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CLINICAL INVESTIGATION STROKE/NEUROINTERVENTIONS

Endovascular Treatment of Ruptured Middle Cerebral Artery Bifurcation Aneurysms. A Retrospective Observational Study of Short- and Long-Term Follow-Up

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Abstract
Purpose With the introduction of new devices and the development of approved devices, endovascular techniques are more and more considered as a treatment option for middle cerebral artery aneurysms (MCA). In this study, we present data on ruptured MCA aneurysms that were treated endovascularly in our hospital.
Material and Methods In a retrospective case series of ruptured MCA bifurcation aneurysms, 118 (94%) cases were managed endovascularly between May 2008 and July 2017. Most were managed with coiling (= 62) and the remaining were managed with stent-assisted-coiling (= 35) and endovascular flow disruptor (WEB-device) (= 21). We measured the clinical outcome at the time of discharge and long-term follow-up on the modified Rankin Scale (mRS) and evaluated the rates of periprocedural complications and retreatment.
Results A good clinical outcome (mRS 0–2) at discharge was achieved in 58.5% of these cases. Mortality rate was 19.5%. Nine aneurysms required retreatment. Eighty-three percent demonstrated a good clinical outcome at long-term follow-up (mRS 0–2). In total, 6 (5.1%) procedure-related complications and 10 (8.5%) disease-related complications occurred. No significant difference between reintervention, complications or outcome was found between the employment of different devices ($P > 0.05$). Endovascular treatment of ruptured MCA aneurysms at our practice showed similar morbidity and mortality to data published about surgical clipping.
Conclusion The endovascular device evolution permits a feasible and safe treatment of ruptured MCA bifurcation aneurysms. Endovascular treatment can therefore be considered as an alternative treatment option to microsurgery for this type of aneurysm.

Keywords Middle cerebral artery (MCA) bifurcation aneurysms · Woven-endo-bridge (WEB) device · Stent-assisted coiling (SAC) · Coiling · Ruptured aneurysms

Abbreviations

WEB-Device	Woven-endo-bridge device
RROC	Raymond-Roy classification
mRS	Modified Rankin Scale
H&H	Hunt and Hess Scale
SAC	Stent-assisted-coiling
BAC	Balloon-assisted coiling
ICH	Intracerebral hemorrhage
SAH	Subarachnoid hemorrhage
EVT	Endovascular treatment

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Introduction

Endovascular treatment (EVT) by means of coiling has been the preferred choice of treatment for ruptured intracranial aneurysms since 2002 [1]. Despite the high rate of incompletely occluded aneurysms following EVT, the rehemorrhage rate remained insignificant, as suggested by the cerebral aneurysm re-rupture after treatment study [2]. The best way, however, to treat ruptured middle cerebral artery (MCA) aneurysms is still controversial, as the International subarachnoid aneurysm trial (ISAT) study underrepresented MCA aneurysms and the assessments to retreat incomplete occlusion were mainly subjective.

Thus far, the choice of treatment for MCA aneurysms is microsurgical clipping in most centers [3]. It is probably the preferred choice due to the well-established surgical access, alongside the favorable anatomical and hemodynamic features of the MCA bifurcation aneurysms [4]. It also provides a more definitive exclusion of the aneurysm [3]. Moreover, other methods such as EVT microstents for broad-neck aneurysms may potentially induce postprocedural complications due to the necessity of dual platelet inhibition. Nonetheless, recent publications suggest that both methods demonstrate good clinical outcomes and low complication rates [5, 6].

In this article, we present data on 9 years of endovascular treatment and long-term outcome of ruptured MCA bifurcation aneurysms performed by four neurointerventionalists at a university hospital and a community hospital. Treatment of these aneurysms consisted of various different techniques such as coiling, stent-assisted-coiling (SAC) and endosaccular flow disruptor.

Methods

Data Collection and Study Population

The data were collected from the electronic medical records of two hospitals. We identified the patients who were treated by endovascular means for ruptured MCA bifurcation aneurysms between May 2008 and July 2017 and analyzed their data, retrospectively. There was no treatment failure or crossover from endovascular therapy to surgical clipping during initial treatment.

