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Risk factors and clinical and neurological consequences of intraoperative rupture of brain aneurysms in microsurgical operations

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Keywords
AA-arterial aneurysm, IOC-intraoperative complications, SAH-subarachnoid haemorrhage, IORA-intraoperative rupture of aneurysm

ABSTRACT

Objective. to assess the frequency, risk factors and clinical and neurological consequences of intraoperative rupture of arterial aneurysm (AA) of the brain (B) in clipping operations of the B AA.

Materials and approaches. A retrospective analysis of microsurgical operations clipping of cerebral aneurysms in 1449 (100%) patients for the period from 2011 to 2018 was performed, of which 141 (9.73%) cases had intraoperative rupture of the aneurysm (IORA). Preoperative examination: clinical and neurological examination, CT of the brain, cerebral angiography (CAG), duplex scanning of the main vessels of the head and neck. The analyzed criteria are risk factors of IORA: AA size, localization, shape, duration of surgery after the primary rupture of AA, the presence of hypertension and the patient's condition before surgery.

Results. The frequency of IORA in clipping operations of B AA was 9.73% (141 patients) in a series of observations 1441 (100%). Most often IORA-141 (100%) was registered in clipping operations of AA of complex ACA-AcomA (86 (61%) cases out of 141 (100%)). IORA is possible at all stages of the operation with the maximum frequency of contact breaks – 135 (95.74%); the rarest-6 (4.26%) - non - contact IORA (at the stage of craniotomy) was recorded. At the preoperative stage, the vast majority of patients with subsequent IORA were diagnosed with cerebral edema, AA of large size, atherosclerotic changes in the aneurysm-affected segment of the artery and cervical areas of the aneurysm, high blood pressure during surgery, adhesive arachnoid changes. At the time of discharge from the hospital, according to the Glasgow results scale: 69 (48.94%) full or partial restoration of labor activity, 18 (12.77%) had limited daily activities without the need for outside assistance, 37 (26 24%) deep disability) Deaths were in the group of "contact" IORA - 17 (12.06%). At 6 (4.26%) of "non-contact" IORA, a deepening of initial neurological symptoms was recorded with a suppression of the level of consciousness, the addition of pyramidal insufficiency, speech impairment and psycho-organic syndrome, and a deepening of the phenomena of initial cerebral arterial vasospasm.

Conclusions. IORA is predominantly in contact with a frequency of occurrence-9.73 %. The most common risk factors for IORA were: cerebral edema, large AA, atherosclerotic changes in the aneurysm-affected artery segment and cervical

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aneurysm sites, high blood pressure during surgery, adhesions arachnoid changes. IORA leads to deepening of initial neurological symptoms, phenomena of initial vasospasm of cerebral arteries with the level of total mortality-17 (12.06%).

Introduction. Essays on the history of brain aneurysm surgery

The first description of cerebral aneurysm belongs to Weissmann in May 1676. It took two centuries until Hodson (1815) and Bramwell (1886) established that the extravasation of blood into the subarachnoid space is a consequence of the rupture of an intracranial aneurysm and called this form of "subarachnoid" hemorrhages (HSA)[22].

The start of brain aneurysm surgery is provided by the Scottish neurosurgeon Dot, who in 1933 published two cases of microsurgical exclusion of a cerebral aneurysm from the bloodstream by enveloping the aneurysm with a piece of muscle [1]. On March 23, 1937, Walter Dandy first excluded a SAC-shaped aneurysm of the right internal carotid artery from the bloodstream by clipping the neck of the aneurysm with a metal clip to a 43-year-old patient. In 1944 Walter Dandy published the first monograph devoted to the surgical treatment of brain aneurysms, in which the author publishes the results of surgical treatment of 107 patients with various localisations of aneurysms, thereby demonstrating that patients with such a complex pathology necessarily require surgery [3].

Nowadays microsurgical and endovascular approaches are used in aneurysm surgery (Konovalov A. N., 1973; Oleshkevich F. V., 1973; Zozulya Yu. A., 1986; Romodanov A. P. et al., 1990; Shcheglov V. I., 1998; Serbinenko F. A., 1971; Suzuki J., 1979; Yasargil GM, 1984).

