Clinical Study

Incidence of Vasospasm, Outcome, and Quality of Life after Endovascular and Surgical Treatment of Ruptured Intracranial Aneurysms: Results of a Single-Center Prospective Study in Switzerland

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Background. Outcome after endovascular versus surgical treatment of ruptured aneurysms is still controversial. The aim of this study was to analyze the incidence of cerebral vasospasm (CVS), outcome, and quality of life in patients undergoing endovascular or surgical treatment. **Methods.** This single-center prospective study included all patients undergoing aneurysm occlusion over a one-year period. All patients underwent postinterventional CT scan, TCD, and angiography on day 9 ± 2 . Outcome (Barthel Index, NIHSS, mRS, MMSE) was evaluated at 6 and 12 weeks. Quality of life (EuroQoL, SF-12) was assessed at 6 months. **Results.** A total of 66 patients were included. The overall mortality due to CVS was 9.9%, and higher in the surgical (14.6%) than in the endovascular group (4%). The incidence of symptomatic (29.2% versus 24%) and angiographic (70.7% versus 52%) CVS was not statistically significant different between the two groups. No differences in outcome or quality of life (SF-12) could be demonstrated. **Conclusions.** The outcome and quality of life of patients undergoing endovascular or surgical treatment seems not to significantly differ if demographic, radiological, and intensive care parameters are similar. A trend toward lower incidence of CVS in patients undergoing endovascular treatment was observed.

1. Introduction

The management of intracranial aneurysms has changed dramatically through the time. Since the introduction of microneurosurgery in the 1960s, the outcome in patients suffering SAH after rupture of aneurysms improved dramatically. The technological developments that allow the endovascular treatment of aneurysms are gaining popularity due to the associated low morbidity and feasibility of the methods. This fact is supported by approximately 1100 new cases treated each month worldwide with intracranial endovascular devices [1]. Since the introduction of coiling techniques in Switzerland, more than 1000 patients underwent endovascular treatment [2].

The incidence of subarachnoid hemorrhage-induced vasospasm (CVS) in patients undergoing endovascular treatments compared to surgical occlusion of ruptured aneurysm is still controversial [3–6]. Moreover, differences in outcome between patients undergoing endovascular and surgical treatment have not been extensively studied [5–12]. In terms of comparison of quality of life between patients treated with endovascular and surgical techniques, only one study has been published so far [13]. The majority of the studies published comparing the incidence of CVS, outcome, and quality of life were done retrospectively and did not analyze demographic data and risk factors for CVS. Nevertheless, none of these studies comparing the incidence of CVS in both

treatment groups included follow-up angiographic studies as part of a standardized evaluation protocol for CVS.

The aim of this prospective study was to analyze and compare the incidence of CVS, influencing risk factors, outcome, and quality of life in patients undergoing either surgical or endovascular treatment of ruptured aneurysms in a single institution.

2. Materials and Methods

2.1. Patient Population and Treatment Protocol. A total of 94 patients presenting with SAH were admitted in our institution during a one-year period. In 16 patients (17.1%) angiographic studies failed to demonstrate an aneurysm as cause of the SAH. Twelve (11.7%) patients who did not undergo occlusion of the aneurysm and died immediately after admission were also excluded. Finally, this prospective study included 66 (70.2%) patients with aneurysmal SAH proven on CT and angiography who underwent occlusion of ruptured aneurysms. Demographic characteristics are shown in Table 1.

All patients were admitted at the Intensive Care (ICU) or Intermediate Care (IMC) Unit in order to assure an optimal oxygenation and adequate hemodynamic management prior and after occlusion of the aneurysm. Monitoring of blood pressure and intracranial pressure (ICP), if indicated, was performed. Hemodynamic, ICP, and cerebral perfusion pressure (CPP) were documented hourly. Fluid control was documented hourly and summarized twice a day. Initial routine laboratory examination included coagulation status, electrolytes, hematology, liver and renal function, and arterial blood gases. These parameters were controlled and documented throughout the treatment once a day. All patients underwent computerized tomography (CT) at admission, 2 days after occlusion of the aneurysm, and 6 weeks after treatment. Initial cerebral angiography was performed in all patients after admission.