The patients were treated by four interventional neuroradiologists from the neuroradiology department of Augsburg university hospital. The aneurysm size was determined by the greatest diameter of the aneurysm.

Endovascular Procedure

The EVTs were divided into three groups. Principal coiling group, which included target coils (Stryker neurovascular, Fremont, CA, USA), Microplex or hydrogel-coated coils (MicroVention Terumo, Aliso Viejo, CA, USA)) and SAC, which included neuroform/neuroform atlas (Stryker Neurovascular, Fremont, USA) and LVIS/LVIS Jr (Microvention—Terumo, Tustin, CA, USA)). Lastly, treatment via woven-endo-bridge device (WEB device; MicroVention—Terumo, Tustin, CA, USA).

We started the procedure with prophylactic measures. Upon placing the first coil, we administered an intravenous dose of heparin (5000 IU) to prevent thromboembolic events. In case of SAC, as it has been the protocol at our hospital since 2012, the patients received a 100 mg dose of intravenous acetylsalicylic acid and a bolus of tirofiban (Aggrastat®, Correvio International Sàrl) (bolus 25 µg/kg body weight, infusion 9 µg/kg body weight/hour for 12 h). Four hours before the tirofiban infusion was about to finish, we administered a loading dose of either 600 mg clopidogrel (Plavix®, Sanofi-Aventis) or 180 mg ticagrelor (Brilique® AstraZeneca). The platelet inhibition was tested using a platelet function test. Following the procedure, the patient received a dual antiplatelet therapy, which consists of 100 mg of acetylsalicylic acid for at least 6 months and ADP receptor antagonist (clopidogrel 75 mg once a day or ticagrelor 90-mg two times daily) for 6 weeks. Patients in the WEB group received a single form of prophylaxis, 100 mg of acetylsalicylic acid for 6 weeks. In case of an insufficient platelet inhibition under clopidogrel (75 mg), patients received ticagrelor two daily doses of 90 mg alternatively.

Outcome and Follow-Up

Correct device placement without any intraluminal protrusions (coil and WEB device) was classified as technical success and verified via digital subtraction angiography. Clinical outcome was evaluated at the time of discharge and on follow-ups using the modified Rankin scale (mRS). First follow-up was routinely scheduled, as per our hospital follow-up protocol, 3–6 months after the procedure. On the first follow-up, we performed contrast-enhanced magnetic resonance angiography (CE-MRA), time-of-flight MRA (TOF-MRA) and in most cases digital subtraction angiography to evaluate the aneurysm status and determine if further treatment was required. If no treatment was necessary, then MRA was then performed on each of the upcoming follow-ups at 18 months, 3 years and 5 years.

Complications and Retreatment

Electronic medical records were screened for complications. In case of relevant recanalization, the interventionalist looked at each case closely and decided for reintervention on a case-by-case basis. The recanalization was classified according to the Raymond-Roy classification (RROC) [7].

Statistical Analysis

Statistical analysis was performed using SPSS (release 25.0.0, IBM, Armonk, NY, USA). Continuous data were expressed as means ± standard deviation (SD). Categorial variables were compared with the use of Chi-square or Fisher–Freeman–Halton tests, as appropriate. After verification of non-Gaussian distribution of every parameter by the Shapiro–Wilk test, we opted for a nonparametric test (Kruskal–Wallis-*H* test) to analyze differences between the three independent samples. Post hoc and Dunn–Bonferroni tests were used to differentiate the groups. A two tailed *P*-value of less than 0.05 was considered to indicate statistical significance.

Ethical Standards and Patient Consent.

The study was approved by the ethics committee for both sites at each trial site; due to the retrospective character of data collection and analysis, written informed consent was waived.

Results

A total of 1184 aneurysms were treated at Augsburg university hospital ($n = 1009$) and Vogtareuth Hospital ($n = 175$) between May 2008 and July 2017. Patients who were treated with other devices such as flow diverters or remodeling balloons were excluded from the study due to the low caseload. Exclusion criteria also included aneurysms that required emergency evacuation and simultaneous clipping as a result of space-occupying intracerebral hemorrhage ($n = 7$); aneurysms located anatomically outside the MCA bifurcation (proximal M1 or distal M2–M4 segments); and, lastly, unruptured aneurysms. Of those who remained, 118, treated with coiling, SAC and WEB device, were included in the study, corresponding with nearly all ruptured MCA aneurysms (94.1%) during this period being treated by the same neuroradiologists from Augsburg university hospital (see Fig. 1). The demographic data are provided in Table 1.

