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RESEARCH

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Series of fast reperfusion with simultaneous proximal and distal aspiration in patients with acute ischemic stroke

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Abstract

Background Various endovascular techniques for the recanalization of large vessel occlusion in patients with acute ischemic stroke have been established. In this series a combined distal and proximal aspiration technique was used as a novel approach. The aim of this study was to investigate, whether this technique achieves reperfusion faster and if embolization in distal territories can be reduced.

Results The success of the treatment was dependent on the localization of the clot. Fast reperfusion was achieved in all patients when the clot was located at the level of the middle cerebral artery. Aspiration failed when the vessel occlusion was located at the level of the carotid-T and subsequent rescue treatment was performed. Median groin puncture to reperfusion time was 20 min (range 9–66). No Embolization to new territories (ENT) and no intracerebral hemorrhage were observed. One patient died. In all other patients favorable neurological outcome was observed as measured by a modified Rankin score at discharge (mRS 0, range 0–1).

Conclusion Simultaneous proximal and distal aspiration appears to be fast and effective. Furthermore, it reliably prevented ENT in patients with vessel occlusion at the level of the middle cerebral artery in a small cohort.

Keywords Stroke, Anterior circulation, Mechanical thrombectomy, Distal aspiration, Proximal aspiration, Balloon guide catheter, ADAPT, SAVE, PROTECT PLUS, Stent retriever

Background

The treatment of acute ischemic stroke caused by large vessel occlusion in the anterior circulation has been revolutionized by the introduction of endovascular recanalization techniques. In the majority of the studies mechanical recanalization was achieved with stent retrievers [1]. A different approach is the direct aspiration technique (ADAPT) [2, 3]. A large guide catheter is placed in the internal carotid artery and used to advance a distal access catheter to the proximal end of the clot. Suction is applied, which removes the clot. Various combinations of different techniques have been proposed [4–6]. The advantages of direct aspiration approach encompass a faster puncture to recanalization time and a superior cost effectiveness [7, 8]. However, an in vitro model as well as a number of clinical trials showed complications such as distal embolization in the affected vessel and embolization to new uninvolved territories [8–10]. Embolization was significantly reduced under the usage of a distal balloon guide catheter by creating blood flow arrest [11].

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The aim of this study was to investigate, whether a combination of the advantages of direct aspiration and balloon guide catheter is feasible to achieve rapid reperfusion with possible reduction of distal emboli. Therefore, the novel double aspiration technique was developed. Here, simultaneously distal aspiration through a distal aspiration catheter and proximal aspiration by means of a balloon guide catheter are combined.

Methods

A retrospective analysis of a prospectively maintained database of all stroke patients with proximal vessel occlusion of the anterior circulation treated with thrombectomy between April 2019 and December 2020 was carried out.

All patients who were treated with the double aspiration technique were identified. As various thrombectomy techniques were performed during the same time period, these patients were not treated consecutively. The primary endpoint was the successful recanalization rate, which was defined by the modified Thrombolysis in Cerebral Infarction stadium (mTICI). Secondary endpoints were time interval from groin puncture to reperfusion, total number of passes, radiation dose, rate of distal embolization in the affected vessel territory, embolization to new territories and clinical outcome at discharge measured by the modified Rankin score (mRS).

Patient selection

Inclusion criteria were as follows: proximal intracranial large vessel occlusion of the anterior circulation, no signs of intracranial hemorrhage based on non-enhanced computed tomography (NECT) and National Institute of Health Stroke Scale (NIHSS) score of > 4. Patients were eligible for thrombectomy if known symptom onset was no longer than 8 h ago. Two patients with unknown symptom onset were included in the study based on positive imaging profile, which was evaluated by additional whole brain perfusion. Exclusion criteria were simultaneous occlusions of other intracranial vessels, intracranial hemorrhage based on NECT, simultaneous presence of relevant diseases such as pulmonary artery embolism and NIHSS score of < 4.

