Clin Neuroradiol (2019) 29:435–443
https://doi.org/10.1007/s00062-018-0683-3

ORIGINAL ARTICLE

Revascularization Techniques for Acute Basilar Artery Occlusion

Technical Considerations and Outcome in the Setting of Severe Posterior Circulation Steno-Occlusive Disease

Eberhard Siebert[1] · Georg Bohner[1] · Sarah Zweynert[2] · Volker Maus[3] · Anastasios Mpotsaris[3,4] · Thomas Liebig[1] · Christoph Kabbasch[3]

Received: 18 November 2017 / Accepted: 19 March 2018 / Published online: 12 April 2018

Abstract

Purpose To describe the clinical and radiological characteristics, frequency, technical aspects and outcome of endovascular treatment of acute basilar artery occlusion (ABO) in the setting of vertebrobasilar steno-occlusive disease.

Methods Retrospective analysis of databases of two universitary stroke centers including all consecutive patients from January 2013 until May 2017 undergoing thrombectomy for a) acute stroke due to basilar artery occlusion and either significant basilar artery stenosis or vertebral artery stenosis/occlusion as well as b) presumed embolic basilar artery occlusions. Demographics, stroke characteristics, time metrics, recanalization results and outcome were recorded. Interventional strategies were evaluated concerning the thrombectomy technique, additional angioplasty, type of approach with respect to lesion pattern (ipsilateral to steno-occlusive VA lesion: dirty road or contralateral: clean road) and sequence of actions.

Results Out of 157 patients treated for ABO 38 (24.2%) had associated significant vertebrobasilar steno-occlusive lesions. An underlying significant basilar artery stenosis was present in 23.7% and additionally significant steno-occlusive vertebral lesions were present in 81.5%. Thrombectomy was performed with primary aspiration in 15.8% and with stent-retrievers in 84.2%. Successful revascularization (TICI 2b-3) was achieved in 86.8%. In 52.6% additional stent angioplasty was performed, in 7.9% balloon angioplasty only. The clean road approach was used in 22.5% of cases, the dirty road in 77.4%. Final modified Rankin scale (mRS) was 0–2 in 6 patients (15.8%) and 3–5 in 32 (84.2%). The in-hospital mortality was 36.8%. There were no statistically significant differences in outcome compared to presumed cases of embolisms.

Conclusion Endovascular treatment of ABO with underlying significant vertebrobasilar steno-occlusive lesions is effective and reasonably safe. Specific procedural strategies apply depending on individual patient pathology and anatomy. Although high rates of recanalization can be achieved, outcomes tend to be poor.

Keywords Basilar artery occlusion · Thrombectomy · Stroke · Tandem occlusion · Vertebral artery occlusion

Introduction

The prognosis of both symptomatic severe vertebrobasilar stenosis as well as acute basilar occlusion (ABO) is poor with substantial mortality rates of up to 21% for symptomatic posterior circulation stenoses and up to 85% for ABO if left untreated [1–4]. Although endovascular thrombectomy (ET) is frequently used to treat ABO, randomized data on its effectiveness in this situation are so far lacking. From a procedural point of view, additional severe stenotic lesions in the posterior circulation make ET more technically difficult and potentially risky as access may be more complicated and additional angioplasty or stenting with acute platelet inhibition may be required. Uniform

✉ Eberhard Siebert
eberhard.siebert@charite.de

1 Institute of Neuroradiology, Charité—University Medicine Berlin, Charitéplatz 1, 10117 Berlin, Germany

2 Dept. of Neurology, Charité—University Medicine Berlin, Berlin, Germany

3 Dept. of Neuroradiology, University Hospital of Cologne, Cologne, Germany

4 Dept. of Neuroradiology, University Hospital of Aachen, Aachen, Germany

guidelines for the management of this particular situation are not available. Although substantial experience in the treatment of arteriosclerotic disease in the vertebrobasilar circulation has been accumulated over the last decades, only a limited number of case series have been published on modern ET for ABO with concomitant basilar artery stenosis, severe vertebral artery stenosis or occlusion, which presented very heterogeneous results [5–10]. This bi-institutional case series describes the clinical and radiological characteristics, frequency and technical aspects of ET as well as outcome in this challenging group of conditions and provides an outcome comparison with presumed embolic basilar occlusions.

Methods

Patients

This study was a retrospective analysis of the prospectively maintained stroke thrombectomy databases of two university stroke centers. The study included all consecutive patients undergoing mechanical thrombectomy from January 2013 until May 2017 for acute stroke due to basilar occlusion and either an underlying basilar artery stenosis of at least 70% or with a tendency to re-occlude or a significant vertebral artery stenosis (>70%) or occlusion (atherosclerotic group). Baseline demographics as well as relevant cardiovascular risk factors were recorded from the interdisciplinary stroke databases. In a second step, the identical database search was performed to retrieve all cases of acute basilar occlusion of presumed embolic origin (embolic group). All patients were evaluated by a neurologist on admission and the baseline National Institutes of Health Stroke Scale (NIHSS) as well as the modified Rankin scale (mRS) values at discharge were recorded. Patients were given systemic thrombolytic therapy according to national guidelines if presenting within 4.5 h from symptom onset and no contraindications were present.