The majority of all treated aneurysms (72.9%) were between 2 and 7 mm in size. Wide-necked aneurysms were commonly treated by SAC or WEB device and, to a lesser extent, by simple coiling. No significant difference in dome-to-neck ratio was found between the aneurysms treated by WEB device (2.7 ± 0.8), coiling (3.1 ± 1.1) or SAC (3.5 ± 2.0) (Table 2). Thirty-five aneurysms were treated by SAC of which 28 were treated by single stenting and 7 by double stenting.

Two aneurysm ruptures occurred following the intervention causing the death of one patient. Other complications were procedure-related, as thromboembolic events ($n = 3$, 2.5%), that were treated with GP-IIb/IIIa-Inhibitors, and disease-related as the severe vasospasms ($n = 9$, 7.6%) which occurred during hospitalizations. The vasospasms were treated with spasmolytic agents; however, they still caused new infarctions and led to two deaths. The rest of the patients demonstrated good clinical outcome (mRS $\leqq$ 2) (Table 3). Initial median Fisher score was 3 ± 0.7.

Nine recurrent aneurysms at follow-up needed retreatment. The majority were in the first 6 months, and one was after 12 months. Of the WEB device-treated aneurysms, two (9.5%) required retreatment; of the SAC and coil-treated aneurysms, this was 3 (8.6%) and 4 (6.5%), respectively (Table 4). Three of the nine patients with recurrent aneurysm requested surgical reintervention but the remaining 6 accepted EVT for retreatment. Four deaths occurred during the follow-up period: One resulted from a severe hypertensive hemorrhage (3 months after discharge); another resulted from a hemorrhage secondary to an ischemic infarct in a territory not related to the treated aneurysm (24 months after discharge); and two were due to pulmonary embolisms (96 and 108 months after discharge). No rehemorrhages of the initial treated aneurysms occurred. Follow-up data at discharge was available for all surviving patients (95/118). Long-term follow-up data were collected from 76/95 cases and included 8/9 cases after reintervention. Latest follow-up periods were after 3–6 months in 13 cases, 6–24 months in 14 cases, 24–48 months in 18 cases, 48–72 months in 12 cases, 72–96 months in 12 cases and after 108 months in 7 cases.

Discussion

In this article, we present our data on treatment and long-term outcome of endovascular approach for ruptured MCA aneurysms. Approximately, 25% (283/1184) of all encountered aneurysms treated at Augsburg university hospital and Vogtareuth hospital by an endovascular approach were either ruptured or unruptured MCA aneurysms—in line with the published literature (14–29%) [1, 8]. Potential selection bias for easily accessible aneurysms was almost excluded as nearly all MCA bifurcation aneurysms (94%) were treated with an endovascular technique regardless of morphology or vessel anatomy. The main reason for a non-endovascular approach was surgical emergencies in which evacuation of space-occupying intracerebral hemorrhage was required—as was the case in seven ruptured MCA bifurcation aneurysms evidenced on

