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Anesthesia, complications, and clinical outcome for ruptured intracranial aneurysms: a retrospective comparison between endovascular coiling and neurosurgical clipping

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Aim: To compare anesthetic practice, perioperative complications, and clinical outcomes of endovascular coiling versus neurosurgical clipping in our university hospital over a 2-year period.

Materials and methods: This was a retrospective review of the hospital charts of 30 patients with cerebral aneurysms treated by endovascular coiling compared with 52 patients treated by neurosurgical clipping. Information including demographics, preoperative neurological status, timing of intervention, anesthetic management, duration of the postoperative intensive care and hospital stay, intra- and postoperative complications, and clinical outcome at hospital discharge were compared and analyzed. $P < 0.05$ was considered to be significant.

Results: The surgical group had greater consumption of certain anesthetic agents whereas the endovascular group had more frequent episodes of hypertension (>30% more than the baseline measurement) during the procedure. We recorded significantly longer durations of stay in the intensive care unit for surgical patients. Clinical outcome at discharge was significantly better in patients treated with endovascular coiling ($P = 0.004$). There were significantly more cases of hyponatremia ($\text{Na} < 135 \text{ mmol/L}$) in the surgical group.

Conclusion: Compared with neurosurgical clipping, endovascular coiling was associated with significant benefits in terms of reduced consumption of anesthetics, stay in the intensive care unit, and perioperative complications, as well as a better clinical outcome.

Key words: Subarachnoid hemorrhage, anesthesia, intracranial aneurysm, coiling, clipping

Introduction

For more than 15 years, endovascular treatment has been a method of choice in treating intracranial aneurysms (1). In the beginning, it was primarily used for surgically inaccessible aneurysms located in the posterior cerebral circulation in patients with severe systemic disease (2). After controlled randomized trials such as the International Subarachnoid Aneurysm Trial in 2002 and 2005, which showed a better clinical outcome after 1 year in patients treated with endovascular treatment, the percentage of patients treated with this method has significantly increased in many countries (3,4). Several studies with small sample sizes followed that study and showed the benefits of endovascular treatment with respect to morbidity and mortality (5-8). It has been reported that better results of endovascular treatment are particularly evident in older patients with better neurological status on hospital admission, and in patients with a small aneurysm of the anterior cerebral circulation (3,9).

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The increased number of endovascular interventions for treating cerebral aneurysms can cause certain problems, such as repeated blood flow through the aneurysm, so there may be a more frequent need for endovascular reintervention (10, 11).

Some of the issues addressed by different authors include work outside the operating room, the differences in the number and treatment of complications during the intervention, the percentage and severity of postoperative complications, and total hospital costs of endovascular treatment (12-16). There are many specific characteristics in the anesthetic approach, clinical course, and complications of this procedure compared with standard neurosurgical treatment of cerebral aneurysms (17,18).

Several studies investigated some of these differences, but their results were not consistent (5,15,19).

The aim of this retrospective study was to compare the anesthetic approach, clinical course, and outcome in patients with cerebral aneurysms treated by endovascular coiling methods or neurosurgical clipping in the Clinical Center of Vojvodina during an interval of 2 years.

Material and methods

After the first endovascular treatment studies done with 2 patients in 2007, the number of endovascular treatments of cerebral aneurysms in the Clinical Center of Vojvodina increased. In the period from April 2008 to April 2010, the endovascular coiling method was used to treat 30 patients. Therefore, we carried out the first evaluation of results in our institution by comparing 2 groups of patients with endovascular coiling (EVC) and neurosurgical clipping (NSC).

After receiving the approval of the Center's Ethics Committee, we reviewed the medical records of all patients who underwent intervention for cerebral aneurysms in a 2-year period. Endovascular treatment and neurosurgical treatment were performed in 30 and 52 patients, respectively.

The decision regarding which treatment (endovascular or neurosurgical) the patient should

receive was made in cooperation and agreement with senior neurosurgeons and interventional neuroradiologists. The decision was based on the aneurysm location, neurological status upon hospital admission, and the presence of systemic comorbidities.

All anesthetic and neurosurgical records were reviewed.

The data recorded were basic demographic data, American Society of Anesthesiologists (ASA) score as a premorbidity indicator, and World Federation of Neurological Surgeons (WFNS) score of neurologic status on admission to the hospital. Information about aneurysm location, the ratio of ruptured and unruptured aneurysms, and the period from rupture up to definitive treatment were also recorded.