Imaging

In all patients either computed tomography (CT) and CT angiography (CTA) or magnetic resonance imaging (MRI) including diffusion-weighted imaging (DWI) and MR angiography (MRA) were performed and confirmed acute basilar occlusion as well as additional relevant stenosis or occlusion in the posterior circulation which were recorded in the following detail: basilar artery (BA) occlusion (proximal basilar up to the anterior inferior cerebellar artery (AICA) origin, midbasilar up to superior cerebellar artery (SCA) origin, BA terminus, combined vertebrobasilar) vertebral artery stenosis/occlusion (V1–4). Posterior circulation (pc)-ASPECTS score on CT or MRI was evaluated as described previously [11].

Time Metrics and Outcome

Concerning time metrics the following parameters were recorded: onset to door time, door to groin time, procedural duration as well as onset to recanalization time. For patient outcome mortality, the NIHSS and mRS at discharge were recorded and outcome was dichotomized by mRS 0–2 as favorable and mRS 3–6 as unfavorable.

Endovascular Therapy

Treatment was performed with the patient under general anesthesia in all cases. Procedural details were left to the discretion of the treating neurointerventionalists and varied according to individual vascular anatomy as well as pattern of steno-occlusive disease. In one center the standard approach consisted of a Neuron MAX 088 guide catheter (Penumbra Inc., Alameda, CA, USA), which was advanced over a 5 F diagnostic catheter into the distal V2 segment. This allowed telescopic insertion of 5 F or 6 F aspiration catheters, such as SOFIA, SOFIA Plus (MicroVention, Aliso Viejo, CA, USA) or Penumbra MAX or ACE series aspiration catheters. In the other center a 6 F Envoy MPC (Codman Inc., Raynham, MA, USA) guiding catheter was placed in the distal V2 segment, followed by coaxial insertion of a 5 F SOFIA aspiration catheter or a DAC044 catheter (Concentric Medical, Mountain View, CA, USA). A large bore aspiration catheter was advanced over a microwire and microcatheter up to the occlusion either as stand-alone a direct aspiration first-pass technique (ADAPT) or after passing the vertebrobasilar occlusion(s) with the microcatheter and the delivery of a stent-retriever. Mechanical thrombectomy was performed either with primary constant aspiration (ADAPT) or with a stent-retriever maneuver with concomitant distal aspiration. After successful thrombectomy significant fixed BA stenoses >70% or reoccluding stenoses were treated by angioplasty, either by balloon or stent percutaneous transluminal angioplasty (PTA). In selected cases, angioplasty was performed prior to thrombectomy in order to be able to advance the system to the ABO. Thrombectomy type as well as number of attempts were recorded. In the case of vertebral artery occlusion or significant stenosis (>70% dissected or ulcerated and the likely source of basilar embolism) different strategies were followed ranging from conservative therapy to balloon or stent angioplasty depending on the collateral status (relative sizing of both vertebral arteries, contralateral VA stenosis or occlusion, patency of the posterior communicating arteries, patency of the stenosis prior to distal thrombectomy, cause of the stenosis (arteriosclerosis vs. dissection) and preference of the operator).

Approach laterality ipsilateral ("dirty road") or contralateral ("clean road") to the vertebral stenosis or occlusion was recorded. Periprocedural antiplatelet management was also recorded and varied according to individual preferences, type of angioplasty performed, as well as situative factors, such as estimated size of the stroke, time elapsed since symptom onset, prior systemic rt-PA (recombinant tissue-type plasminogen activator) therapy, patient being medicated with aspirin, ADP receptor antagonists or anticoagulants for other reasons. Antiaggregation options included: intra-arterial or intravenous tirofiban, aspirin alone, aspirin and clopidogrel or systemic heparinization. Angiographic outcome was assessed by TICI (thrombolysis in cerebral infarction) scores and complications such as vessel perforation and symptomatic intracerebral hemorrhage were recorded.

Statistics

Data are reported as median and interquartile range (IQR). Univariate analyses were performed using the Mann-Whitney U-test and the Fisher's exact test where appropriate. Statistical significance was set at $p = 0.05$. SPSS software (SPSS 18, Chicago, IL, USA) was used for all analyses.

