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Endovascular treatment of cerebral aneurysms using hydraulically detachable coils

Wewnątrznaczyniowe leczenie tętniaków naczyń mózgowych przy uzyciu spirali odczepianych hydraulicznie

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Summary

Background: Authors analysed results of endovascular treatment using platinum hydraulically detachable coils in ruptured and unruptured cerebral aneurysms. The aim of the study was to evaluate the efficacy of the presented method and safety of the treatment for patients with cerebral aneurysms.

Material/Methods: Authors describe a clinical analysis in a group of 129 patients with 153 cerebral aneurysms treated with endovascular embolization in Department of Neurosurgery and Neurotraumatology of University of Medical Sciences in Poznań, Poland. 116 patients were hospitalized with a history of subarachnoidal hemorrhage, while 13 patients were without previous onset of bleeding. In bled group the clinical condition was assessed according to Hunt-Hess's scale. All patients were treated using Balt (MDS Pression) hydraulically detachable coils system. Based on angiographic examination results one evaluated the anatomical conditions of the aneurysm, its size, and relationship of the aneurysmal sac to its neck. Considering 116 patients with ruptured aneurysms, endovascular embolization within 72 hours was performed in 70 cases, in case of 46 patients the procedure was delayed.

Results: Complete occlusion of the lumen of the aneurysmal sac was achieved in 126 (82.3%) patients, while incomplete occlusion in 27 (17.7%). The efficacy of embolization was connected with the size and morphology of the aneurysm, as well as the relationship of the neck to the aneurysmal sac. Complete embolization was obtained specially in case of small aneurysms and those with a narrow neck.

Conclusions: Authors proof justness of transarterial embolisation as a highly effective first choice procedure of aneurismal sack exclusion from cerebral circulation.

Key words: **intracranial aneurysm • endovascular embolization • subarachnoid hemorrhage**

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Background

The development of endovascular methods in the treatment of cerebral aneurysms began in the sixties and seventies of the past century, initiated by Lussenhop, Velasquez and Serbinienko [1, 2].

The first embolization procedures in case of aneurysms were performed using balloons and unbound coils [1, 2]. The above-mentioned procedures were connected with increased risk of complications, which developed during the introduction of catheters into the vessels, as well as during dilatation of the aneurysm. The dynamic development of embolization techniques was observed in the nineties of the past century when detachable coils were used for the very first time. Initially, patients in severe general condition and those with posterior circulation vascular malformations were qualified towards endovascular procedures, due to surgical approach difficulties. Development of embolization techniques and availability of numerous coils, as well as better embolization equipment lead towards the qualification of patients with bleeding and non-bleeding aneurysms, considering endovascular procedures. Nowadays, the following coil systems are used in the endovascular treatment of cerebral aneurysms: hydrolytically, mechanically and hydraulically detachable coils. The latter are manufactured by two companies: Cordis, Johnson&Johnson (Trufil DCS) and Balt (MDS Pression). In case of our study patients MDS system hydraulically detachable coils were used.

The aim of the study was to evaluate the efficacy of the presented method and safety in the treatment of patients with cerebral aneurysms, using platinum hydraulically detachable coils, manufactured by Balt.

Material and methods

In the year 2005, 129 patients (81 female and 48 male) with 153 cerebral aneurysms were subjected to endovascular embolization treatment at the Department of Neurosurgery and Neurotraumatology of the University of Medical Sciences in Poznań. Seventeen patients were diagnosed with multiple aneurysms – 43, including five with 12 non-bleeding aneurysms, which were diagnosed by means of MR angiography confirmed by DSA examinations. Average patient age amounted to 46.3 years, ranging between 18 and 73 years.

Considering 153 aneurysms treated by means of endovascular embolization, 128 (83.6 %) were supplied in 116 patients with a history of meningocerebral hemorrhage, while 25 (16.4 %) in 13 patients were non-bleeding. In case of 116 patients with subarachnoid bleeding the clinical condition, according to Hunt-Hess's scale was as follows: I^0 – 15 (12.6%) patients, II^0 – 35 (30.6%) patients, III^0 – 42 (36.9%) patients, and IV^0 and V^0 – 24 (19.8%) patients. The distribution of Hunt-Hess and Fisher grades on admission are shown in table 1.