Imaging and clinical assessment

The computed tomography workup consisted of non-enhanced computed tomography and CT-angiography. The angiographic images were evaluated with respect to the initial occlusion site and the mTICI grade after recanalization. NECT was performed the day after thrombectomy. Consultant neurologists with two to twenty years of experience assessed the neurologic status at admission and discharge.

Technical description of the method

The internal carotid artery was catheterized in roadmap technique with a hydrophilic guide wire. A 8F balloon guide catheter (BGC) was placed in the distal internal carotid artery (8F Cello®, Medtronic, Dublin, Ireland). A distal aspiration catheter (5F Sofia®, Microvention, Tustin, USA) was advanced to the proximal end of the thrombus. With the use of a 60 ml vacuum pressure syringe negative pressure was applied. The distal aspiration catheter was gently pushed forward toward the occlusion until no flow was seen within the syringe. The balloon of the BGC was inflated and connected to another vacuum pressure syringe. Under fluoroscopy the distal aspiration catheter was slowly retrieved under continuous aspiration through both the distal aspiration catheter and the BGC (Figs. 1, 2). The distal aspiration catheter was removed and flushed.

When no back-flow was observed within the BGC, the BGC was pulled back under permanent aspiration after deflating the balloon to remove the entrapped thrombus. Control angiograms were acquired and

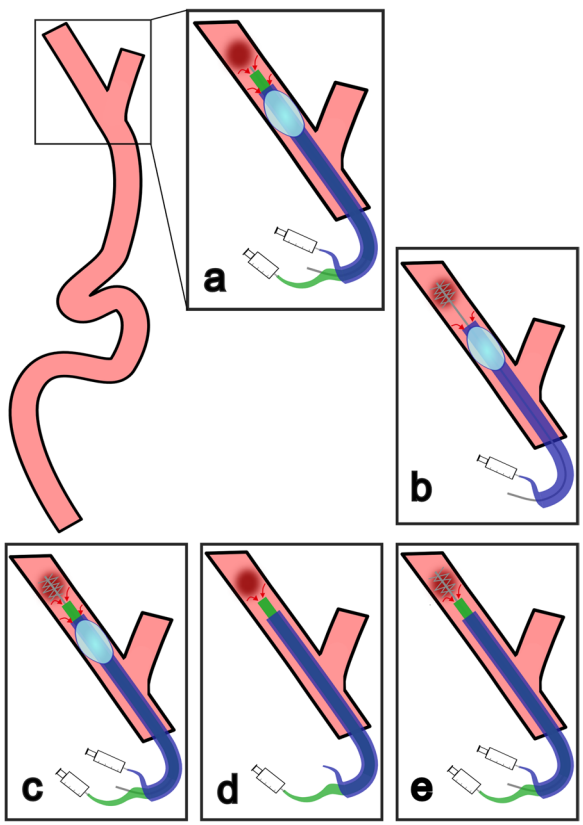

Fig. 1 Comparison of the double aspiration method to existing methods. **a** Shows the proposed method with a distal aspiration catheter (green) and BGC (blue). **b** Standard method with a stent retriever (grey) instead of a aspiration catheter **c** PROTECT PLUS method **d** ADAPT and **e** SAVE