The decision how to occlude the aneurysm was based on a case-by-case evaluation in which different angiographic and clinical factors were considered. Angiographic findings included location, size, and shape of the aneurysm, as well as tortuosity of the proximal vessels. Clinical data included age, initial neurological findings, and systemic comorbidities.

All patients received steroids (Prednisolone 150 mg p.o. or Methylprednisolone 120 mg i.v.) and oral nimodipine (90–360 mg). A total of 32 (48%) patients were additionally included in a multicentric prospective phase II study testing the effects of the endothelin receptor antagonist clazosentan [14–16]. During a 14-day period after SAH, these patients received placebo (n : 7), or clazosentan 1 mg (n : 8), 5 mg (n : 8), or 15 mg (n : 9).

After occlusion of the aneurysm, patients were classified according to the risk for development of CVS. The criteria to consider patients as high risk for CVS included severity of clinical findings (WFNS [17] grades 3–5, Hunt and Hess [18] grades II–V) [19–21], volume of blood in the cisterns and ventricles (Fisher grades 3 and 4) [22], signs of rebleeding

prior to treatment [23], young age [24], nicotine consumption [25], cocaine abuse [26, 27], hypertension [28, 29], and hyperglycemia [29]. Gender was not considered as risk factor for CVS in this study [30]. The aneurysms were occluded within 48 hours after admission and the patients remained at least 2 days at the ICU. Patients with clinical and radiological signs of hydrocephalus underwent ventriculostomy prior to the occlusion of the aneurysm. In patients with no signs of hydrocephalus on CT, lumbar drainage was implanted. Drainage of cerebrospinal fluid (CSF) was maintained for at least 4 days after admission. Ventricular catheters were removed if ICP remained normal after 24 hours monitoring with closed drainage. All patients were transferred to the IMC in order to allow further hemodynamic monitoring throughout the next 7 days. During this period negative fluid balance and hypotension was avoided with fluid replacement and vasoactive medication. As soon as clinical and angiographic signs of CVS were detected or demonstrated, the patient was transferred again to the ICU in order to undergo hypertension, hypervolemia and hemodilution therapy (HHH-therapy) [31]. The systolic blood pressure was raised to 180 mmHg, central venous pressure (CVP) was kept between 8–12 mmHg, hematocrit was attempted to be maintained lower than 30%. If necessary, cardiac output and pulmonary capillary wedge pressure were monitored invasively using a pulmonary artery catheter. Hemodynamic and vital parameters were prospectively documented once a day in order to allow the analysis of factors influencing the incidence and severity of CVS.

2.2. Assessment of Vasospasm. The diagnosis of symptomatic or clinical CVS was considered if deterioration of level of consciousness defined as one-point decrease in the mGCS or development of focal neurological signs occurring between days 3 and 14 after SAH could be documented. Clinical assessment in terms of mGCS and neurological examination was performed three times a day and documented prospectively. All patients included in this study underwent cerebral angiography on day 9 ± 2 after SAH. Angiographic CVS was classified in proximal or distal, and focal or diffuse. The severity of CVS was classified into mild (<33%), moderate (34–66%), and severe (67–100%). Grade of obliteration of the aneurysm was assessed in the postinterventional angiography as follows: 100%, >90%, 70–90%, and <70%. Transcranial Doppler (TCD) was performed every two days or daily if CVS was diagnosed. TCD criteria for CVS included: increase in velocities of 30%, increase in absolute values (50 cm/sec), or a Lindegaard index greater than 3. Endovascular treatment of CVS was not performed. All patients suffering CVS underwent CT scan prior to discharge in order to assess possible ischemic lesions.

2.3. Measurement of Outcome and Quality of Life. Assessment of functional status was based on responses of questionnaires performed 6 and 12 weeks after admission. Computerized scoring algorithms served to classify the patients according to the Mini Mental Status Examination [32], modified Rankin Scale (mRS) [33, 34], National Institutes of Health Stroke

TABLE 1: Demographic characteristics and clinical and radiological findings on admission.