Table 1. Patient characteristics.
Tabela 1. Charakterystyka pacjentów leczonych wewnątrznaczyniowo.

Characteristics	No of Patients
All patients	129
Male/Female	48/81
Age	46.3 years (18–73)
Hunt and Hess grade	
I°	15 (12.6%)
II°	35 (30.6%)
III°	42 (36.9%)
IV° i V°	24 (19.8%)
Fisher grade	
0–2	57 (44%)
3–5	72 (56%)

All patients were subjected to CT and in selected cases to MR angiography, followed by selective DSA angiography of both carotid and vertebral arteries using the Philips Elegra apparatus. All angiographic examinations were performed by means of Seldinger's method from the femoral approach.

Based on angiographic examination results we evaluated the anatomical conditions of the aneurysm, its size, and relationship of the aneurysmal sac to its neck. Additionally, we determined the relationship of the aneurysm to arteries localized in the vicinity. Special attention was exempted to aneurysms branching of the M1/M2 segment of the middle cerebral artery. In case of anterior communicating artery aneurysms we precisely evaluated the blood inflow, and in case of one-sided aneurysmal filling the patency and width of the opposite A1 segment were determined.

The middle cerebral artery was the most common localization of aneurysmal embolization – 41 cases (26.8%), followed by the anterior communicating artery – 36 cases (23.5 %) (tab. 2 a and b).

All procedures were performed under general anesthesia, including 150 cases from the femoral approach and three from the carotid approach, due to significant atheromatous lesions and tortuosity of the brachiocephalic trunk and common carotid artery. The femoral approach used a 6F introducer (Balton), situated in the common femoral artery. A 6F Casasco director was introduced into the common carotid or vertebral arteries (Balt). Afterwards, a 10+ Vasco micro-catheter was inserted into the aneurysmal sac (Balt). Type J directors were used, 0.07–0.09 in diameter (Balt).

All aneurysms were supplied by means of hydraulically detachable embolization coils (Balt), compatible with the micro-catheter. MDS embolization systems are produced in two diameters: 0.010″ and 0.018″ thickness with different coil diameters and lengths, either 3D or helical. Additionally, in case of the 0.010″ diameter soft coils are available. The diameter of the produced coils ranges between 2 and 20 mm, while the length between 25 and 550 mm. After the introduction of the embolization coil into the aneurysmal sac the above-mentioned is released from the director by means of physiological saline stream pressure administered using a special syringe localized on the other end of the director, possessing an internal canal. The volume of physiological saline required for coil detachment ranges between 0.1–0.15 ml. After the release of the coil inside the aneurysmal sac the director is removed from the micro-catheter. During embolization patients received 5000 units of intravenous heparin. Additionally, macro- and micro-catheter lavage was performed using 0.9 % NaCl diluted with heparin at a dose of 1000 u/ liter.

Considering 116 patients with ruptured aneurysms, endovascular embolization up to 12 hours after bleeding was

Table 2 a. Aneurysm location.
Tabela 2 a. Lokalizacja tętniaków.

Localization of aneurysms – anterior part of Willis circle			
	Bleeding aneurysms	**Non-bleeding aneurysms**	**Total**
Internal carotid artery	10	6	16 (10.4%)
Ophthalmic artery	5	1	6 (3.9%)
Middle cerebral artery	36	5	41 (26.8%)
Pericallosal artery	5	2	7 (4.6%)
Anterior communicating artery	31	5	36 (23.5%)
Posterior communicating artery	17	3	20 (13.1%)

Table 2 b. Aneurysm location.
Tabela 2 b. Lokalizacja tętniaków.

Localization of aneurysms – posterior part of Willis circle			
	Bleeding aneurysms	**Non-bleeding aneurysms**	**Total**
Basilar artery	11	2	13 (8.4%)
Posterior cerebral artery	5		5 (3.2%)
Superior cerebellar artery	2		2 (1.3%)
Posterior inferior cerebellar artery	6	1	7 (4.6%)

performed in 10 (8.1%) patients, up to 24 hours in 22 (18.9%), up to 72 hours in 38 (32.4%), and in case of 46 (40.5%) patients the procedure was delayed. Most of the cases where coiled within 4–8 hours since admission.