Results

Patients

Out of 157 patients treated with ET for acute BA occlusion between January 2013 and May 2017 in both institutions, 38 patients (24.2%) had associated underlying significant BA stenosis or upstream significant vertebral artery (VA) stenosis or occlusion and were included in this study. The baseline patient characteristics are shown in Table 1. The average NIHSS was 18. The most important cause of stroke according to the TOAST criteria (Trial of Org 10172 in Acute Stroke Treatment) in this selected group of patients was atherosclerosis (70.3%). Systemic thrombolysis was performed in 11 (28.9%) patients. In 14 patients the time of symptom onset was unknown (36.8%).

Imaging

Details on imaging characteristics are shown in Table 1. The PC-ASPECTS was 9 on average. Occlusion of the BA was more frequent at the vertebrobasilar junction and proximal to middle artery segments than distally. An underlying significant BA stenosis >70% or with observed recoil over minutes up to reocclusion was present in 9 (23.7%) patients. Additional significant steno-occlusive vertebral lesions were present in 31 patients (81.5%), located most commonly at the ostium (V1, 12 patients) and in the intradural segment (V4, 12 patients). Further angiographic findings are summarized in Table 2.

Table 1 Baseline patient and stroke characteristics ($n = 38$)

Age (years), median (IQR)	66 (56–74)
Female sex (*n*, %)	7, 18.4%
Arterial hypertension	86.8%
Atrial fibrillation	18.4%
Diabetes	28.9%
Chronic renal failure	8.1%
Peripheral arterial occlusive disease	37.8%
Hyperlipidemia	56.7%
Obesity	18.9%
Wake-up/unknown time window (*n*, %)	14, 36.8%
Bridging therapy (*n*, %)	11, 28.9%
Baseline NIHSS, median (IQR)	18 (10–25)
Onset-to-door time (min), median (IQR)	310 (229–413)
Door-to-groin time (min), median (IQR)	120 (69–167)
Onset-to-recanalization time (min), median (IQR)	500 (352–719)
Picture to puncture (min), median (IQR)	110 (75–149)
Stroke cause	
Arteriosclerosis	70.3%
Cardioembolism	13.1%
Dissection	7.8%
Undetermined	8.8%
pc-ASCPECTS (median, range) [a]	9, 4–10
BA thrombectomy (%)	24.2%

[a] 29x CT(computed tomography)/CTA(computed tomography angiography), 9x MRI(magnetic resonance imaging)/MRA(magnetic resonance angiography)

Time Metrics and Outcome

In Table 1 an overview on time metrics is given. To summarize, mean onset-to-door and onset-to-recanalization times were 356 ± 242 min and 543 ± 272 min. Picture to puncture and procedure time were 125 ± 88 and 102 ± 63 min, respectively.

Endovascular Therapy

Details on endovascular therapy are shown in Table 2. On average 2 ± 2.35 (mean ± SD, range1–9) thrombectomy maneuvers were performed in the BA, leading to a TICI score of 2b/3 in 86.8%. Thrombectomy was achieved with aspiration only (ADAPT technique) in 6 cases (15.8%) and with stent-retrievers in 32 cases (84.2%). If the primary ADAPT technique was unsuccessful, stent-retriever thrombectomy was performed. In 20 patients (52.6%) additional stent angioplasty was performed and in 2 patients balloon angioplasty only (5.3%). In 16 patients (42.1%) no angioplasty was performed. Reasons for the latter included: estimated

Table 2 Angiographic characteristics and endovascular procedure

Basilar occlusion site	
Combined vertebrobasilar	9
Proximal basilar	12
Mid-basilar	14
BA terminus	4
Underlying basilar artery stenosis (*n*, %)	9, 23.7%
Additional VA stenosis/occlusion (*n*, %) [a]	31, 81.5%
V1	12
V2	6
V3	4
V4	12
Bilateral VA occlusion (*n*, %)	6, 15.8%
Thrombectomy	
SR with distal aspiration (*n*, %)	32, 84.2%
ADAPT (*n*, %)	6, 15.8%
No. of maneuvers (mean ± SD, range)	2 ± 2.35, 1–9
Angioplasty	
Balloon angioplasty only (*n*, %)	3, 7.9%
Stent angioplasty (*n*, %)	20, 52.6%
No angioplasty (*n*, %)	16, 42.1%
Duration of procedure (min), median (IQR)	91 (55–135)
TICI	
0–2a	13.2%
2b–3	86.8%
Number of stents (in *n* patients)	1 (18), 2 (2)
Stented vessels	
VA (*n*, %)	11, 28.9%
BA (*n*, %)	9, 23.6%
Dirty road (*n*, %)	24, 77.4%
Clean road (*n*, %)	7, 22.5%
Complications	
Vessel perforation (*n*, %)	1, 2.6% (V4, fatal)
Vessel reocclusion	5, 13.2% (1 stented, 4 non-stented, 4 caused major stroke, 3 associated with mortality, 1 clinically silent)
Intraprocedural medication	
Aspirin (*n*, %)	10, 26.3% (500 mg ASA i.v.)
Heparin (*n*, %)	18, 47.4% (3000–5000 IU i.a./i.v.)
Tirofiban (*n*, %)	4, 10.5% (i.a./i.v.)
Clopidogrel (*n*, %)	4, 10.5% (300 mg, gastric tube)