Fig. 1 Study design

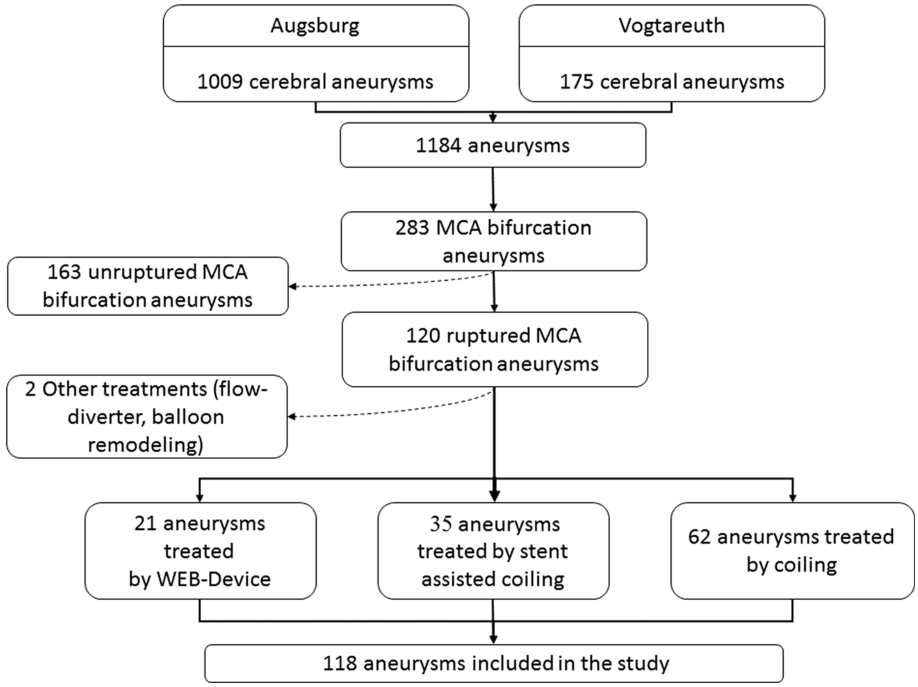

Table 1 Demographic data

	Total (*n* = 118)	Coiling (*n* = 62)	SAC (*n* = 35)	WEB device (*n* = 21)
Age (years) [mean ± SD]	51.9 ± 10.9	50.3 ± 10.9	53.9 ± 11.6	53.6 ± 9.5
Sex [*n*]				
Male	25 (21.2%)	11 (17.7%)	9 (25.7%)	5 (23.8%)
Female	93 (78.8%)	51 (82.3%)	26 (74.3%)	16 (71.2%)
Hypertension [*n*]	65 (55.1%)	29 (46.8%)	21 (60.0%)	15 (71.4%)
Diabetes [*n*]	9 (8.5%)	3 (4.8%)	6 (17.1%)	0 (0.0%)
Current or former smoking [*n*]	39 (33.1%)	23 (37.1%)	10 (28.6%)	6 (28.6%)
GCS at admission [median ± SD]	13.0 ± 4,5	14.0 ± 4.2	12.0 ± 4.9	10.0 ± 4.8
H&H at admission [median ± SD]	2.0 ± 1.2	2.0 ± 1.2	2.0 ± 1.2	3.0 ± 1.3

cranial computed tomography with midline shift, perifocal edema and intraventricular hemorrhage.

Endovascular Techniques

Following the recommendation of ISAT in 2002 and its endorsement of EVT [1], stent designs have drastically improved to allow for stenting of smaller vessels, new devices such as intrasaccular and extrasaccular flow diverters started to appear on the market, and the coils were upgraded to have bioactive and softer structure. These developments advanced the endovascular approach to manage a wide variety of MCA aneurysms. However, despite these advancements, the mortality rates from subarachnoid hemorrhage remained high in EVT and posed a serious challenge.

The present study demonstrates remarkable results of mortality rates that are notably lower than rates of previous data on spontaneous subarachnoid hemorrhage (19.5% vs. 26%) [9]. However, when compared with rates following EVT of ruptured aneurysms, the results were considerably high (19.5% vs. 7.5%) [1]. This fluctuation in the results can be explained by the following factors. One major reason may be the underrepresentation of MCA aneurysms in the ISAT and as a result a distortion of the results. Secondly, it is difficult to determine the extent of selection bias, which may have led to including less severe cases in the ISAT and shape the outcome [10]. Thirdly, the high mortality rate resulted to a greater extent from the large