	Surgical treatment			Endovascular treatment		
	Total	Clinical CVS	No clinical CVS	Total	Clinical CVS	No clinical CVS
Patients	41	12	29	25	6	19
Age (years)	50.2 ± 10.6	51.2 ± 7.1	49.8 ± 11.6	54.9 ± 9.3	55.1 ± 7.4	54.8 ± 9.8
Gender (f: m)	30:11	11:1	19:10	17:8	4:2	13:06
BMI (m ² /kg)	24.9 ± 3.9	24.7 ± 3.9	24.6 ± 3.9	26.4 ± 4.5	23.8 ± 2.7	27 ± 4.6
WFNS grading	1.9 ± 1.2	2.2 ± 1.5	1.8 ± 1.1	2.2 ± 1.5	2 ± 1.3	2.3 ± 1.6
Grade 1–3 (%)	82.3	75	86.2	72	83.3	68.4
Grade 4–5 (%)	17.7	25	13.7	28	16.7	31.6
mGCS	13.7 ± 2.4	12.7 ± 3.7	14.1 ± 1.5	12.7 ± 3.8	13.1 ± 2.9	12.5 ± 4
Hunt & Hess grading	2.2 ± 0.5	2.41 ± 0.6	2.2 ± 0.4	2.5 ± 1	2.5 ± 0.9	2.5 ± 1
Grade 1–3 (%)	97.6	91.7	100	84	83.3	84.2
Grade 4–5 (%)	2.4	8.3	0	16	16.7	15.8
Initial mean arterial pressure (mmHg)	100.7 ± 18.3	109.4 ± 22.1	91.7 ± 15.1	101.4 ± 10.3	117.9 ± 17.5	96.2 ± 18.1
Time interval SAH—admission (mean hours/range)	21/0.4–312	21.5/0.4–124	20.8/0.5–312	19.5/0.5–206	39.4/1–206	12.3/0.5–159
Headache (%)	97.5	100	96.6	92	100	89.5
Unconsciousness (%)	43.9	50	41.5	31	33.3	36.8
Nausea/vomiting (%)	65.9	50	75.9	76	83.3	73.7
Neck stiffness (%)	61	50	65.5	64	83.3	57.9
Seizures (%)	7.3	8.3	6.8	28	16.7	31.6
Focal neurological deficits (%)	19.5	16.6	20.7	8	0	10.5
Hydrocephalus (%)	26.8	25	27.6	32	33.3	36.8

CVS: cerebral vasospasm; BMI: body mass index; WFNS: World Federation of Neurosurgical Societies; mGCS: modified Glasgow Coma Score; SAH: subarachnoid hemorrhage. All data are expressed as mean ± standard deviation.

Scale (NIHSS) [35], and Barthel Index [36, 37]. The mRS categorizes patients into six classes: score 0, no neurological symptoms or disabilities; score 1: no disabilities despite neurological symptoms; score 2: slight disability (unable to perform all activities of daily living); score 3: moderate disability (walks without assistance); score 4: severe disability (unable to walk without assistance); score 5: bedridden; score 6: death. The Barthel Index combines scores for several activities of daily living to produce a score (index) ranging from 0 to 20 with higher score representing a better functioning.

Quality of life was assessed using the quality of life questionnaire EuroQoL (EQ-5D) [38–40] including a 100-point visual analog scale (VAS) at 12 weeks after admission and the SF-12 [41] (QualiMetric Inc., Lincoln, RI, USA) at six months. EuroQoL consists of five domains of health (mobility, self-care, usual activities, pain/discomfort, and anxiety/depression), each of which is divided into three levels: (1) no problems, (2) some or moderate problems, and (3) extreme problems. For practical reasons the results are given in percentage of patients presenting with levels 2 or 3. The written German version of the SF-12 was sent to the patients per mail and standard scoring algorithms were used to score their responses to the 12 multiple-choice questions [41]. Score for SF-12 physical component summary (PCS) and mental component summary (MCS) scales can range from 0 to 100. The US population mean score is 50 and the

corresponding is 10; higher scores indicate a better health state. The reliability and validity of the SF-12 was recently proved in patients with cerebral aneurysm [42]. The EQ-5D questionnaire is an instrument for subjectively describing and valuing health state. It includes five different dimensions: mobility, self-care, usual activities, pain/discomfort, and anxiety/depression which are categorized as no, moderate, or severe limitations or complains. The VAS included in the EQ-5D evaluates the subjective health state and defines 100 points as the best and 0 as the worst imaginable state.