The first method of surgical treatment of brain aneurysms was carotid artery ligation, which was used by A. Pare (1510-1590) as a method of stopping arterial bleeding in victims with neck wounds. For decades, it was the only possible method of surgical treatment of AA, which at the end of the XIX century. widely used by the founders of neurosurgery (Horsley, 1891; Shing, 1911). The latter described AA as random finds of " cysts that pulsate."

In 1960, removable clips, which are widely used in AA surgery were proposed. In the 1970s, neurosurgery began to use the operating microscope. Given the rapid development of cerebrovascular neurosurgery, in particular microsurgical clipping of brain aneurysms, in the 1980s and 1990s, a large number of publications appeared on the problem of intraoperative complications (IOC), including intraoperative ruptures of aneurysms (IORA), with clipping of cerebral aneurysms [1].

But despite the historical development and achievements of modern neurosurgery, cerebral IORA remains the most frequent IOC [2,3,4]. There are contact and non-contact IORA. Contact include IORA, which occur during direct mechanical action on the aneurysm: during the retraction of the medulla with a spatula, during arachnoid dissection, clipping the neck of a sacculated aneurysm. IORA, which occurs in the early stages of an operation, is considered non-contact, prior to the dissection of the dura mater (DM), when there is no mechanical effect on the aneurysm (when shifting the patient on the operating table, induction of anesthesia, osteoplastic trepanation). According to the literature [9,10] contact IORA occur in 91-94% of cases, non-contact IORA-2.5-9% of cases. The main criteria and risk factors, which affect the frequency of IORA, consider the size of the aneurysm, its location, shape, duration of surgery after the primary rupture of the aneurysm, the presence of hypertension and the severity of the patient's condition before surgery [11,12,13,14,15,16,17,18]

The size of the aneurysm. Most authors believe that non-contact IORAs are more likely to be expected in small aneurysms (5-6 mm), and contact IORAs in large aneurysms (more than 15 mm), as they are more difficult to isolate and exclude from the bloodstream [6,14].

Localization of AA. The greatest risk for IORA is represented by aneurysms of ACA-AcomA and ICA complex [19] through hemodynamic prerequisites and a high frequency of such aneurysms (23.2-40.3%) [20].

The severity of the patient's condition before surgery. To date, a clear relationship between IORA and the severity of the patient before surgery has not been established. Some authors indicate that the incidence of IORA is higher in patients with severity of IV-V degree according to the Hunt–Hess scale [18,21]. However, J. Schramm and C. Cedzich (1993), P. D. Le Roux et al. (1996), T. Inagawa (1999) have not established a clear dependence of the frequency of IORA on the severity of patients according to the Hunt-Hess scale.

Time of surgery after a primary AA rupture. Surgery in the early stages after the primary rupture of the aneurysm, in the presence of cerebral edema, with difficulty in accessing AA, the need to perform sufficient traction of the cerebral substance is often accompanied by IORA [5,7,11,12,15,11].

Methods and materials

A retrospective analysis of the surgical treatment of 141 patients with intraoperative ruptures in the course of clipping of brain aneurysms, out of the total number of 1449 operated patients in the period from 2011 to 2018, was performed. The age of the patients ranged from 19 to 78 years (average age-46.7 + 11.6 years). Males-71 (50.35%), females-70 (49.65%). After primary rupture 121 (85,82%) patients were operated, repeated rupture was observed in 20 (14,18%) patients.

Perioperative examination of patients included clinical and neurological examination, brain CT scan, cerebral angiography (CAG), ultrasound (US) duplex scanning with a color Doppler mapping of the head and neck vessels mode and transcranial Doppler (TCD) was performed in all patients according to the standard methods at admission and in dynamics of perioperative period every 2 days, and in severe cases, daily. The severity of vasospasm (BC) was established by the complex of data of CAG and TCD, the following US criteria were used: the severity of distinct degree-systolic linear velocity (syst. linear velocity of blood flow) > 240 cm/s, critical degree-syst. linear velocity of blood flow>300 cm/s.