In case of patients with multiple aneurysms, simultaneous embolization of two aneurysms was performed in seven patients. In the above-mentioned patients it was impossible to localize the ruptured aneurysm. In the remaining cases the second procedure was postponed, due to the risk of vasospasm or deterioration of the patients' clinical condition. Bleeding aneurysms were diagnosed on the basis of their shape and blood distribution in the cerebral fluid collections. Surgical procedures were also abandoned in case of non-bleeding aneurysms, when one observed an unfavorable coefficient of the size of the aneurysmal sac to the neck of the aneurysm. The above-mentioned was connected with fear of spring prolapse from the aneurysmal sac. Recurrent interventions in case of aneurysmal embolization were preceded by the modeling of the neck of the aneurysm using vascular stents or balloon remodeling.

In 133 cases embolization was performed by means of coils introduced into the aneurysmal sac, without additional vascular protection. Sixteen embolizations in case of aneurysms with a wide neck were preceded by nitynol Leo stent implantations (manufactured by Balt), while four required balloon remodeling.

At the end of the embolisation procedure patients were woken up (unless there were medical indications for artificial coma or the neurological status of the patient was too serious) and transfered to Neurosurgical Intensive Care Unit or Intensive Care Unit. In some cases radiological intervention had to be followed by neurosurgical ones (external drainage, haematoma removal etc). Anti-vasospasm therapy induced in every patient immidietly after admission (i.v. Nimotop administration, fluids), was extended with intensive triple-H therapy after embolisation. After four hours we started with the low-mass-weight-heparins (LMWH) with the patient-depending dose. In a cases of planned stent implantations patients were treated with salicylic acid and ticlopidinum before and after embolisation wheresas in urgent surgery theses drugs were administered postoperativly.

As a rule, we ordered every patient to have a DSA after a period of six months. Whenever the recanalisation was revealed the decision if to add coils or not was made by a team of radiologist and neurosurgeon.

Results

Complete occlusion of the lumen of the aneurysmal sac was observed in 126 (82.3%) patients (fig. 1 and 2), while incomplete occlusion in 27 (17.7%) (fig. 3).

Results of endovascular treatment correlated closely to the size of embolised aneurysms. Complete exclusion of aneurismal sack from intracranial circulation was achieved in majority of cases in small aneurysms less than 10 mm in diameter – ratio 104/112 (93%), For giant aneurysms ratio was 8/18 (44%) (tab. 3).

Figure 1 a. Anterior communicating artery aneurysm, filling from the right side. Visible segmental spasm of A1 part of anterior cerebral artery.
Rycina 1 a. Tętniak tętnicy łączącej przedniej, wypełniający się od strony prawej. Widoczny odcinkowy skurcz odcinka A1 tętnicy przedniej mózgu.

Figure 1 b. The same patient. DSA examination after complete aneurysm embolization.
Rycina 1 b. Ten sam chory. Badanie DSA po całkowitej embolizacji tętniaka.

Figure 2 a. Middle cerebral artery aneurysm in M1/M2 segment.
Rycina 2 a. Tętniak M1/M2 tętnicy środkowej mózgu.

Figure 2 b. The same patient. DSA examination after complete aneurysm embolization.
Rycina 2 b. Ten sam chory. Badanie DSA po całkowitej embolizacji tętniaka.

The second important parameter influencing treatment efficacy was aneurysms sack to neck coefficient. According to measurements of the aneurysmal sac/neck coefficient, which proved low and medium in most cases the risk of spring prolapse from the aneurysmal sac was significant (tab. 4). For wide neck aneurysms (coefficient < 1,5) treatment effects for detachable coils only without implanting of nitinol stent were worse comparing to those in aneurysms with narrow neck (tab. 5).

Limited vasospasm, which was observed directly after aneurysmal bleeding, was noted in 15 patients. The above-mentioned was of local character limited to the nourishing vessel. Diffuse vasospasm after bleeding was observed in three cases (fig. 4 a, b). The occurrence of a vasospasm and its extent correlated with the patients' clinical condition. In most cases these patients comprised the III^0 and IV^0 groups, according to the H-H scale. They required delayed embolization, and their condition improved after the administration of spasmolytic agents.