[a] Multiple vessel segments possible
ASA acetylsalicylic acid, *BA* basilar artery, *VA* vertebral artery, *IU* international units, *SR* stent-retriever

major previously established ischemic infarction at the time of endovascular treatment with assumed relevant propensity of intracranial hemorrhage with platelet inhibition ($n = 14$) and dissecting stenosis ($n = 3$) (Fig. 1), which were considered to be unsuited for stenting, downgrading of a VA stenosis to <50% after aspiration of adherent thrombus ($n = 1$), and primary clean road approach in the case of VA stenosis or occlusion ($n = 1$) in a patient with well-preserved posterior circulation perfusion. Stent angioplasty was performed in the following vessel segments: V1 ($n = 5$), distal V3/pre-PICA V4/post-PICA V4/vertebrobasilar junction ($n = 6$) and BA ($n = 9$) (Fig. 2).

Concerning the procedural sequence in VA stenosis or occlusion cases ($n = 31$) BA thrombectomy was generally performed first; however, in 6 cases balloon PTA under aspiration protection had to be performed first to establish a working channel sufficient for advancing the catheter system, perform distal thrombectomy and then potentially perform stenting last ($n = 3$).

The clean road approach was used in 7 patients (22.5%) while the dirty road was used in 24 patients (77.4%). Out of the latter in 10 cases the VAs were either highly stenotic or occluded bilaterally (32.2%) and in 8 cases (25.8%) severe contralateral VA hypoplasia was present. In 6 cases (19.4%) with high-grade stenosis or occlusion of the intradural VA segment with PICA (posterior inferior cerebellar artery) compromise, in part extending into the BA, it was decided to treat more completely via the dirty road approach. Approach laterality was not categorized in the remainder of cases which consisted of BA stenosis without significant VA steno-occlusive lesions ($n = 6$). The following stents were used: in the vertebral artery: Enterprise (Codman Inc., Raynham, MA, USA), Palmaz (Johnson & Johnson, Warren, NJ, USA), Solitaire AB (eV3, Irvine, CA, USA), Acclino (Acandis, Pforzheim, Germany), Wallstent (Boston Scientific, Cork, Ireland), Adapt (Boston Scientific), Express (Boston Scientific) and in the basilar artery: Enterprise (Codman) and Pharos Vitesse (Codman).

The intraprocedural medication in the case of angioplasty consisted of heparin alone ($n = 10$) (3000–5000 IU i. v.), heparin (5000 IU i. v.) plus aspirin (500 mg i. v.) ($n = 3$), aspirin alone ($n = 2$) (500 mg i. v.), aspirin (500 mg i. v.) plus clopidogrel (300 mg per nasogastric tube) ($n = 2$), heparin (5000 IU i. v.) plus aspirin (500 mg i. v.) plus clopidogrel (300 mg p. o.) ($n = 1$), or continuous tirofiban infusion i. a. or i. v. which was switched to aspirin (100 mg p. o.) and clopidogrel (600 mg p. o.) after a control CT, 22 h post treatment with 2 h overlapping the tirofiban infusion ($n = 4$).

Complications occurred in six patients (15.8%) and consisted of one intradural vertebral artery perforation during balloon angioplasty resulting in a fatal SAH (subarachnoid hemorrhage) as well as five vertebrobasilar reocclusions. These occurred in the following locations and circum-