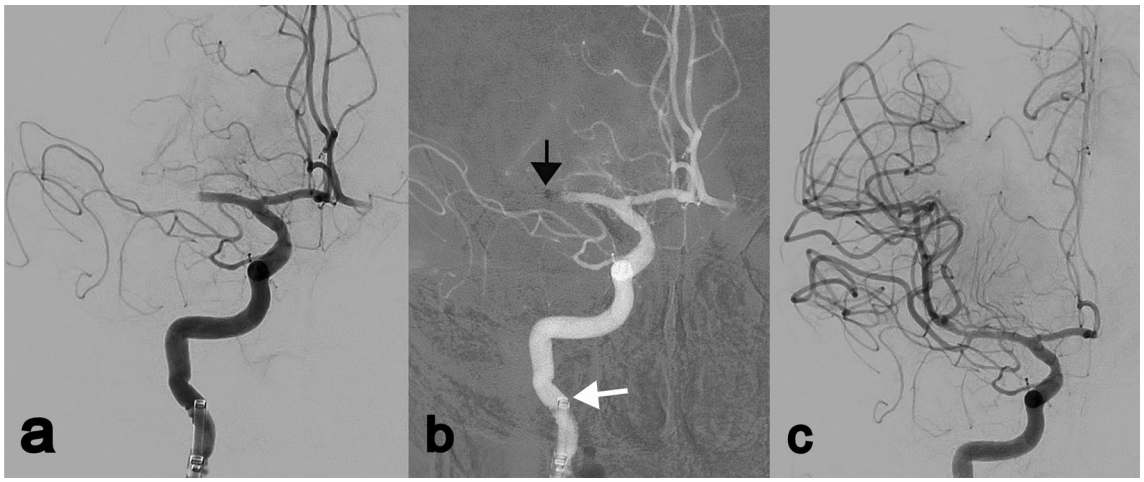

Fig. 2 Case studies illustrating the double aspiration technique. The initial angiogram on the left depicts a proximal occlusion of the right medial cerebral artery (**a**) in a 73-year-old female patient with an initial NIHSS of 8 and hemiparesis with predominant involvement of the left arm. A balloon guide catheter is advanced into the distal internal carotid artery and a distal aspiration catheter is pushed to the proximal end of the clot (**b**). The balloon is inflated and suction is applied to the distal aspiration catheter and to the BGC. The white arrow points at the inflated balloon of the BGC and the black arrow indicates the marker of the distal aspiration catheter on the roadmap image. The distal aspiration catheter is removed under constant proximal and distal aspiration. The control angiogram shows a complete recanalization of the treated vessel (**c**). The time between the event and groin puncture was 2 h 30 min

the whole procedure was repeated if necessary. If the direct aspiration approach failed, a fast switch to a rescue treatment with a stent retriever introduced through the balloon guide catheter, which was already in place, was performed.

Results

Fifteen patients with large vessel occlusion in the anterior circulation were treated. Mean age of the patients was 72 years (median 82, range 23–90). In the study group 40% were male (Table 1).

Prior to mechanical recanalization, five patients received intravenous thrombolysis. Three patients showed vessel occlusion at the level of the carotid-T and twelve patients exhibited an occlusion of the

Table 1 Patient characteristics

Patient number	Age (years)	Sex	MRS baseline	NIHSS baseline	MRS discharge	NIHSS discharge
1	83	F	5	14	0	6
2	52	M	5	14	1	3
3	84	F	4	6	0	2
4	72	F	5	8	0	2
5	82	F	5	9	0	5
6	23	F	5	13	0	2
7	85	M	5	8	Dead	Dead
8	53	M	5	8	0	0
9	90	F	5	12	0	0
10	82	F	5	8	0	0
11	53	M	4	6	1	2
12	83	M	4	6	0	2
13	78	F	5	13	0	0
14	84	F	5	9	1	3
15	75	M	5	9	1	2

MRS modified Rankin scale, *NIHSS* National Institute of Health Stroke Scale, *F* female, *M* male

middle cerebral artery. The thrombus was in the left M1 segment of the middle cerebral artery in seven patients. Left M2 segment was occluded in one patient. Right M1 segment was affected in four patients. Right carotid-T was occluded in one and left carotid-T in two patients. Recanalization with double aspiration alone failed in the cases with occlusion of the carotid-T. Recanalization with double aspiration alone was successful in all patients with occluded middle cerebral artery.

The analysis of the patients with successful recanalization of the medial cerebral artery using double aspiration yielded the following results. Mean NIHSS score at admission was 9.6 (median 9, range 6–14) and mean Modified Rankin Scale (MRS) score was 4.7 (median 5, range 4–5). Mean time from symptom onset to groin puncture was 154 min (range 90–230) and mean time from groin puncture to recanalization was 19 min (median 19, range 9–32). Mean fluoroscopic time was 6.8 min (median 6.6 range 3–11.2) and mean dose area product (DAP) was 28.1 Gy·cm^2 (median 24, range 9.2–65.7). A final reperfusion result of mTICI 2c-3 was achieved with an average of 1.5 attempts. First pass recanalization was achieved in 54% of these cases. Mean NIHSS score at discharge was 2.4 (median 2, range 0–6) and mean MRS score was 0.3 (median 0, range 0–1) (Table 2).