To assess anesthesia specificity, we compared the duration of the intervention, the type of anesthesia, the administered drugs, and monitoring. We collected data about the hemodynamic stability of patients during the intervention, consumption of drugs for rapid raising or lowering of blood pressure, and fluid intake during the intervention. One episode of pressure change of $\pm 30\%$ was regarded as representing hemodynamic instability. For rapid lowering of the blood pressure, we used the intravenous antihypertensive drug urapidil, and for rapid control of the blood pressure, we used the vasoactive drug ephedrine.

We also monitored the perioperative clinical course, and we compared the number of days in the intensive care unit (ICU), need for mechanical ventilation, duration of hospital stay, central nervous system complications during and after the intervention, and systemic complications during the postoperative period. Clinical outcomes of both types of intervention were evaluated using the Glasgow Outcome Scale (GOS), where each patient is indicated by a corresponding number on a scale from 1 (dead) to 5 (almost complete recovery) based on data from hospital records on discharge from hospital (20).

For statistical data analysis, we used SPSS 10.0 (SPSS Inc., Chicago, IL, USA). Differences between the groups were analyzed using Student's t-test for normally distributed data and the Mann-Whitney

test for data that were not normally distributed. For nonparametric data, we used the chi-square test. $P < 0.05$ was considered to be statistically significant.

Results

Demographic characteristics, comorbidities, neurological status, and basic characteristics of aneurysms for both groups are presented in Table 1. Patients in both groups shared similar characteristics, except for sex. Females were significantly dominant in the EVC group. More aneurysms in the posterior circulation were treated with endovascular coiling than with surgical clipping.

Statistically significant differences were obtained for the lower consumption of propofol, fentanyl, and midazolam in the EVC group, whereas mean end tidal CO_2 was significantly lower in the surgical group. The duration of the procedure was significantly shorter in the EVC group (Table 2). For the induction of anesthesia, propofol was given to all patients except 2 patients in the EVC group and 3 in the surgical group, because those patients were intubated before entering the operating room. Remifentanyl was used in 21 patients in the EVC group and in 14 patients in the surgical group ($P < 0.05$).

In the treatment of hemodynamic instability, we usually applied ephedrine and urapidil, but metoprolol was used occasionally. In the EVC group, we had a significantly higher number of hypertension episodes and consequently a higher consumption of urapidil for lowering the blood pressure (Table 3).

Table 1. General characteristics of patients and aneurysms.

Variables	EVC	Neurosurgical
Age (years)	54.2 ± 8.9	51.3 ± 9.8
Sex (n) M/F	7/23	20/32
Weight (kg)	77.2 ± 19.4	74.7 ± 16.6
ASA	2.7 ± 0.5	2.6 ± 0.6
WFNS Grade 1 (n)	15	20
Grade 2 (n)	9	7
Grade 3 (n)	2	9
Grade 4 (n)	4	14
Grade 5 (n)	0	2
Aneurysm location		
Anterior circulation	21	49
Posterior circulation	9*	3
Time from rupture (days)	55.3 ± 95.26	13.2 ± 33.43
No. ruptured (n)		

Data are expressed as numbers or means ± SD.

EVC = Endovascular coiling

WFNS = World Federation of Neurological Surgeons

ASA = American Society of Anesthesiologists

* $P < 0.05$

Blood transfusions were given to 8 patients in the surgical group, whereas none of the patients in the EVC group received them.

Standard monitoring, including electrocardiography (ECG), pulse oximetry, noninvasive measurement of blood pressure, and end tidal CO_2 , was carried out. Invasive measurement of blood pressure was applied to 29 patients in the

Table 2. Anesthetic types and characteristics.

Variables	EVC	Neurosurgical
Duration of intervention (min)	237.2 ± 77.3*	285.5 ± 58.6
Propofol (mg)	163.1 ± 57.6*	465.1 ± 657.6
Midazolam (mg)	2.9 ± 2.1*	5.5 ± 4.7
Fentanyl (µg)	164.4 ± 8.2*	512.1 ± 399.3
Mean ETCO_2 (kPa)	3.7 ± 0.3*	3.5 ± 0.4
Mean inspired sevoflurane (vol%)	1.3 ± 0.2	1.2 ± 0.4
Remifentanyl (patients) (n)	21*	14

Data are expressed as numbers or means ± SD.

* $P < 0.05$

Table 3. Hemodynamic stability of patients and fluid intake.