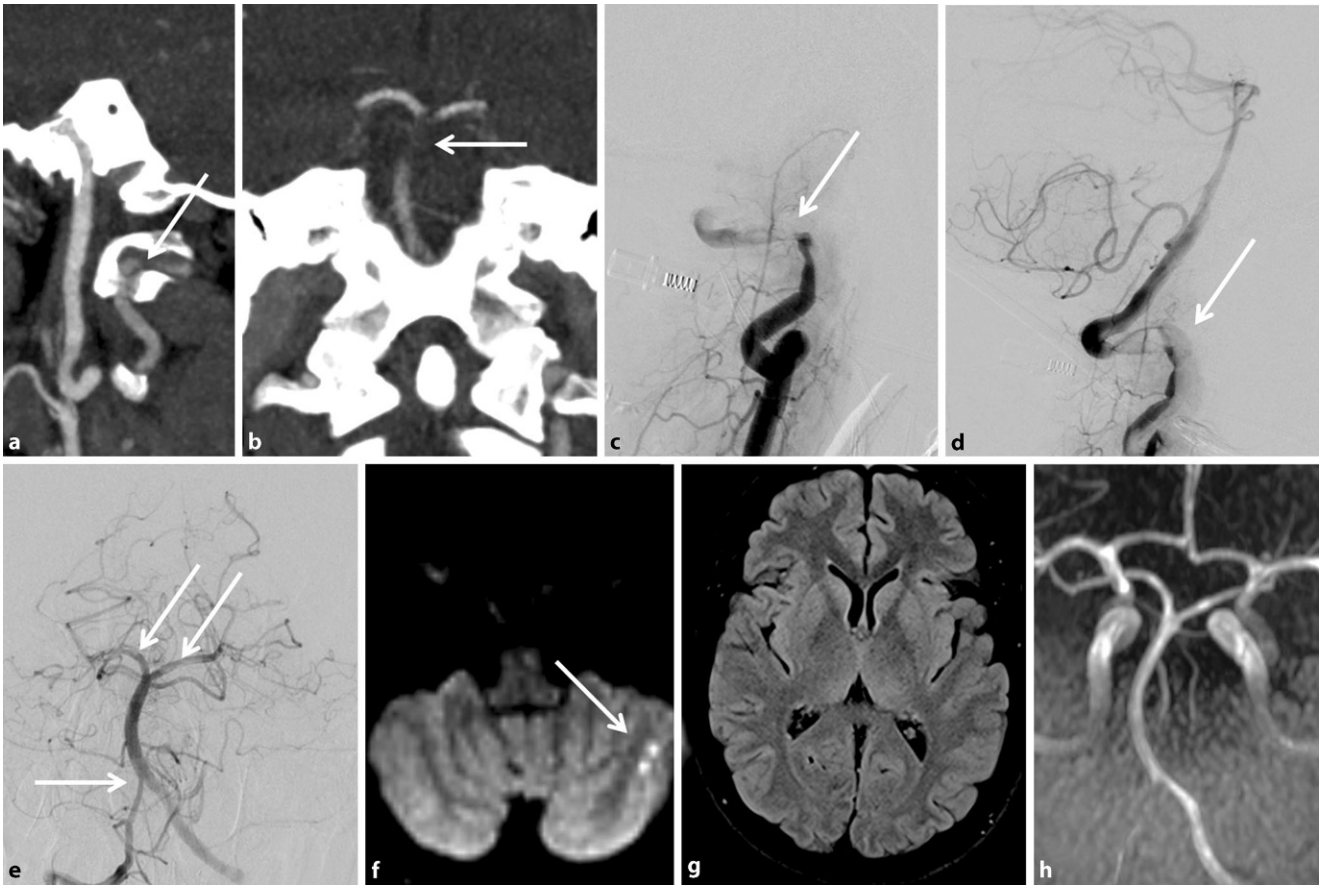

Fig. 1 36-year-old male with spontaneous nuchal pain and intermittent neurological symptoms, deteriorating to coma in the emergency room. **a** CTA shows a high-grade stenosis of the left dominant vertebral artery V3 segment due to dissection (*arrow*) and **b** an embolic distal basilar artery occlusion (*arrow*). **c** Lateral digital subtraction angiography (DSA) shows the dissection in V3/VA (*arrow*) and impaired filling of the artery. **d** After passing the dissection with a 6F SOFIA catheter under applying of manual aspiration and an additional ADAPT thrombectomy maneuver, complete recanalization could be achieved, while the dissected V3 segment was left untreated (*arrow*). The patient was heparinized and given aspirin 100 mg/d permanently. **e** DSA in posterior-anterior view after injection of the right VA shows complete recanalization of the BA and posterior cerebral arteries (PCA) (*arrows*). **f** Follow-up MRI after 24 h shows minimal cerebellar infarctions in the diffusion weighted image (*arrow*), while the cerebrum did not exhibit additional ischemia (**g**). **h** Time of flight (TOF) angiography shows full patency of the BA and PCAs. The patient woke up neurologically intact, experienced a short TIA 1 h prior to the MRI with complete resolution of symptoms and has since then been asymptomatic (NIHSS 0, mRS 0)

stances: 3 BA reocclusions (1 after stenting, 1 after balloon angioplasty only, 1 after thrombectomy only), 1 V1 segment reocclusion (after balloon angioplasty only) and 1 V4/BA reocclusion (after passage of aspiration catheter only): four reocclusions caused major stroke, in three cases associated with mortality, whereas one reocclusion remained clinically silent.

Patient Outcome

Of the patients 6 (15.8%) had a favorable outcome as defined by mRS 0–2 whereas 32 (84.2%) had an unfavorable outcome as shown in Table 3. The in-hospital mortality was 36.8% (14 patients) and included 7 patients in both the stented and the non-stented group.

Comparison of patients with ABO and ABO+

During the same time 120 patients with acute embolic BA occlusions were treated by our institutions. A detailed comparison of both groups is given in Table 4. To summarize, NIHSS, recanalization results, in-hospital mortality and mRS at 90 days did not differ between the two groups. The procedural duration was significantly longer in the ABO group with additional steno-occlusive disease (91 min vs. 49 min).