2.4. Statistical Analysis. Quantitative data are expressed as mean values ± standard deviation. Differences between groups were assessed by using the Student's *t*-test. Linear regression analysis was performed. Statistical significance was assumed when the probability value was less than 0.05.

3. Results

3.1. Study Population. A total of 66 patients (age: 52 ± 10; female: 47, 71.2%) were included in this study. Table 1 shows the demographic characteristics and clinical and radiological findings on admission. The aneurysms were clipped in 62.1% (*n*: 41) and coiled in 37.9% (*n*: 25) of the patients. The initial clinical findings distributed in both groups are shown in Table 1. No statistical differences between the patients

undergoing clipping, coiling in the initial evaluation in terms of WFNS, mGCS, and Hunt and Hess grading could be demonstrated.

The aneurysm location, size, and treatment modality are shown in Table 2. A trend for endovascular treatment in large aneurysms (8.6 ± 4.2 mm) compared to patients undergoing clipping (6.5 ± 3.2 mm) could be observed. The obliteration of the aneurysm was evaluated angiographically on day 9 ± 2 and classified in four groups: 100%, >90%, 70–90%, and <70%. No rebleeding caused by rerupture after occlusion of the aneurysm was observed. Multiple aneurysms were documented in 25 (37.9%) patients.

3.2. Incidence and Risk Factors for Vasospasm. The overall incidence of CVS detected clinically was 27.2% (n : 18) and angiographically was 63.6% (n : 42). There was no statistically significant difference in clinical and angiographic CVS of patients undergoing endovascular and surgical treatment. In the surgical group the incidence of symptomatic and angiographic CVS was 29.2% and 70.7%. In contrast, the incidence of symptomatic and angiographic CVS in patients undergoing endovascular was 24% and 52%, respectively (Table 3). The linear regression analysis demonstrated no statistically significant correlation between angiographic CVS and factors such as age, gender, BMI, WFNS grading, GCS, Hunt & Hess classification, and Fisher CT grading.

Angiographic CVS was classified as proximal (n : 32, 91.4%) or distal (n : 3, 8.6%), and focal (n : 25, 71.4%) or diffuse (n : 10, 28.6%). The severity of CVS was distributed into mild (n : 13, 37.1%), moderate (n : 14, 40%), and severe (n : 8, 22.9%). Cerebral infarction signs on CT after SAH treatment were documented in 7 (17.1%) patient in the surgical and 2 (8%) patient in the endovascular group. Among these patients only one in each group survived.

TCD confirmed angiographic CVS in only 51% of patients. The rest of patients presenting with angiographic CVS were not detected with TCD. Therefore, TCD did not influence the decision for CVS treatment in our series. In this series, the inclusion of patients in the endothelin receptor antagonist clazosentan study (placebo, 1, 5, or 15 mg) did not influence significantly the incidence and severity of angiographic (56.2% versus 70.5%, $P = 0.23$) and symptomatic (28.1% versus 37.5%, $P = 0.88$) CVS regardless of the technique used for occlusion of the aneurysm.

The only risk factors for CVS, which differed significantly between patients undergoing clipping and coiling, were hematocrit and sodium values throughout the treatment (Table 3). Nevertheless, risk factors such as initial CT findings, decreased platelet count, cigarettes consume, CVP, volume deficits, and minimal systolic BP values did not differ significantly in both groups.

3.3. Outcome and Quality of Life after Vasospasm. The overall mortality due to CVS was 9.9%. The mortality of patients who underwent clipping was higher than in patients who underwent endovascular treatment (14.6% versus 4%) (Table 4). This difference was, nevertheless, not statistically significant.

FIGURE 1: Barthel index at 12 weeks according to type of treatment (surgical group: 97.5 ± 7.6 , endovascular group: 88.4 ± 29.6 , $P = \text{NS}$).

FIGURE 2: Physical and mental component summaries of the SF-12 at 6 months distributed according to treatment type ($P = \text{NS}$). Abbreviations: PCS: physical component summary; MCS: mental component summary; ¹all patients; ²patients suffering cerebral vasospasm.