Four (2.6%) patients were diagnosed with intraoperative bleeding from the aneurysmal sac. In three cases the above-mentioned was caused by coil or micro-catheter perforation. In one patient, bleeding was observed after the administration Reo Pro, due to stent thrombosis. In two patients, hemorrhage concerned the basilar artery and in two, the anterior communicating artery. These complications were diagnosed in patients with ruptured aneurysms.

Figure 3 a. Middle cerebral artery aneurysm in M1/M2 segment. Widespread vasospasm of this artery.
Rycina 3 a. Tętniak M1/M2 tętnicy środkowej mózgu. Rozlany skurcz naczyniowy tętnicy środkowej mózgu.

Figure 3 b. The same patient. DSA examination after complete aneurysm embolization.
Rycina 3 b. Ten sam chory. Badanie DSA po całkowitej embolizacji tętniaka.

Table 3. The efficacy of embolization in correlation to the size of the aneurysm.
Tabela 3. Skuteczność embolizacji w zależności od wielkości tętniaka.

Embolization	Size		
	small	large	huge
Complete 126	104 (82.5%)	14 (11.1%)	8 (6.3%)
Incomplete 27	8 (29.6%)	9 (33.3%)	10 (37%)

Table 4. Size and sac/neck coefficient of the aneurysms.
Tabela 4. Wielkość tętniaków i współczynnik worek/szyjka.

Size of the aneurysm		Aneurysmal sac/neck coefficient		
		<1.5	1.6–2.5	>2.5
small <10 mm	112 (73.2%)	46	57	9
large 11–20 mm	23 (15.1%)	5	12	6
huge > 20 mm	18 (11.7%)	2	8	8
	153 (100%)	34%	50%	15%

Table 5. The efficacy of embolization in correlation to the aneurysmal sac/neck coefficient.
Tabela 5. Skuteczność embolizacji w zależności od współczynnika worek/szyjka.

Embolization	Aneurysmal sac/neck coefficient		
	< 1.5	1.6–2.5	> 2.5
Complete 126 (82.3%)	35 (27.7%)	48 (38%)	43 (34.1%)
Incomplete 27 (17.7%)	14 (51,8%)	11 (40,7%)	2 (7%)

Figure 4 a. Internal carotid artery aneurysm.
Rycina 4 a. Tętniak tętnicy szyjnej wewnętrznej lewej.

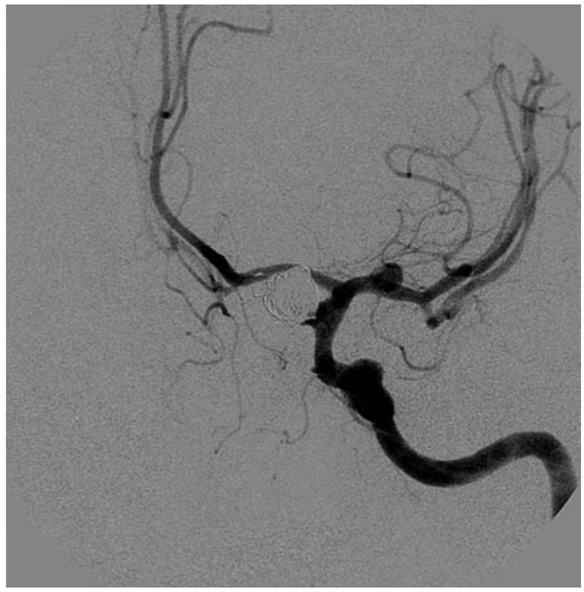

Figure 4 b. The same patient after treatment. DSA obtained after endovascular treatment shows the aneurysm filled with coils. A tiny residual neck is still visible.
Rycina 4 b. Ten sam chory. Badanie DSA po embolizacji tętniaka. Widoczne nieznaczne zakontrastowanie szyi tętniaka.

Direct complications connected with embolization comprised vasospasms, which lead towards ischemic cerebral stroke. The above-mentioned occurred most often in the elderly. In such cases intensive spasmolytic therapy proved inefficient. Vasospasm occurred in 23 cases and distant complications DID (delayed ischaemic deficyt) were noted in 18 patients. Mortality amounted to 6.2%, being connected with the extent of bleeding-hematocephalus, concomitant diseases (hypertension, diabetes, arteriosclerosis, cardiovascular insufficiency), and to a lesser extent with the embolization procedure.