Discussion

The purpose of this retrospective study was to describe procedural aspects, safety and outcome of a multimodal en-

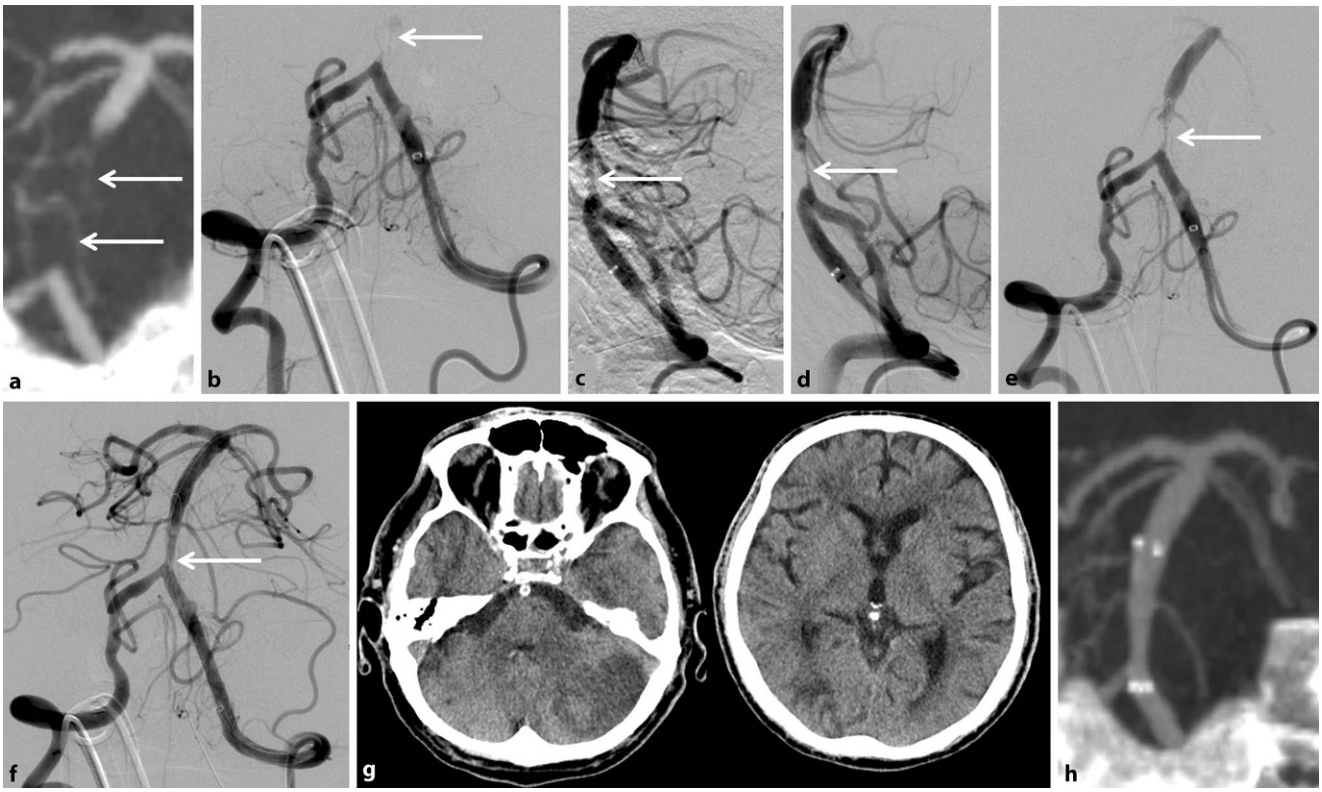

Fig. 2 **a** TOF angiography shows proximal to mid-basilar occlusion in a 66-year-old male with episodic TIAs for 2 weeks. **b** Angiographically confirmed proximal basilar artery occlusion. **c** After primary manual aspiration with a SOFIA 6 F catheter the angiographic run shows both recanalization of the BA and an underlying stenosis (*arrow*), which shows **d**, **e** significant recoiling or reclotting within the following minutes (*arrows*). **f** After reocclusion and reaspiration (not shown), a tirofiban bolus was infused intra-arterially and for basilar artery stenosis angioplasty was carried out with a 4 × 22 mm Enterprise stent (*arrow*) which was not postdilated. **g** Follow-up CT imaging after 24 h shows limited infarctions in the cerebellum and the right occipital lobe and no hemorrhage. **h** 24 h follow-up CTA shows patency of the stent. After imaging control, the patient was treated with 100 mg aspirin and 600 mg clopidogrel and tirofiban was stopped 2 h later

dovascular approach including modern thrombectomy techniques in 1) ABO with underlying BA stenosis or 2) ABO due to relevant stenosis or acute occlusion of a vertebral artery with thromboembolism. The role of interventional ET in these clinical situations is not yet clear and in particular, data of mechanical thrombectomy in conjunction with balloon or stent angioplasty are still limited to small single center case series [5, 6, 12, 13]. Furthermore, procedural aspects concerning revascularization strategies, sequence and technique in this challenging group of serious conditions have only sparsely been evaluated or discussed in the literature.