No statistically differences of outcome parameters (mRS, Barthel Index, NIHSS, and MMSE) could be demonstrated between both groups (Figure 1).

In terms of assessment of quality of life using the EuroQoL (EQ-5D), only mobility was demonstrated to be significantly less impaired in patients undergoing surgical treatment (12.1% versus 34.8%). In patients who survived clinical CVS, an additional statistically significant less impairment (level 2 or 3) in terms of mobility, self-care, usual activities, and pain/discomfort could be demonstrated in the surgical group compared to the endovascular group (Table 4). Interestingly, anxiety, depression, and self-evaluation of health state (VAS) did not differ significantly regardless of the type of aneurysm occlusion technique. Moreover, the evaluation of quality of life measured by the SF-12 (physical and mental component summary) at 6 months after SAH did not differ significantly (Figure 2).

TABLE 2: Location, size, and degree of obliteration of the aneurysm according to treatment modality.

	Surgical treatment			Endovascular treatment		
	Total	Clinical CVS	No clinical CVS	Total	Clinical CVS	No clinical CVS
N Patients	41	12	29	25	6	19
Location of the aneurysm						
ICA	4	1	3	2	1	1
MCA	14	3	11	1	0	1
PComA	10	3	7	5	2	3
AComA	12	5	7	9	1	8
BA	0	0	0	7	2	5
VA	0	0	0	1	0	1
PICA	1	0	1	0	0	0
Aneurysm size, maximal diameter (mm)	6.5 ± 3.2	6.7 ± 2.3	6.4 ± 3.5	8.6 ± 4.2	8.9 ± 4.4	8.5 ± 4.2
Degree of obliteration (%)*						
100	82.9	100	75.9	52	33.3	57.9
>90	4.9	0	6.9	28	50	21.05
70–90	4.9	0	6.9	16	0	21.05
<70	7.3	0	10.3	4	16.7	0

CVS: cerebral vasospasm, MCA: middle cerebral artery; ICA: internal carotid artery, PComA: posterior communicating artery; AComA: anterior communicating artery; BA: basilar artery; VA: vertebral artery; PICA: posterior inferior cerebellar artery; *: based on postinterventional angiography at day 9 ± 2 after SAH.

4. Discussion

4.1. Incidence of Vasospasm and Risk Factors. The overall incidence of symptomatic and angiographic vasospasm in this prospective study was 27.2% and 63.6%, respectively. These data are similar to previous series reported in the literature [34]. Among the patients that developed DIND in our series, 13.6% had signs of ischemic lesions on CT. The fact that these findings are higher than in previous reports might be explained due to the higher sensitivity to detect ischemic lesions using modern CT technologies [43]. More recent series reported an incidence of 19% of CT infarctions after SAH treatment [19]. In a recent study analyzing 505 patients undergoing surgical treatment of ruptured aneurysms, a total of 28% patients had signs of CT infarctions [12]. In our series, patients undergoing endovascular treatment had less ischemic lesion on CT after treatment. The incidence of CT infarctions after endovascular treatment has been reported to be higher in other series [12]. Comparing the incidence of CT infarctions between the periods of 1993–1996 and 1997–2000, Hoh et al. [12] found no significant difference despite the advances in the treatment of SAH. In our study, the incidence of clinical and angiographic CVS did not differ significantly in both treatment groups. These observations are similar to some previous reported studies. Hoh et al. [6] analyzed 515 in a retrospective study (243 patients prospectively) based mainly on TCD findings. The authors found no significant difference in total CVS or symptomatic CVS when patients who underwent clipping were compared with patients who underwent coiling. The authors demonstrated an incidence of symptomatic CVS of 28% in the clipping group and 33% in the coiling group.