Subarachnoid (SAH) hemorrhage was detected in 67 (47.52%) patients, subarachnoid parenchymal hemorrhage – in 49 (34.75%) patients; subarachnoid ventricular – in 6 (4.26%) patients; subarachnoid parenchymal-ventricular – in 19 (13.46%) patients; SAH complicated by the formation of intracerebral hematoma – in 50 (35.46%) patients.

In the acute period of AA rupture (the first 21 days) 127 patients were operated (73 patients-the first 3 days; 35 patients-4-7 days after the rupture; 15 patients-8-14 days; 4 patients-15-21 days, 22 days and later-14 patients (Tab.1).

The period from the moment of AA rupture prior the operation	Number of patients	
	N	P, %
1-3 days	73	51.77
4-7 days	35	24.82
8-14 days	15	10.64
15-21 days	4	2.84
After 21 days	14	9.93
Total	141	100

Table 1. Term of operation after the last AA rupture

Before the operation, the severity of the patients' condition was assessed according to the Hunt-Hess scale (Tab.2), the level of consciousness according to the Glasgow coma scale.

Among the patients operated in early terms patients with severity of a condition of III-IV degree on H-H prevailed. With the increase in the duration of the operation, the proportion of patients in a compensated state (I-II degree according to H-H) increased.

Severity of the condition according to the scale of the Hunt-Hess	Number of patients	
	N	P, %
I	34	24.11
II	61	43.26
III	37	26.24
IV	5	3.55
V	4	2.84
Total number	141	100.00

Table 2.

Consciousness before the operation was clear in 86 (62.41%) patients, moderate stunning-in 32 (22.70%) patients, deep stunning – in 13 (9.22%), SOPOR-in 3 (2.13%), moderate coma (according to GCS 6-7 points) – in 1 (0.71%) patient, deep coma (according to GCS 4-5 points) – in 4 (2.84%) patients.

Focal neurological disorders before surgery were in 40 (28.37%) patients. In 13 (9.42%) patients there were violations of motor functions of the Central type, 17 (12.32%) - oculomotor disorders, 6 (4.35%) - a combination of paresis and oculomotor disorders, 1 – a combination of motor and mental disorders, 2 (1.45%) – a combination of motor and afatic disorders.

Computer tomography. All patients underwent brain CT before a surgery. Intracranial haemorrhage was assessed by CT scan (Fig.3) According to the scale of C. M. Fisher et al. (1980) (Tab. 4). The presence of cerebral edema or cerebral ischemia,

lateral or axial displacement were also taken into account.

The nature of the hemorrhage	Number of patients	
	Ab.	%
Subarachnoid	67	47,52%
Subarachnoid parenchymal	49	34,75%
Subarachnoid ventricular	6	4,26%
Subarachnoid parenchymal ventricular	19	13,46%
Total	**141**	**100**

Table 3. The nature of intracranial hemorrhage.

Degree of SAH		Number of patients	
		Ab.	%
I	Blood in the liquor spaces is not visualized	5	3.62
II	Diffuse hemorrhage or vertical size in the cistern less than 1 mm	73	52.90
III	The apparent convolution in the cistern or the vertical size of the blood signal in the cistern is more than 1 mm	54	39.13
IV	Intracerebral or intraventricular hemorrhage	6	4.35
Total		**138**	**100**

Table 4. Degree of SAH according to the Fisher scale.

Cerebral angiography. All patients underwent cerebral angiography at the planning stage of the operation. According to the results of CAG, 135 (95.74%) patients had single aneurysms, 6 (4.26%) had multiple aneurysms (Table. 5).

Localization of aneurysm (rupture)	Number of patients	
	Ab.	%
ACA-AcomA on the left	47	33.33
ACA-AcomA on the right	36	25.53
MCA on the left	9	6.38
MCA on the right	17	12.06
ICA on the left	11	7.80
ICS on the right	14	9.93
PICA on the left	0	0
PICA on the right	1	0.71
Multiple AA	ACA-AcomA AA rupture	6	3	4.26	2.13
	MCA AA rupture		1		0.71
	ICA AA rupture		1		0.71
	PICA AA rupture		1		0.71

Table 5.