Discussion

In earlier studies various combinations of devises for clot removal were used. The different methods contain either stent retrievers or aspiration catheters or both. For some of them additionally a balloon guide catheter is used. In the new method a distal aspiration catheter and BGC are proposed as opposed to the commonly applied standard method in which a stent retriever replaces the aspiration catheter [12]. The PROTECT PLUS method combines a stent retrieve, a distal aspiration catheter and a BCG [6]. In ADAPT and SAVE there is no BGC used but a guide catheter only [13, 14]. Therefore, it is not possible to create blood flow inversion. While the ADAPT method removes the clot via the aspiration catheter [13], like in the suggested method, the SAVE method uses a stent retriever instead [4].

In this study the new double aspiration technique for stroke treatment was investigated and compared to the existing ones in terms of, whether this technique achieves reperfusion faster and if embolization in distal territories can be reduced. The novel method is the combination of a distal aspiration catheter with distal aspiration and additional proximal aspiration by means of a balloon guide catheter. This resulted in very fast recanalization rates and good functional outcomes when the clot was located at the level of the middle cerebral artery. This technique was unsuccessful when the clot was located at the level of the carotid-T.

Table 2 Technical and procedural data

Patient number	i.v. lysis	Occlusion site	Recanalization technique	Number of passes	Fluoroscopic time (min)	DAP (Gy·cm$^{2)}$	mTICI	Symptom onset-groin puncture (min)	Groin puncture-reperfusion (min)
1	Y	LM1	DA	2	9.55	39.9	3	230	32
2	N	LM2	DA	1	7.13	18.8	3	Unclear	21
3	N	RM1	DA	1	6.34	20.4	3	96	19
4	N	RM1	DA	1	5.09	17.9	3	150	18
5	N	LM1	DA	2	4.39	13.8	3	Unclear	11
6	N	LM1	DA	1	3.01	9.2	3	80	9
7	Y	LM1	DA	1	10.19	65.7	3	150	24
8	Y	RCT	SR	3	13	20.1	3	115	44
9	N	LCT	SR	7	31	61.8	2c	210	66
10	N	LCT	SR	3	6.48	20.1	3	75	22
11	Y	RM1	DA	1	6.39	26.9	3	222	17
12	N	RM1	DA	2	9.25	33.7	2c	75	23
13	N	LM1	DA	2	5.29	24.4	3	90	18
14	Y	LM1	DA	2	6.53	21.5	3	120	18
15	N	LM1	DA	2	7.20	37.5	3	154	20

i.v. rtPA intravenous recombinant tissue plasminogen activator, *Y* yes, *N* no, *LM1* left m1 segment of the middle cerebral artery, *LM2* left m2 segment of the middle cerebral artery, *RM1* right m1 segment of the middle cerebral artery, *RCT* right carotid-T, *LCT* left carotid-T, *DAP* dose area product, *unclear* wake up stroke, *mTICI* modified treatment in cerebral ischemia score, *DA* Double Aspiration, *SR* Stent retriever

Table 3 Overview of Groin puncture to recanalization times of previous studies

Study name	Min	1.qrt	Median (min)	3.qrt	Max	Mean (min)	Standard deviation
Present study: Double aspiration	9	14.5	19	22.5	32	19.1	7.8
double aspiration + bail out stent retriever	9		20		66	25.5	
PROTECT PLUS [6]						21	
Aspiration first pass thrombectomy [8]						25	21–30
Stent retriever first line thrombectomy [8]						35	30–41
ADAPT [13]						31.6	23.3
ADAPT + bail out stent retriever [13]						56.8	29.1
SAVE [14]		25	34	52			
Aspiration group.[10]		24	38	60			
Stent retriever group.[10]		31	45	60			
ADAPT [18]						55.6	31.3
SAVE [18]						52.1	25.3
PROTECT PLUS [12]	24.5				63.5	37	
BGC + stent retriever [12]	14				46	24	