New therapeutic strategies which could influence the lower incidence of CVS compared to previous series might

include the introduction of CSF drainage (ventricular or lumbar) in our treatment protocol [44]. TCD showed a low sensitivity to detect clinical and angiographic CVS in patients developing CVS in our series. Only 51% of the patients suffering angiographic CVS presented with TCD criteria for CVS. In a consecutive series of 415 patients, Rabinstein et al. [10] observed an incidence of symptomatic CVS in 39% in patients who underwent clipping compared to 30% in patients who underwent coiling. The authors demonstrated that patients with better clinical grades (WFNS I–III) at hospital admission were less to suffer symptomatic CVS when treated with endovascular techniques compared with surgical treatment. More recently, Dehdashti et al. [11] reported the results of a study in 72 patients, an incidence of symptomatic CVS of 25% in patients undergoing clipping and 15% in patients undergoing coiling of ruptured aneurysms. The authors found no statistical significance comparing the neurological deficits in both groups. In our study, the incidence of angiographic and symptomatic CVS was not statistically significant between the endovascular and surgical treatment groups.

In our series, the only risk factor for CVS detected to be different in the two treatment groups was hematocrit and sodium values, which remained nevertheless within normal limits. Natriuresis following SAH is frequently associated with hypovolemia caused by cerebral salt wasting and may be related to increased secretion of brain natriuretic peptide [45]. The differences of sodium values in the two treatment groups may be explained with the fact that patients treated with endovascular techniques had a less negative fluid balance compared to the surgical group [46]. Recent clinical trials have demonstrated marked prevention of vasospasm with the endothelin receptor antagonist clazosentan, yet patient outcome was not improved [14, 15]. The analysis

TABLE 3: Risk factors for cerebral vasospasm on admission and during the treatment in patients undergoing surgical and endovascular treatment.

	Total	Surgical treatment		<i>P</i> value surgical versus endovascular	Endovascular treatment		
		Clinical CVS	No clinical CVS		Total	Clinical CVS	no clinical CVS
Total patients	41	12	29	—	25	6	19
Patients with angiographic CVS (%)	70.7	91.7	62.1	NS	52	83.3	36.8
Patient with clinical CVS (%)	29.2	—	—	NS	24	—	—
Platelet count ($\times 1000/\mu\text{L}$)	263.3 $\pm$ 64.3	298.7 $\pm$ 69.7	248.6 $\pm$ 57	NS	280.3 $\pm$ 76.1	315.6 $\pm$ 75.4	269.2 $\pm$ 74.8
Lowest platelet count/admission count > 0.7 (%)	85.4	83	86	—	80	66	84
Hematocrit (L/L)	0.33 $\pm$ 0.04	0.32 $\pm$ 0.03	0.33 $\pm$ 0.04	<i>P</i> < 0.05	0.35 $\pm$ 0.05	0.33 $\pm$ 0.06	0.36 $\pm$ 0.04
Mean systolic blood pressure (mmHg)	139 $\pm$ 13.6	147 $\pm$ 14.1	136 $\pm$ 11.8	NS	143 $\pm$ 17	158 $\pm$ 12	139 $\pm$ 15.1
Episodes of hypotension (SBP < 105 mmHg)	0.68 $\pm$ 1.1	0.67 $\pm$ 1.2	0.69 $\pm$ 1.1	NS	1.04 $\pm$ 1.3	0.5 $\pm$ 0.7	1.2 $\pm$ 1.4
Maximal ICP (mmHg)*	26 $\pm$ 9.1	29 $\pm$ 8	25 $\pm$ 9	NS	34.7 $\pm$ 16.8	44 $\pm$ 15	30 $\pm$ 10
Patients undergoing ICP monitoring (%)	31.7	42	27	—	48	66	42
Angiographic vasospasm on admission (%)	7.3	8.3	6.9	—	16	50	5.3
Fisher CT grading	3.3 $\pm$ 0.8	3.6 $\pm$ 0.6	3.2 $\pm$ 0.9	NS	3.5 $\pm$ 0.9	3.1 $\pm$ 1.1	3.6 $\pm$ 0.7
Grade 1-2 (%)	17.1	8.3	20.7	—	16	16.7	15.8
Grade 3-4 (%)	82.9	91.7	79.3	—	86	83.3	84.2
Mean fluid balance (mL)	-132 $\pm$ 630	-195 $\pm$ 394	-106 $\pm$ 693	NS	-109 $\pm$ 412	-199 $\pm$ 214	-93 $\pm$ 448
Patients with negative fluid balance (%)	63.4	75	58.7	—	60	83.3	52.6
Episodes of negative fluid balance	4.1 $\pm$ 1.9	4.8 $\pm$ 0.9	3.7 $\pm$ 2.1	NS	4.1 $\pm$ 2.2	4 $\pm$ 2.6	4.1 $\pm$ 2.1
Inclusion in the Clazosentan study* (<i>n</i>)	23	7 (28.1%)	16 (69.5%)	NS	9	2 (22.2%)	7 (77.7%)
Sodium (mmol/L)	141.5 $\pm$ 2.1	141 $\pm$ 1.9	142 $\pm$ 2	<i>P</i> < 0.05	138.8 $\pm$ 3.1	136.6 $\pm$ 2.6	140 $\pm$ 2.7
Glucose (mmol/L)	6.7 $\pm$ 0.8	6.8 $\pm$ 0.6	6.7 $\pm$ 0.8	NS	6.9 $\pm$ 0.9	6.7 $\pm$ 0.4	6.9 $\pm$ 0.9
Cigarette use (%)	48.8	75	38	—	52	33.3	57.9
Cigarette use (py)	14.3 $\pm$ 17.9	19.5 $\pm$ 21.7	12.3 $\pm$ 14.9	NS	20.2 $\pm$ 19.7	15 $\pm$ 16.1	19.9 $\pm$ 20.1