Our bicentric case series of 38 patients represents one of the largest studies with modern thrombectomy devices concerning these rare but clinically important constellations of vascular occlusion. All thrombectomy procedures in this series were performed using latest generation distal aspiration catheters alone (ADAPT technique, 6/38, 15.8%) or in combination with stent-retrievers (32/38, 84.2%).

In ABO with underlying BA stenosis we favor the endovascular approach through the dominant patent vertebral artery. In cases of concomitant tandem vertebrobasilar occlusions no guidelines exist as to which vascular approach should be favored. We conceptionally favor the clean-road access through the unaffected vertebral artery if its diameter permits access. We consider this approach to be less prone to distal thromboembolism and constitutes the fastest and safest route to achieve BA recanalization; however, in real life, the approach via the stenosed or acutely occluded VA, the so-called dirty road is imperative in the majority of cases (77% in this study) due to frequent contralateral VA hypoplasia, chronic occlusion, bilateral steno-occlusive disease or the fact that the ipsilateral VA stenosis represents a potential source of further thromboembolism if left untreated [5]. In this study it could be shown that depending on individual patient anatomy and pathology both the clean road and the dirty road approach are technically feasible and that the latter is not an insurmountable obstacle since we were able to pass an underlying stenosis or occlusion in every case ($n = 24$).

The role of interventional treatment strategies in symptomatic vertebrobasilar stenotic disease has not yet been firmly established and no randomized controlled data are available for the particular ABO thrombectomy situation

Table 3 Clinical outcome of patients

Favorable outcome (mRS 0–2)	6, 15.8%
Unfavorable outcome (mRS 3–6)	32, 84.2%
Mortality	36.8% (14 patients)
Symptomatic cerebral hemorrhage (*n*, %)	1, 2.6%

[14–16]. In our study the antiplatelet regimen and the decision between stent and balloon angioplasty were at the surgeons discretion. Periprocedural complications occurred in 6 patients (15.8%). In one patient a balloon PTA of the stenosed intradural vertebral artery led to vessel perforation with subsequent fatal SAH. In 5 cases we detected vertebrobasilar reocclusion after initially successful recanalization. Remarkably, 4/5 reocclusions (80%) were recorded after blunt passage of the aspiration catheter or balloon PTA solely without additional stenting whereas only a single case occurred after stent PTA (BA reocclusion $n=3$, 1 following stenting, 1 following balloon angioplasty only and 1 following thrombectomy only, V1 $n=1$, following balloon-PTA only, V4/BA after passage of aspiration catheter only). Since no post-procedural sICH (symptomatic intracerebral hemorrhage) were detected irrespective of any antiplatelet regimen, vertebrobasilar stent PTA might be a more durable alternative to balloon angioplasty, if required, with an acceptable safety profile [17]. In vertebrobasilar tandem occlusions the order of action is not standardized und guidelines do not exist. Analogous to the treatment of anterior circulation tandem occlusions we favor the retrograde approach, i.e. TE of the ABO first followed by definite stent or balloon PTA of the stenosed or occluded vertebral artery segment in order to achieve faster cerebral reperfusion [18]. The antegrade approach with primary balloon or stent PTA followed by TE of the ABO might be a viable alternative if the stenosed/occluded vertebral artery segment cannot be directly penetrated by the guiding catheter or distal access catheter in the initial step. Both approaches have disadvantages. Secondary VA angioplasty after successful initial TE in the retrograde approach bears the risk of VA-BA re-embolization. Secondary TE after successful initial stent PTA of the VA bears the risk of 1) dislocation of the stent while probing it with the guiding or aspiration catheter and 2) entrapment of the stent retriever in the mesh of the implanted stent if the stent retriever is not pulled back completely into the aspiration catheter during the thrombectomy maneuver.

Despite favorable revascularization rates of 86.8% TICI 2b/3 and a moderate procedural complication rate (15.8%), the rate of good clinical outcome, mRS 0–2 at 90 days follow-up is low (6/38, 15.8%) and the mortality is high (14/38, 36.8%). These sobering results reflect the severity of sequelae that follow major vessel vertebrobasilar stroke per se, even after successful endovascular recanalization therapy. In part this may be explained by the difficulty in rapidly diagnosing posterior circulation stroke and the subsequent delay in transferring patients for TE (both centers are supraregional referral centers for thrombectomy), reflected in long mean onset to door times of 356 min ± 242 min. Furthermore, we have to state that mean procedural times of 102 ± 63 min originate from the high level of complexity of such combined procedures but also bear potential for improvement. Early initiation of treatment has been identified as the most important factor for a good outcome in acute vertebrobasilar occlusions [19].