min minimum, *qrt* quartile, *max* maximum

For the proposed double aspiration technique, a median time of 19.1 min from groin puncture to aspiration was needed. If a bail out stent retriever had to be used median time was 25.5 min. To prevent the need for a time-consuming distal passage of microcatheter and microwire, a additional stent retriever was only applied in cases, where the double aspiration technique failed. This is in line to earlier studies. The superior speed of ADAPT, which uses a distal aspiration catheter alone, in comparison to the recanalization with stent retrievers has been demonstrated in several studies with a median time interval of 20–30 min between groin puncture and reperfusion [3, 15–18]. In case the bail out catheter was needed the groin puncture to reperfusion time was 56.8 min [13]. In the prospective Compass study, the median time to final reperfusion was 10 min faster in the direct aspiration group compared to the stent retriever group [8].

For the novel technique a BGC is used. Among the patients no one had embolization to new territories. Earlier studies showed the effectiveness of BGC in prevention of embolization.

No BCG is used in the ADPAT and Stent retriever Assisted Vacuum-locked Extraction (SAVE) methods. In the SAVE technique, a stent retriever was combined with a distal aspiration catheter. The thrombus was retrieved under continuous distal aspiration and proximal aspiration through the implemented long sheath [4, 14, 18]. In the ADAPT technique and the SAVE technique there is insufficient proximal flow arrest and flow reversal during the withdrawal of the clogged distal aspiration catheter into the sheath. Distal embolization and embolization to a new territory occurred in up to 6% of the cases when the ADAPT technique was used [15, 17]. In comparison to long sheaths, only BGC allowed reliable blood flow arrest and flow reversal in an in vivo model [19] as well as in an experimental in vitro study with a flow model [20]. The results of the present study confirmed this.

Some earlier studies suggest, that the best method for clot removal must be a combination of double aspiration, through the distal access catheter and the BGC, and an additional stent retriever. Therefore in the Protect plus study, the deployed stent retriever with the trapped thrombus was retrieved as a unit with the distal aspiration catheter while aspiration was applied to both the distal aspiration catheter and the BGC [6]. Reliable flow reversal is established at least immediately after the distal aspiration catheter is extracted, so clot fragments in the internal carotid artery are removed. Blasco et al. [12] compared patient groups that were treated with a combination of BGC, stent retriever and distal access catheter, like in the Protect plus study, versus BGC and stent retriever alone. The additional distal access catheter in combination with a stent retriever and a BGC led to a longer time interval between puncture and recanalization and was not associated with better outcomes as compared to the combination of a stent retriever with a BGC [12]. An explanation for this might be, that the diameter of the BCG, on which aspiration was applied, is reduced by the diameter of the distal access catheter and the stent retriever. Therefore aspiration might not be as sufficient resulting in higher rates of negative events like distal embolization.

When comparing the mean groin puncture to reperfusion times of the PROTECT PLUS study (21 min) [6] and