Transcranial Doppler. TCD in the perioperative period was carried out in all cases: before surgery 25 (17.73%) patients, after surgery - in all cases (100 %). With an increase in the linear velocity of blood flow through the arteries of the base of the brain more than 120 cm/s and the value of the Lindegaard index more than 3, vascular spasm was considered moderate, with a blood flow rate exceeding 200 cm/s and the value of the Lindegaard index more than 6 - expressed. Angiospasm was assessed as non-widespread if it covers 1-2 arteries of the arterial circle of the brain, and was considered common with spasm of 3 or more arteries. Among the examined patients before surgery angiospasm was detected in 11 (7.80%) patients (Tab.6).

The degree of vasospasm	Number of patients (out of 141)		Number of patients (out of 11)	
	Ab.	%	Ab.	%
I	10	7.09	10	90.91
II	1	0.71	1	9.09
III-IV	0	0	0	0

Table 6.

Surgical interventions. All patients underwent microsurgical interventions. In 107 (75.89%) patients clipping of aneurysm with blood washing from basal cisterns was performed, in 22 (15.60%) patients – clipping of aneurysm was combined with removal of intracerebral hematoma, in 3 (2.13%) patients – clipping of aneurysm of was combined with external ventriculostomy, in 6 (4.26%) patients operated on vital indications due to dislocation syndrome and

volume intracranial hemorrhage - clipping of the aneurysm, removal of intracerebral hematoma and decompression trepanation of the skull were performed. Intraoperative assessment of the blood flow in the aneurysm-affected arterial segments of cerebral arteries and radicality of clipping was assessed using intraoperative contact dopplerography with a 20 Hz sensor. In the postoperative period, MSCT-angiography and CAG were performed.

Results and discussion

Treatment results were assessed at hospital discharge according to the Glasgow results scale (Jennett B., Bond M., 1975). This scale includes 5 stages (Tab.7).

Value	Number of points
Recovery of the patient without neurological disorders, or with minimal deficiency. Complete or partial recovery of labour activities.	5
Moderate disability. Neurological disorders that limit daily activities, but the patient does not need help.	4
Deep disability. The patient needs outside care	3
Vegetative state or a deep psycho-organic disorders	2
Death	1

Table 7.

Satisfactory results were recorded in most cases – 81 (61.71%) at the time of discharge from the hospital: complete or partial resumption of work – 69 (48.94%), recovery of labour activities without the need for assistance was 18 (12.77%) according to the Glasgow results scale (Tab.8).

Number of points (Glasgow results scale))		Description	Number of patients	
			Ab.	%
5	Complete recovery	Recovery of the patient without neurological disorders, or with minimal deficiency. Complete or partial recovery of labour activities.	69	48.94
4	Moderate disability	Neurological disorders that limit daily activities, but the patient does not need help.	18	12.77
3	Deep disability.	The patient needs outside care	37	26.24
2	Vegetative state	-	0	0
1	Death	-	17	12.05

Table 8. Glasgow results scale

Recorded IORA dominated on the stages of the isolation and clipping of AA – 126 (89.36%) (Tab. 9).

The stage of the operation at which the AA rupture occurred	Number of patients	
	Ab.	%
Non-contact (at the stage of craniotomy)	6	4.26
Early arachnoid dissection	3	2.13
When the affected AA artery is isolated	6	4.26
When an aneurysm is isolated	119	84.40
At the stage of aneurysm clipping	7	4.96

Table 9. The frequency of IORA at different stages of surgical interventions.

Non-contact AA rupture was recorded in 6 (4.26%) patients out of 141 (Tab.10), men 4 (2.84%), women 2 (1.42%), age from 40 to 52 years; 5 (3.55%) patients underwent clipping of single aneurysms, in 1 (0.71%) – multiple (ACA-AcomA on the right and MCA on the right); in all cases, the aneurysms were of medium size (from 4.0 mm to 14 mm); 3 (2.13%) patients were operated after primary hemorrhage, 3 (2.13%) – after repeated AA ruptures; 2 (1.42%) patients had SAH and 4 (2.84%) - subarachnoid parenchymal hemorrhage with the formation of intracerebral hematoma.