Variables	EVC	Neurosurgical
SAP prior to intervention (mmHg)	152 ± 24	153 ± 25
SAP 5 min after the introduction of anesthesia (mmHg)	127 ± 23	122 ± 23
SAP at the beginning of the procedure (mmHg)	119 ± 15	124 ± 24
SAP >30% from the first value (n) Yes/No	12/18*	6/46
SAP <30% from the first value (n) Yes/No	18/12	34/18
Ephedrine (mg)	9.1 ± 10.2*	22.7 ± 31.6
Urapidil (mg)	22.4 ± 32.1*	5.3 ± 8.4
Crystalloids (mL)	1766.7 ± 639.8	1759.4 ± 763.5
Colloids (mL)	675.2 ± 653.5	668.1 ± 410.7

Data are expressed as numbers or means ± SD.

SAP = Systolic arterial blood pressure

*P < 0.05

EVC group and 49 in the surgical group. Central venous pressure was monitored during day 0 of the intervention for 11 patients in the EVC group (mean value: 8.7 mmHg) and 22 patients in the surgical group (mean value: 5.6 mmHg).

Postoperative mechanical ventilation was performed in 9 of 30 patients in the EVC group and in 49 of 52 patients in the surgical group (P < 0.05). Due to a need for prolonged mechanical ventilation, a tracheotomy was performed in 2 patients in the EVC group and 8 patients in the surgical group. Postoperative course, clinical outcome, and systemic

complications are shown in Table 4. Patients in the EVC group had fewer days in the ICU. There were also fewer cases of hyponatremia (Na < 135 mmol/L) in this group. The GOS level was also significantly better in the EVC group than in the surgical group (P = 0.004). Perioperative and postoperative neurological complications are presented in Tables 5 and 6.

Discussion

Endovascular treatment of aneurysms has been done in Serbia since 2007. Vojvodina is a region in Serbia with about 2 million inhabitants, of whom about 1.5

Table 4. Postoperative course, clinical outcome, and systemic complications.

Variables	EVC	Neurosurgical
Duration of stay in intensive care (days)	2.6 ± 4.7*	3.6 ± 4.6
Duration of stay in hospital (days)	16.2 ± 19.3	15.6 ± 10.8
GOS at discharge	4.2 ± 1.2*	3.4 ± 1.3
Hyponatremia (n)	2*	15
Sepsis (n)	1	3
Pneumonia (n)	5	10
Perioperative heart ischemia (n)	0	4

Data are expressed as numbers or means ± SD.

GOS = Glasgow Outcome Scale

*P < 0.05

Table 5. Neurological complications before and during the intervention.

Complications	EVC	Neurosurgical
Vasospasm	3	10
Aneurysm rupture	1	12
Thromboembolism	1	0
Cerebral edema	0	9
Subdural/intracerebral hematoma	1	6

Data are expressed as numbers.

million have access to our neurosurgical clinic. The 30 patients with cerebral aneurysm who were treated by endovascular coiling during the 2-year interval represent a relevant number for the first analysis of this method in the Clinical Center of Vojvodina. In the present study, we focused on differences in anesthetic techniques, postoperative course, and complications between the endovascular and surgical treatment because the existing literature does not offer enough information about these issues.

Our study showed no significant differences between the EVC and the neurosurgical groups in relation to patient age, comorbidities (ASA score), and neurological status on hospital admission (WFNS score), which indicated that there were no special selections of patients for one or the other method at our university hospital. Decisions regarding appropriate treatment should be made by neurosurgeons and neuroradiologists according to the characteristics of the aneurysm and the general condition of the patient. Endovascular methods are advantageous in patients with serious cardiac and respiratory disorders and in those with posterior circulation aneurysms in the brain due to being less invasive on the body of the patient and having a shorter duration of the intervention, as shown in this study's results. Early treatment of ruptured cerebral aneurysms (1 to 3 days after rupture) performed in order to reduce the risk of rerupture is a common practice in our hospital (21). Nevertheless, many patients arrived at our hospital >3 days after rupture and intervention was carried out in the delayed period after easing the spasm (after day 14 of rupture). This problem must be solved by faster detection of disease

Table 6. Postoperative neurological complications.

Complications	EVC	Neurosurgical
Meningitis	1	4
Dysphasia	2	3
Vasospasm	4	14
Hemiparesis	6	11
Brain infarction	1	8
Hydrocephalus	2	5
Cranial nerve weakness	0	3

Data are expressed as numbers.

and more efficient transport of patients from the entire territory covered by the Clinical Center of Vojvodina. EVC patients waited longer for intervention because this group had more cases in which the intervention was performed at a delayed time.