The authors observed no significant changes in the appearance and character of embolized aneurysms between the 6 and 18 months. Most of our patients discharged in good general condition undergo control angiography between the 6 and 12 month after the procedure. In four cases additional coils had to be inserted after control angiography performed after one year, since initial treatment.

Discussion

The significant advantage of endovascular treatment is the possibility of combining complete diagnosis and the procedure of supplying the bleeding aneurysm. In the most studies there was the superiority of endovascular embolization over open surgery, including clipping demonstrated [3, 4]. The above-mentioned superiority concerned rapid aneurysmal clamping, avoidance of cerebral retraction during the surgical procedure and ensuing complications, as well as avoidance of increasing vasospasm following the administration of spasmolytic agents. Considering the time factor, one should note that the mentioned method is burdened with decreased risk of complications, independently of concomitant diseases, in comparison to treatment by means of craniotomy and clipping. Additionally, the approach and elimination of aneurysms in difficult accessible localizations, where the risk of intraoperative bleeding and ensuing complications might negatively influence treatment results seems to be another advantage. This is especially true of aneurysms localized in the posterior part of Willis' circle.

The efficacy of endovascular procedures in case of bleeding and non-bleeding aneurysms was mentioned by numerous authors [5, 6, 7]. Histopathological examination results performed on animal models confirmed the efficacy of platinum coil embolization, due to thrombogenesis [8]. Endovascular embolization in combination with incomplete aneurysmal clipping has also been described [9]. The introduction of embolization material into the clipped residual aneurysm seems safer, as compared to re-craniotomy. Many authors consider each residual aneurysm after clipping as the potential source of bleeding. Endovascular embolization is becoming more widely used, even in case of non-bleeding aneurysms diagnosed on the basis of MR angiography, not always confirmed by means of DSA examinations. In such cases, precise endovascular treatment qualification seems essential, considering all possible risk factors [5, 10, 11, 12].

The advantage of hydraulically detachable coils consists in the full control of the embolization material, even after the protrusion of the micro-catheter. The availability of 3D coils is another advantage, which seems especially important in case of an unfavourable aneurysmal neck/sac coefficient, stabilizing the coils in case of large aneurysms.

The disadvantage of the above-mentioned system, especially in case of bleeding aneurysms consists in the release of coils by means of a stream of normal saline, which after detachment penetrates the aneurysmal sac under significant pressure responsible for possible rupture. Cloft and Kallmes [11] described aneurysmal sac rupture as a complication of GDC coil embolization, based on the analysis of 17 different publications. The above-mentioned authors determined the risk of aneurysmal sac rupture amounting to 4.1% in case of bleeding and 0.5% in case of non-bleeding aneurysms. Considering our material, we noted bleeding in four cases during the embolization of 153 (2.6%) aneurysms.

In case of bleeding uncomplicated by intracerebral hematoma and vasospasm, hospitalization has significantly shortened. Considering our study patients recurrent bleeding was not observed, as mentioned by some authors [10, 11, 13, 14, 15, 16]. What seems disturbing is the difficulty in foreseeing the arrangement of coils in the aneurysmal sac, which is responsible for the development of thrombi and potential source of embolism. Partial recanalization of the aneurysmal sac is caused by the thrombolytic effect, as well as the translocation of coils, due to the stream of blood. Other authors [7, 13, 17, 18] presented different results concerning the filling of the aneurysmal sac and recanalization. Służewski and co-authors [12] evaluated 160 angiographic results, considering patients subjected to endovascular procedures (mean observation period: 37 months), demonstrating recanalization in 9% of patients (aneurysms >15 mm). After reoperation 7% demonstrated incomplete occlusion and 5% were subjected to a third procedure [12].

Conclusions

1. The presented technique using hydraulically detachable coils proved highly effective in the embolization of cerebral aneurysms, and was not connected with the occurrence of direct procedure complications unique for hydraulically detachable coils.

2. The most common complication observed during the procedure was the occurrence of a vasospasm and disseminated intravascular clotting which are typical embolisation procedure complications. The amount of those was similar to other literature series.

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