Table 2 Aneurysm characteristics before treatment

	Total (n = 118)	Coiling (n = 62)	SAC (n = 35)	WEB-device (n = 21)	P-value
Aneurysm size [n]					
2 mm–7 mm	86 (72.9%)	51 (82.3%)	21 (60.0%)	14 (66.7%)	0.111***
8 mm–15 mm	27 (22.9%)	10 (16.1%)	10 (28.6%)	7 (33.3%)	
16 mm–25 mm	2 (1.7%)	1 (1.6%)	1 (2.9%)	0 (0.0%)	
> 25 mm	3 (2.5%)	0 (0.0%)	3 (8.6%)	0 (0.0%)	
Aneurysm neck (in mm) [mean ± SD]	3.3 ± 1.2	2.9 ± 1.1	3.7 ± 1.4	3.6 ± 0.8	0.001*
Aspect ratio (dome height/neck width) [mean ± SD]	3.2 ± 1.4	3.1 ± 1.1	3.5 ± 2.0	2.7 ± 0.8	0.271*
Side [n]					
Right	66 (55.9%)	36 (58.1%)	17 (48.6%)	13 (61.9%)	0.561**
Left	52 (44.1%)	26 (41.9%)	18 (51.4%)	8 (38.1%)	
Partially thrombosed [n]	0 (0.0%)	0 (0.0%)	2 (5.7%)	0 (0.0%)	0.117**

*Kruskal–Wallis-H test; **Fisher–Freeman–Halton test; ***Chi-Square.

Table 3 Complications

	Total (n = 118)	Coiling (n = 62)	SAC (n = 35)	WEB-device (n = 21)
Procedure-related complication [n]	6 (5.1%)	3 (4.8%)	3 (8.6%)	0 (0.0%)
Intraprocedural rupture	2 (1.7%)	1 (1.6%)	1 (2.9%)	0 (0.0%)
ICA dissection	1 (0.8%)	1 (1.6%)	0 (0.0%)	0 (0.0%)
Thromboembolic event	3 (2.5%)	1 (1.6%)	2 (5.7%)	0 (0.0%)
Disease-related complication [n]	10 (8.5%)	6 (9.7%)	4 (11.4%)	0 (0.0%)
Vasospasms	9 (7.6%)	6 (9.7%)	3 (8.6%)	0 (0.0%)
Seizure	1 (0.8%)	0 (0.0%)	1 (2.9%)	0 (0.0%)
Total (n = 118)	19 (16.1%)	9 (14.5%)	9 (25.7%)	1 (4.8%)

proportion of the aneurysms that were treated by SAC—a device mostly used for difficult aneurysms [11]. Treatment of MCA bifurcation aneurysms especially lead to higher incidence of complications [12]. A major reason might be due to the lack of antiplatelet activity assessment, which might lead to a higher incidence of in-stent thrombosis [13]. However, that was not the case among our patients (see Table 3), probably due to the consequent use of a platelet function test.

We encountered a few complications during EVT. In addition to hemorrhagic events and intraprocedural ruptures, three thromboembolic events occurred while intervening without specific distribution, but were immediately treated with intravenous GP-IIb/IIIa-Inhibitors. This low number might be a result of the prophylactic intravenous dose of Tirofiban, which we favored over Clopidogrel [14, 15]. Other complications were mainly postprocedural and had a disease-related etiology. A good example of these complications is relevant vasospasms, which occurred in nine patients (7.7%). Vasospasms are more often reported in aneurysmal SAH, especially in MCA aneurysms [16]. Nearly all vasospasms (8/9) were treated with intraarterial injection of nimodipine via microcatheter, and one patient was treated with intraarterial papaverine. The dose of nimodipine varied, depending on the severity of the vasospasms: 3 mg per territory (right anterior circle of Willis, left anterior circle of Willis or posterior circle of Willis) but never exceeded 6 mg per treatment or per patient. All nine (7.7%) postprocedural-relevant vasospasms finally led to cerebral infarction.

RROC has become the widely used classification system for evaluating aneurysms after intervention [7]. This classification, however, is only applicable to certain techniques such as coiling or SAC. For instance, when we applied RROC directly after the employment of devices, the occlusion rate differed between the patients treated with WEB device and the patients treated with coiling and SAC. Especially after WEB device employment, the aneurysm perfusion may be classified falsely high by RROC as the secondary thrombosis, and final occlusion of the aneurysms