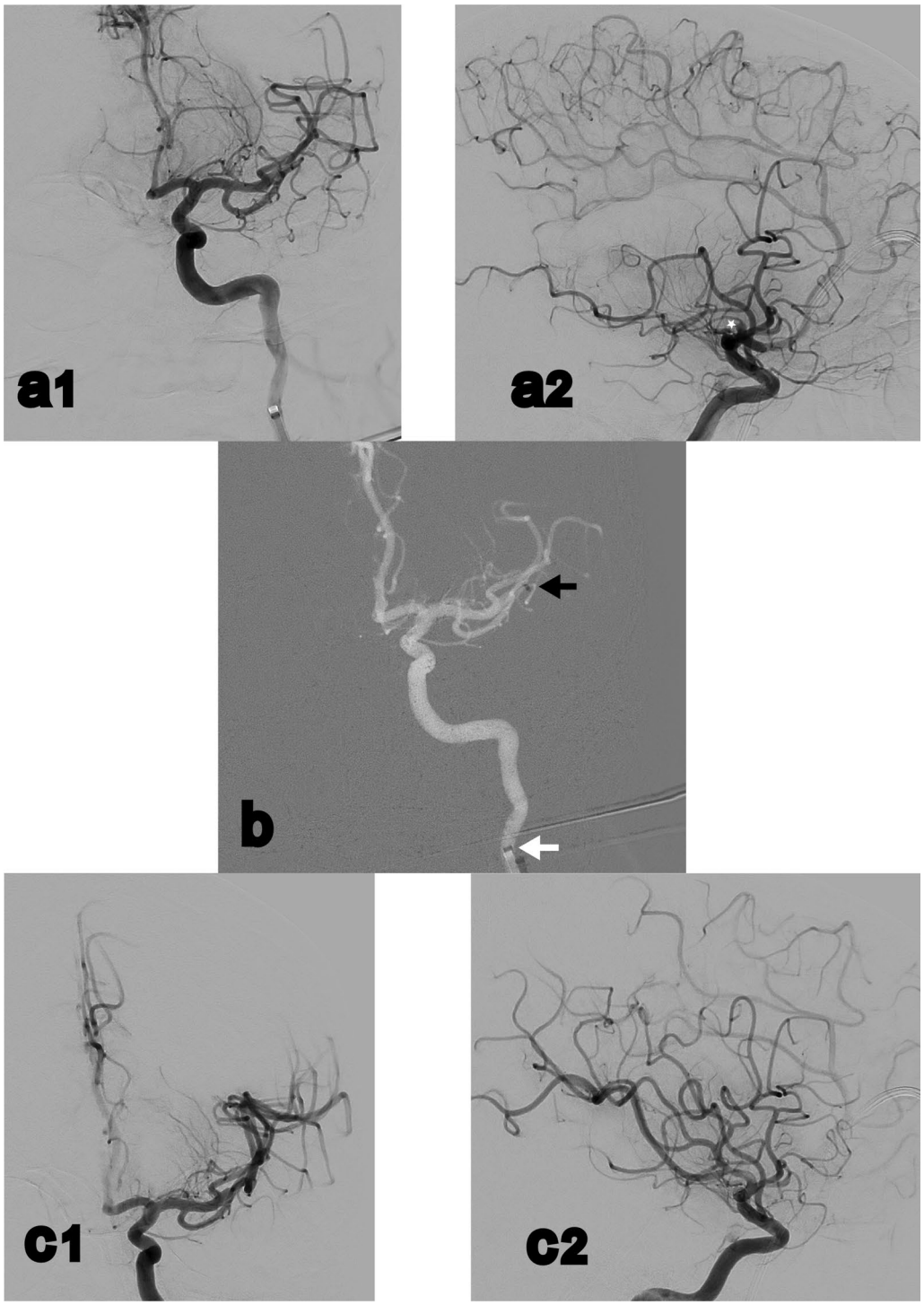

Fig. 3 This 53-year-old patient showed an occlusion of the middle m2 segment. The initial NIHSS was 14 and symptoms were hemiparesis with predominant right arm involvement and loss of speech. The occlusion (white star) is shown in the anterior–posterior (**a1**) and sagittal (**a2**) plane before intervention. **b** showes the intervention. **c1** was the anterior–posterior, **c2** the sagittal plane after the intervention

the study of Blasco et al. [12] (37 min in the PROTECT PLUS group vs. 24 min in the BCG + stent retriever group) to the new double aspiration technique without stent, the last one is clearly superior in speed (19 min) while showing similar clinical outcomes. Without the use of a stent retriever this method is not only faster, but also economically advantageous. To finally confirm