In EVC interventions, either deep sedation or general anesthesia was applied (17). The benefits of general anesthesia include a complete state of rest in the patient for several hours and more efficient reactions to possible cardiovascular or respiratory system disorders. In all patients undergoing EVC or surgical treatment, all principles of safe neurosurgical anesthesia were applied (17,18). General anesthesia with a combination of sevoflurane and opioid analgesic (fentanyl or remifentanyl) was administered in both groups, except 5 patients in the surgical group who were administered total intravenous anesthesia (propofol + remifentanyl or fentanyl). The type of anesthesia was determined by the general condition of each patient and the personal preference of the attending anesthesiologist. The mean doses of each anesthetic administered for every EVC and NSC patient (sevoflurane, propofol, fentanyl, and midazolam) are presented in Table 2. Lower consumption of some anesthetics received in EVC group (fentanyl, propofol, and midazolam) is a consequence of the shorter duration of the intervention, reduced painful stimulus, and neurological status of the patient. Continuous infusion of remifentanyl was an important part of the general anesthesia for most of the EVC group, unlike the NSC group, because it can help with rapid postoperative awakening. Rapid postoperative awakening of patients with cerebral aneurysms is a

reliable indicator of both the patient's condition and the success of the intervention. In the EVC group, this goal was achieved much more frequently than in the surgical group. The reason for this was a shorter and less invasive intervention, accompanied by fewer intraoperative complications. The significantly lower concentrations of CO₂ at the end of expiration in surgical patients was not a surprise, since they have a greater need for hypocapnia that should decrease brain tension and ease the surgical approach to the aneurysm (15).

Regarding monitoring, anesthetic standards that apply to interventional neuroradiological procedures should not differ from standards in operating rooms (17). In the interventional radiology room, invasive arterial pressure measurement was applied as a part of the operating room standards for this type of procedure, together with the rest of the compulsory monitoring that includes an ECG, pulse oximetry, and capnography.

Analysis of hemodynamic stability during the procedure showed significantly more episodes of hypertension (>30% more than baseline) in the EVC group. That could have been caused by differences in the cardiovascular disease between the 2 groups, although this is statistically unproven. Due to frequent episodes of hypertension in the EVC group, significantly greater doses of the intravenous antihypertensive drug urapidil were used. In the surgical group, we had a greater consumption of the vasoactive drug ephedrine, which was usually necessary to achieve adequate arterial pressure values in surgical hemostasis. In every patient with acute subarachnoid hemorrhage, there is some degree of hypovolemia (18), which is why we paid special attention to the recompensation of fluid during the intervention. Unlike the findings of other studies (15,19), we did not have a statistically significant difference in the use of crystalloids and colloids between the groups. In the surgical group, we had significantly more postoperative tracheotomies because of the need for prolonged mechanical ventilation (22). The percentage of tracheotomies was higher than in other studies (5). This is because early tracheotomy is our practice 3 to 5 days after the initiation of mechanical ventilation in patients who are considered to have slower neurological recovery.

In the postoperative course, there was a significant difference in the number of days in the ICU, whereas the number of days spent in the hospital after intervention was similar to data from other studies (14). Among the systemic complications after the rupture of cerebral aneurysms, hyponatremia (Na < 135 mmol/L) due to a disturbance in the secretion of brain natriuretic hormone or antidiuretic hormone can be frequent (23). Sherlock et al. (24) showed a similar percentage of hyponatremia in both groups. This was in contrast to the present study and a study by Gupta et al. (5) in which significantly more cases of hyponatremia were noted in the surgical group. The percentage of perioperative and postoperative neurological complications (particularly vasospasm and cerebral infarction) was higher in the surgical group. These results are the consequence of the invasiveness and duration of the surgery and do not differ much from those of other studies (5,15,16,25). Compared with the surgical method, this is another advantage of the endovascular method for treating cerebral aneurysms.

Retrospective analysis of neurological status using the GOS at hospital discharge was the method we used to assess clinical outcome in both types of intervention. The time for determining the GOS score has its limitations, because it would have been more representative if the assessment had been done after 3 or 6 months, which we could not do due to lack of data for most patients. However, even data gathered in this way have a certain value and are used in many studies. Our results showed a significantly better GOS level in patients with EVC than in patients who were treated surgically (P = 0.004). These results are compatible with other authors' findings (3,5-8,14,15).

This study had several limitations. Due to the retrospective design, insufficient numbers of patients, uneven selection of patients, and data limited only to medical records, certain complications and problems could have been missed. The complete answer to the questions posed can be obtained only through a prospective and randomized study. However, the present study gives evidence for the beneficial effects of endovascular treatment of cerebral aneurysms, so our hospital will continue to practice this method together with surgical treatment.

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