Table 4 Follow-ups, clinical outcome and retreatment

	Total (*n* = 118)	Coiling (*n* = 62)	SAC (*n* = 35)	WEB device (*n* = 21)	*P*-value
RROC directly postprocedural	–	–	–	–	0.000*
RROC 1 [*n*]	76 (64.4%)	48 (77.4%)	27 (77.1%)	1 (4.8%)	–
RROC 2 [*n*]	30 (25.4%)	12 (19.4%)	7 (20.0%)	11 (52.3%)	–
RROC 3 [*n*]	12 (10.2%)	2 (3.2%)	1 (2.9%)	9 (42.9%)	–
Clinical outcome at discharge [*n*]	–	–	–	–	0.232*
mRS ≦2	69 (58.5%)	40 (64.5%)	15 (42.9%)	14 (66.7%)	–
mRS 3–5	26 (22.0%)	13 (20.1%)	9 (25.7%)	4 (19.0%)	–
mRS 6	23 (19.5%)	9 (14.5%)	11 (31.4%)	3 (14.3%)	–
Follow-up period(in months)[mean ± SD]	36.3 ± 36.1	47.9 ± 37.5	27.6 ± 36.0	16.2 ± 18.1	0.007*
Retreatment [*n*]	9 (7.6%)	4 (6.5%)	3 (8.6%)	2 (9.5%)	0.724**
Clinical outcome at latest follow-up [*n*]	–	–	–	–	0.098**
mRS 0	48 (63.2%)	27 (61.4%)	13 (65.0%)	8 (61.5%)	–
mRS 1	11 (14.5%)	7 (15.9%)	0 (0.0%)	4 (30.8%)	–
mRS 2	4 (5.3%)	4 (9.1%)	0 (0.0%)	0 (0.0%)	–
mRS 3–5	9 (11.8%)	4 (9.1%)	4 (20.0%)	1 (7.7%)	–
mRS 6	4 (5.3%)	2 (4.5%)	2 (10.0%)	0 (0.0%)	–
Occlusion rate at latest follow-up [*n*]	–	–	–	–	0.345*
RROC 1 [*n*]	66 (86.8%)	40 (90.1%)	16 (80.0%)	10 (83.3%)	–
RROC 2 [*n*]	6 (7.9%)	3 (6.8%)	2 (10.0%)	1 (8.3%)1	–
RROC 3 [*n*]	4 (5.3%)	1 (2.3%)	2 (10.0%)	(8.3%)	–

*Kruskal–Wallis–*H* test; **Fisher–Freeman–Halton test; † 6 of 9.

takes a certain time. We evaluated the number of completely occluded (RROC1), reperfused aneurysms (RROC3) and residual necks (RROC2) at discharge and long-term follow-up and compared the outcome to recently published data. Successful EVT outcome, specifically long-term outcome, was commonly observed among our patients (RROC 1 = 86.8%). The rate of complete occlusion of ruptured aneurysms at latest follow-up, including the aneurysms before retreatment, was higher than the rate of complete occlusion of unruptured aneurysms of recent data (86.8% vs. 67.3%) [17]. Yeon et al. reported that around 85% of all coiled aneurysms showed stable minor recanalization after 36 months [18], but none necessitated a reintervention [19]. Since the discrepancy between reintervention (*n* = 9) and occlusion rate (RROC2-3 = 10) was similar to the findings of other authors [20], we compared reintervention with the more objective re-rupture rates. Individual decision of reintervention was made based on the dynamic of the reperfusion, the size, comorbidities and other parameters. Globally, our reintervention rates were similar to other published studies (7.6% vs. 7.6–14%) [21–23]. As reported by several authors, the time span for reperfusion after coiling from intracranial aneurysms ranged from 4.7 to 38 months [23, 24]. In our series, 88.9% of the decisions to reintervene were made within 12 months. Thus, it was essential to perform an angiographic examination within 12 months after the initial treatment.

Endovascular vs. Surgical Approach

The higher rate of recanalization following endovascular intervention in MCA aneurysms is still the main reason why some authors propagate a “clip first policy” [3, 25].

EVT, similar to microsurgery, had a high rate complete occlusion. The rate of complete occlusion following EVT of our ruptured MCA aneurysms (86.8%) was nearly as high as the published rate of complete occlusion following microsurgery of unruptured MCA aneurysms (95.5%) [17]. The reintervention rate, however, which is commonly very small following microsurgery (0–2.5%) [3, 22, 26], was high following EVT in our cohort (7.6%). This fact could not just be explained by a learning curve for new devices as it was reported for WEB-device employment [27].