CVS: cerebral vasospasm; ICP: intracranial pressure; SBP: systolic blood pressure; NS: no statistically significant; *: including all patients receiving placebo and clazosentan (1, 5, and 15 mg). All data are expressed as mean $\pm$ standard deviation.

TABLE 4: Outcome and quality of life after surgical and endovascular occlusion of the aneurysm.

	Surgical Treatment			P value surgical versus endovascular	P value CVS surgical versus endovascular	Endovascular treatment		
	Total	clinical CVS	no clinical CVS			Total	clinical CVS	no clinical CVS
Survivors/total patients	35/41	7/12	28/29	—	—	24/25	5/6	19/19
Survivors (%)	85.4	58.3	96.6	—	—	96	83.3	100
Mortality (%)	14.6	41.6	3.4	NS	NS	4	16.7	0
mRS	1.5 ± 2.2	2.8 ± 3	0.9 ± 1.5	NS	NS	1.5 ± 1.9	3.3 ± 2.1	0.8 ± 1.3
MMSE*	28.4 ± 3.3	29.1 ± 0.9	28.2 ± 3.6	NS	NS	28.9 ± 2	27.3 ± 3.7	29.3 ± 1.4
NIHSS*	1.3 ± 5.3	4.9 ± 11.1	0.3 ± 0.8	NS	NS	4.7 ± 14.6	7.4 ± 11.0	3.9 ± 15.3
Barthel-Index*	97.5 ± 7.6	97.9 ± 5.2	97.4 ± 8.1	NS	NS	88.4 ± 29.6	69 ± 40.3	94.1 ± 23.5
EQ-5D (%)*:	51.5	14.3	61.5	NS	P < 0.05	52.2	80	44.4
Mobility (%)†	12.1	14.3	9.1	P < 0.05	P < 0.05	34.8	80	22.2
Self-Care (%)†	12.1	0	15.4	NS	P < 0.05	21.7	60	11.1
Usual activities (%)†	27.3	14.3	30.8	NS	P < 0.05	39.1	80	27.8
Pain/Discomfort (%)†	30.3	0	38.5	NS	P < 0.05	39.1	60	33.3
Anxiety/Depression (%)†	24.2	14.3	26.9	NS	NS	21.7	60	11.1
Patients' health (VAS)	77.3 ± 17.2	85 ± 14	75 ± 17	NS	NS	77.1 ± 16.5	63 ± 15	80 ± 15
SF-12†:								
PCS	48.69	49.75	48.36	NS	NS	48.22	41.34	49.44
MCS	43.18	44.23	42.85	NS	NS	45.47	35.46	47.42

CVS: cerebral vasospasm; mRS: modified Rankin Score; MMSE: Minimal State Examination; NIHSS: National Institutes of Health Stroke Scale; NS: no statistically significant. *: measurements in survivors. EQ-5D: EuroQoL health state; VAS: visual analog scale for patients' health state (0–100); *: patients reporting problems in at least one of the EuroQoL items. †: patients presenting with any limitation (level 2 or 3); SF-12: Short Form-12; PCS: physical component summary; MCS: mental component summary; †: measurements based on 30 out of 35 patients in the surgical group and 20 out of 24 in the endovascular group. All data are expressed as mean ± standard deviation.

of patients included in this prospective study that were additionally enrolled in the clazosentan study demonstrated no significant difference in incidence of symptomatic and angiographic CVS and mortality.