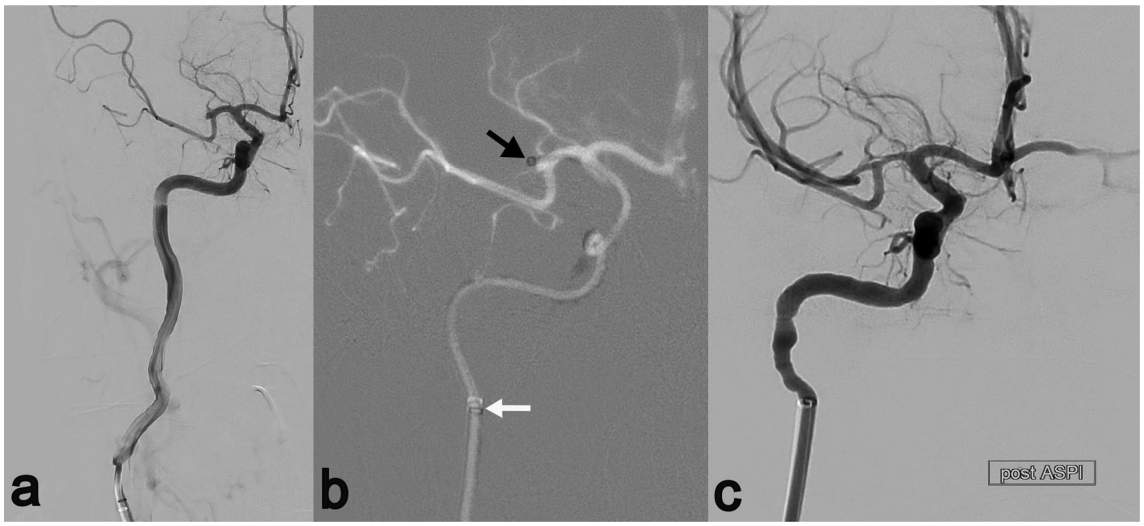

Fig. 4 This 84-year-old patient showed a proximal occlusion of the m2 segment (**a**). The initial NIHSS was 7 and symptoms were hemiparesis with predominant involvement of the left arm. The time interval between event and groin puncture was 1 h 36 min. **b** Shows the intervention. **c** Was after the intervention

this, further research with higher numbers of patients is needed (Table 3).

In the present study the recanalization was unsuccessful when the clot was located at the carotid-T, probably due to a vessel diameter that was too large for the implemented 5F Sofia distal aspiration catheter. This catheter was chosen on base of a recent in vitro study, that showed that the combination of a 5F distal aspiration catheter with an 8F BGC with proximal and distal aspiration during clot retrieval leads to higher first pass recanalization rates with less distal emboli compared to a 6 F distal aspiration catheter with a long sheath [21].

The major limitations of this study encompass the retrospective design and the small sample size. To increase effectivity of combined proximal and distal aspiration, especially at carotid-T occlusions, the combination of large bore distal aspiration catheters with 9 F Balloon guide catheters constitutes a promising approach for further studies. Another limitation is, that the study was executed by a small team and data were collected at a single center.

Conclusion

The combination of a distal aspiration catheter with a balloon guide catheter with simultaneous aspiration for the recanalization of the middle cerebral artery is safe, fast and prevented distal embolization in a small cohort. Further studies are needed to quantify the benefit of additional proximal aspiration when BGC are combined with distal aspiration catheters.

Abbreviations

BGC	Balloon guide catheter
ENT	Embolization to new territories
ICH	Intracerebral hemorrhage
ADAPT	Direct aspiration technique
mTICI	Modified thrombolysis in cerebral infarction stadium
mRS	Modified rankin score
NECT	Non-enhanced computed tomography
NIHSS	National institute of health stroke scale
MRS	Modified Rankin Scale
DAP	Dose area product
SAVE	Stent retriever Assisted Vacuum-locked Extraction

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Author contributions

NL, JZ: Preparation and editing of the manuscript, Figs. 1, 2, 3, 4. LF, PF: Data providing and analysis. PS: Editing of Fig. 2. All authors have read and approved the manuscript.

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Availability of data and materials

All data is listed in the tables attached.

Declarations

Ethics approval and consent to participate

The study protocol and procedures were conducted in accordance with the Declaration of Helsinki. Neither approval of the institutional review board nor patient informed consent were required according to the local ethics committee.

Consent for publication

Not applicable.

Competing interests

Not applicable.

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