In respect to outcome, 58.5% of patients demonstrated good clinical outcome (mRS ≦ 2) following EVT, which was within the range of good clinical outcome following surgery—slightly higher than Güresir et al. [28], but lower than Rodriguez–Hernandez et al. [3]. We compared these findings and summarized the results in Table 5.

Table 5 Review of surgical data for MCA aneurysms

Author	Patients	Good clinical outcome (mRS ≦ 2)	Mortality	Retreatment
Rodriguez et al. [3]	282	198 (70, 2%)	26 (9.2%)	0 (0.0%)
Berro et al. [6]	42	mRS 0–3: 32 (80%)	2 (4.8%)	0 (0.0%)
Güresir et al. [28]	163	89 (55%)	0 (0.0%)	0 (0.0%)
Diaz et al. [22]	9	7 (77, 8%)	N.A	0 (0.0%)

As already published by Molyneux et al., the long-term risk of dependency (mRS 3–5) is significantly higher after a surgical approach than after EVT [29]. Compared to their surgical outcome data (mRS 3–5: 22%), our patients had a lower permanent long-term morbidity (mRS 3–5: 11.8%) [29]. While the reported lower postoperative ischemic complications after EVT, due to the absence of surgical manipulation [5], could not be confirmed, we had nine vasospasms inducing cerebral infarction. Indeed, the intraprocedural rupture rate, which leads to permanent morbidity, was at a lower rate following our endovascular approach (1.7% vs. 7.4%) [3]. Lastly, thromboembolic events of ruptured aneurysms are commonly present following endovascular treatment and noted to worsen morbidity and mortality rates [30]. These events, however, seemed to have similar rates in our cohort (2.5%) compared to published data (1.7%) [3].

Advantages and Disadvantages of Endovascular Approach

The EVT approach presented several advantages over other techniques and shows a great potential to be a future preferred choice of treatment. It allowed for treatment of complex broad-based ruptured aneurysms following the introduction of SAC and WEB device, with outcome and reintervention rates matching simple coiling (see Table 4) [31]. It reduced complications of hemorrhage and thromboembolism through the application of periprocedural tirofiban [14]. It also demonstrated comparable long-term morbidity rates [5]. Nonetheless, the rather low occlusion rates necessitated reinterventions at higher rates than microsurgery, posing a major challenge to successful EVT [3, 6, 22, 28]. This begs the question, what treatment outcome is more important: a higher possibility of re-intervention with low-grade long-term morbidity or a less likelihood of re-intervention but higher probability of long-term morbidity?

Limitations

This study has several limitations. It is a two-center study limited by its non-randomized and retrospective design. Moreover, the comparison with the surgical approach was limited to published data only. Nonetheless, unlike other studies [3], the selection bias for endovascular treatment was at the very minimum. This shows that a wide variety of complex MCA bifurcation aneurysms can be treated endovascularly. The number of cases was low in the WEB group; therefore, the data may have overestimated the potential of the WEB device. The study lacked data on the impact of not using balloon-assisted coiling. Nonetheless, the use of stents and antiplatelet therapy in acute settings caused no significant increase in complications as reported in a recently published meta-analysis [32].

Conclusion

Endovascular treatment of acutely ruptured MCA bifurcation aneurysms is feasible and rather safe. With the introduction of new devices, EVT can be considered as the alternative non-surgical treatment option for this type of aneurysm.

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Compliance with Ethical Standards

Conflict of interest F. Hagen has no conflict of interest. A. Berlis is proctor for Sequent Medical, Microvention, Stryker and Medtronic and received lecture royalities for Penumbra. Fee for CEC from Phenox. M. Skalej has no conflict of interest. CJ. Maurer received an educational grant from Microvention and Stryker.

Ethical Approval For this type of study formal consent is not required.

Informed Consent Informed consent was obtained from all individual participants included in the study.

Consent for Publication For this type of study consent for publication is not required.

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