The frequency of non-contact rupture in our observations was 4.26%. Features of the manifestation of non-contact rupture of AA during surgery were: signs of arterial bleeding with basal spread and signs of edema-swelling of the brain, which were associated with spontaneous short-term (up to several minutes) fluctuation of blood pressure (not significant in relation to the systemic hemodynamics). Two (1.42%) patients were operated on the first 3 days after SAH, 2 (1.42%) – on the 4-6th day after rupture, 1 (0.71%) - on the 9th day after the last AA rupture, 1 (0.71%) – on the 16th day.

In all cases of non-contact rupture of AA, all further stages of surgery: isolation of the arterial segment affected by the aneurysm, isolation of the initial sections of the perforant arteries, neck and body of AA itself, clipping of the aneurysm, were performed using the technique of gradual temporary blocking of blood flow in the proximal segments of the cerebral arteries in relation to the location of the aneurysm. Thus, the gradual blocking of segments of cerebral arteries on the affected side from the proximal segment of the internal carotid artery (ICA) aneurysm to the affected segment (A1 segment of the ACA or the M1 segment of MCA) with a stages offset of clips for temporary locking in the distal direction to the arterial segment affected by the aneurysm and reperfuse of pre-blocked (proximal) segment was performed to 3 (2,13%) patients, in 3 (2,13%) cases a temporary blockage of blood flow to highlight the AA and its clipping of an arterial segment directly affected by the aneurysm (A1 segment of the ACA or the M1 segment of MCA) was technically possible . In the postoperative period, the secondary cerebral ischemia as a result of strengthening of the phenomena of initial cerebral angiospasm in conjunction with the duration of temporary blocking of blood flow, which exceeded 5 minutes, was observed in 2 (1.42%) patients with non - contact intraoperative breaks AA MCA, according to MSCT of the brain.

Operation	AA localization	AA size (mm)	Number of chambers	The period after a rupture	Number of patients			
					Ab.	%	Ab.	%
AA clipping. Rehabilitation of basal cisterns	ACA-AcomA on the right	4-14	Single-chamber	After 21 days	1	0.71	2	1.45
	MCA on the right	4-14	Single-chamber	On the 8-14th day	1	0.71		
AA clipping. Sanitation of the basal cisterns. Removal of I/M stroke-hematoma.	MCA on the right	4-14	Single-chamber	First 3 days	1	0.71	2	1.45
				4-7 days	1	0.71		
AA clipping. Sanitation of the basal cisterns. Removal of I/M stroke-hematoma. Decompressive craniotomy.	ACA-AcomA on the right	9	Single-chamber	First 3 days	1	0.71	1	0.72
AA clipping. Blood washing from the basal cisterns. Decompressive craniotomy.	ACA-AcomA on the right	4-14	Single-chamber	5th day	1	0.71	1	0.72

Table 10. Operation for a non-contact rupture of B AA.

Angiospasm in the early postoperative period was observed in the vast majority-5 (83, 33%) out of 6 (100%) patients with non-contact IORA (Tab.11).

Angiospasm	Number of patients (out of 141)		Number of cases (out of non-contact ruptures -6)	
	Ab.	%	Ab.	%
I degree	0	0	0	0
II degree	3	2.13	3	50.00
III degree	2	1.42	2	33.33
IV degree	0	0	0	0
The absence of vasospasm	1	0.71	1	16.67

Table 11. Angiospasm after surgery.

In all patients with angiospasm in the postoperative period, there was a deepening of the initial neurological symptoms in the form of the

appearance or deepening of pyramidal insufficiency, motor, sensory aphasia or mental disorders. In 1 patient operated on for ACA-AcomA AA on the left, in the postoperative period, right-sided hemiparesis joined; in 1 patient operated on for rupture of SA MCA on the right with the formation of intracerebral hematoma in the postoperative period, there were signs of psychoorganic syndrome (Walter-Buehl triad) according to the explosive type with psychotic complications; in 3 patients, the symptoms combined paresis (sensorimotor, motor aphasia) and organic PSYCHOSYNDROME.

