TG, Chamorro A, Cobo E, et al. Thrombectomy within 8 hours after symptom onset in ischemic stroke. N Engl J Med 2015;372:2296-2306.
24. Goyal M, Demchuk AM, Menon BK, et al. Randomized assessment of rapid endovascular treatment of ischemic stroke. N Engl J Med 2015;372:1019-1030.
25. Campbell BC, Mitchell PJ, Kleinig TJ, et al. Endovascular therapy for ischemic stroke with perfusion-imaging selection. N Engl J Med 2015;372:1009-1018.
26. Saver JL, Goyal M, Bonafe A, et al. Stent-retriever thrombectomy after intravenous t-PA vs. t-PA alone in stroke. N Engl J Med 2015;372:2285-2295.
27. Bracard S, Ducrocq X, Mas JL, et al. Mechanical thrombectomy after intravenous alteplase versus alteplase alone after stroke (THRACE): a randomised controlled trial. Lancet Neurol 2016;15:1138-1147.
28. Goyal M, Menon BK, van Zwam WH, et al. Endovascular thrombectomy after large-vessel ischaemic stroke: a meta-analysis of individual patient data from five randomised trials. Lancet 2016;387:1723-1731.
29. Chueh JY, Puri AS, Wakhloo AK, et al. Risk of distal embolization with stent retriever thrombectomy and ADAPT. J NeuroInterv Surg 2016;8:197-202.
30. Turk AS, Siddiqui AH, Mocco J. A comparison of direct aspiration versus stent retriever as a first approach ('COMPASS'): protocol. J NeuroInterv Surg 2018. https://doi.org/10.1136/neurintsurg-2017-013722. Published Online First.
31. Maus V, Behme D, Kabbasch C, et al. Maximizing first-pass complete reperfusion with SAVE. Clins Neuroradiol 2017. https://doi.org/10.1007/s00062-017-0566-z.