Table 4 Comparison of patients with ABO only and ABO with additional severe steno-occlusive vascular lesions (ABO+)

	ABO+	ABO only	*p-value*
n	38	116 [c]	–
Age (years), median (IQR)	66 (56–74)	76 (63–82)	*0.002*[a]
Female sex, *n* (%)	7 (18.4%)	57 (49.1%)	*0.001*[b]
Baseline NIHSS, median (IQR)	18 (10–25)	12 (8–22)	*0.077*[a]
Rate of thrombolysis, *n* (%)	11 (28.9%)	55 (47.4%)	*0.058*[b]
Onset-to-recanalization time (min), median (IQR)	500 (352–719)	329 (241–450)	*0.001*[a]
Duration of angiography (min), median (IQR)	91 (55–135)	49 (28–93)	*<0.001*[a]
TICI 2b/3, *n* (%)	33 (86.8%)	97 (83.7%)	*0.798*[b]
In-hospital mortality, *n* (%)	15 (39.5%)	40 (34.8%)	*0.687*[b]
mRS at discharge, median (IQR)	5 (3–6)	5 (3–6)	*0.821*[a]
mRS 0–2 at discharge, *n* (%)	6 (15.8%)	23 (24.2% [d])	*0.357*[b]

[a]Mann-Whitney U-test; exact, two-sided *p*-value given
[b]Fisher's exact test, two-sided *p*-value given
[c]Data from 4 patients missing
[d]Valid percentage, 21 missing
ABO acute basilar occlusion, *mRS* modified Rankin Scale, *NIHSS* National Institute of Health Stroke Scale, *TICI* thrombolysis in cerebral infarction

Our study results are grossly in line with the results from the ENDOSTROKE registry concerning baseline demographics, NIHSS (20 vs. 18 in our study) and revascularization rates (TICI 2b/3 79% vs. 86.6%), whereas in-hospital mortality (29% vs. 39.5%) and favorable outcome (mRS0-2 34% vs. 15.8%) were worse in our atherosclerosis group [20]. Concerning our two groups (atherosclerosis vs. embolism) descriptive embolism patients fared better albeit this was not statistically significant (in-hospital mortality (34.8% vs. 39.5%) and favorable outcome (mRS0–2 24.2% vs. 15.8%).

Our study has several limitations, the major ones being inherent to the retrospective descriptive study design as well as the small and unevenly distributed case numbers, the latter prohibiting multivariate analyses; however, since we are not aware of larger or prospective studies for this particular clinical condition, this work represents the highest level of evidence so far. Furthermore, we cannot make any definitive statements on the effects of procedural aspects on outcome since the numbers are too low and there are no control groups. Concerning the etiology of stroke we acknowledge clinical situations in which an unambiguous assignment may be problematic, e. g. as to whether occlusion of a severely stenotic vessel is caused by a cardiac embolism or an acute plaque rupture in patients with concomitant atrial fibrillation; however, both conservative and ET remain largely unaffected by this insecurity. Individual cases varied considerably concerning stroke duration and severity as well as individual patterns of steno-occlusive disease and posterior circulation anatomy. The endovascular procedures were not homogeneous but varied significantly according to the performing neurointerventionalist. A significant proportion of cases consisted of extended time window or wake-up stroke. Furthermore, we have to acknowledge that the average door-to-groin time of about 2 h in this study dating back to patients in 2013 are beyond the current time recommendations and efforts have recently been undertaken to improve this shortcoming. Concerning the safety of the clean versus the dirty road approach, we are well aware that the rate of embolism of small, non-occluding thrombus fragments originated from the untouched dirty road cannot be assessed and reliably excluded on follow-up imaging due to the fact that distinction of periprocedural thromboembolism during the thrombectomy and the aforementioned potential thrombus origin cannot be made definitively; however, BA rethrombosis was not recorded in any case of the clean road approach and an untreated dirty road lesion. These limitations have to be kept in mind when interpreting our results.

To conclude, ABO with underlying BA stenosis and ABO due to relevant stenosis or acute occlusion of a VA with thromboembolism represent a devastating medical emergency with very poor prognosis, if left untreated. In our bicentric series we could show that endovascular treatment is technically feasible, effective and shows a satisfactory safety profile. Specific procedural strategies apply in this unique clinical scenario according to individual patient pathology and anatomy characteristics.

Compliance with ethical guidelines

Conflict of interest E. Siebert, G. Bohner, S. Zweynert, V. Maus, A. Mpotsaris, T. Liebig and C. Kabbasch declare that they have no competing interests.

Ethical standards The study was approved by the institutional ethics committee in Berlin. According to the guidelines of the local ethics committee in Cologne, no approval was necessary for conducting this retrospective, observational study.

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