4.2. Outcome and Quality of Life. Since the introduction of endovascular techniques for the treatment of intracranial aneurysms, very few studies comparing the outcome of patients undergoing surgical and endovascular treatment, have been reported [5–7, 9–12]. Six studies evaluated the outcome based on the GOS exclusively [5, 7, 10–12]: one study included additionally neuropsychological assessment [9] and one reported the outcome in terms of mRS [6]. Only four studies were prospective [5, 7, 9, 11]. In five out of seven studies including 758 patients undergoing clipping and 249 patients undergoing coiling, no differences in terms of outcome (GOS) could be demonstrated [5, 7, 9–11]. Two additional studies including 918 patients undergoing clipping and 193 patients undergoing coiling reported a better outcome in terms of GOS and mRS in patients treated surgically [6, 12]. In our study outcome was assessed not only in terms of GOS and mRS, but also using additional parameters such as Barthel Index, NIHSS, and MMSE. Like most of the studies reported previously, we could not demonstrate a significant difference in outcome in patients treated either surgically or using endovascular techniques.

The quality of life in patients treated with surgical or endovascular techniques has not been studied extensively. To our knowledge, only one report including 93 patients (clip: 56 patients, coil: 37 patients) has been published so far [13]. This Spanish study reported by Katati et al. [13] evaluated the quality of life at one year after SAH using the SF-36. Regarding clinical and radiological findings, the authors found statistical significant differences between both treatment groups only in terms of location of the aneurysm and incidence of CVS. In this series, CVS was reported to be lower in patients treated surgically (12.5% versus 35.1%). The quality of life was observed to be deteriorated in 50% of the patients treated surgically and in 40.5% of the patients treated with endovascular techniques. Interestingly, the authors demonstrated a significant impairment in the categories of social functioning [47] and role-emotional (RE). In both treatment groups SF and RE were scored between 30.4% and 32.4%. The rest of the categories such as physical functioning, role-physical, bodily pain, general health, vitality, and mental health were demonstrated to be less impaired regardless the type of treatment. In our study, quality of life was evaluated with the EuroQoL (EQ-5D) [38–40] and the SF-12 [41]. Recently, King Jr. et al. demonstrated the SF-12 as a reliable and valid instrument for measuring health status in patients with cerebral aneurysms [42]. The authors validated this modified SF-36 questionnaire comparing it with GOS, mRS, Barthel Index, and mental health-HAD [48] (hospital anxiety and depression scale). In our study we could not demonstrate a significant difference in the PCS and MCS between the two treatment groups (Figure 2). The evaluation in terms of EuroQoL only mobility was demonstrated to be significantly less impaired in patients

undergoing clipping of the aneurysm (12.1% versus 34.8%). Moreover, in patients surviving CVS, additional categories such as self-care, usual activities, and pain/discomfort were found to be less impaired in the surgical group. The reason for these findings in our small series is nevertheless unclear. Possible factors influencing these observations might include the lack of removal of the clot in the subarachnoid space in patients treated with endovascular techniques and the meticulous treatment of ICP in cases of cerebral edema [22, 49–51].

Finally, the main limitation of this study is the small population included and the lack of randomization of the type of treatment. In our study, nevertheless, the statistical analysis of the demographic and radiological features showed no differences in both treatment groups.

5. Conclusions

According to the results of this study, the incidence of symptomatic and angiographic CVS, outcome, and quality of life might not significantly differ between patients undergoing endovascular or surgical treatment if demographic and radiological features as well as parameters during intensive care management are similar. Nevertheless, a trend of lower incidence of CVS in patients undergoing endovascular treatment was observed.

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