Contact intraoperative AA rupture was observed in 135 (100%): men – 67 (49.6%), women – 68 (50.4%), which was 95.74% of 141 cases (100%). Age of patients - from 19 to 68 years. The vast majority of patients with contact IORA were operated for ACA-AcomA AA (Tab. 14). In 4 (2.96%) cases there were multiple AA: ACA-AcomA (3 cases) and ICA.

Localization of aneurysm		Number of patients	
		Ab.	%
ACA-AcomA	On the left	47	34.81
	On the right	38	28.15
MCA	On the left	9	6.67
	On the right	14	10.37
ICA	On the left	12	8.89
	On the right	14	10.37
PICA	On the left	0	0
	On the right	1	0.74
Total		135	100

Table 12. Localization of B AA complicated by contact IORA.

The degree of consciousness according to the GCS before surgery in 84 (62.22%) patients was clear, in 30 (22.22 %) was impaired by the type of moderate stunning; in 13 (9.63%) - deep stunning; in 3 (2.22%) – sopor; in 1 (0.74%) – moderate coma (according to the GCS 6-7 points); in 4 (2.97%) - deep coma (according to the GCS 4-5 points).

Out of 71 (52.59%) patients operated on in the first 3 days after AA rupture, 32 (23.7%) patients had SAH; 22 (16.29%)-subarachnoid parenchymal hemorrhage; 3 (2.22%)-subarachnoid ventricular hemorrhage; 14 (10.37%) - subarachnoid parenchymal-ventricular hemorrhage.

The overall mortality rate after IORA was 17 (12.06%) cases out of 141 (100%) cases, whereat deaths in the contact IORA group – 17 (12.6% out of 135 (100%)). Although according to the literature, a significant increase in the number of fatal cases is observed after early IORA, which occurred at the stages of craniotomy before the opening of TMO and the beginning of arachnodal dissection, when there is no possibility of direct control of bleeding from the aneurysm by temporary or permanent blocking of the neck or body of the aneurysm, or the imposition of a temporary clip on the affected segment of the artery, there was no such trend in the analyzed series of observations. However, there was a significant increase in the number of cases of deepening of the initial neurological symptoms in the group of patients with non-contact IORA, which probably, given a larger sample, could be associated with an increase in the number of deaths.

Table 13. Operations on B AA complicated by contact IORA.

Surgical interventions in the first 3 days after AA rupture (81)								
Operation	AA localization	AA size (mm)	Number of chambers		Number of patients			
					Ab.	%	Ab.	%
AA clipping. Rehabilitation of basal cisterns	ACA-AcomA	On the left	4-14	single-chamber	37	26.24	14	9.93
		On the right	15-24	multichamber			3	2.13
			4-14	single-chamber			8	5.67
			up to 3	single-chamber			1	0.71
	MCA on the right	4-14	single-chamber				3	2.13
		15-24	multichamber				1	0.71
	ICA	On the left	4-14	single-chamber			1	0.71
			5-24	single-chamber			1	0.71
		On the right	4-14	single-chamber			5	3.55

AA clipping. Sanitation of the basal cisterns. Removal of I/M stroke-hematoma.	ACA-AcomA	On the left	15-24	double chamber	36	25.53	1	0.71
			4-14	single-chamber			2	1.42
				double chamber			1	0.71
				three-chamber			1	0.71
			up to 3	single-chamber			2	1.42
		On the right	15-24	multichamber			1	0.71
			4-14	single-chamber			5	3.55
				multichamber			1	0.71
			up to 3	single-chamber			1	0.71
	MCA	On the left	4-14	single-chamber			3	2.13
			Up to 3	single-chamber			1	0.71
		On the right	15-24	single-chamber			1	0.71
				multichamber			1	0.71
			4-14	single-chamber			5	3.55
			Up to 3	single-chamber			1	0.71
	ICA	On the left	15-24	single-chamber			1	0.71
			4-14	single-chamber			1	0.71
		On the right	giant	double chamber			1	0.71
			4-14	single-chamber			6	4.26
AA clipping. Drainage of the ventricular system.	PICA on the right	7	single-chamber		1	0.71	1	0.71
AA clipping. Removal of I/M hematoma. Decompressive craniotomy.	ACA-AcomA	On the left	4-14	single-chamber	6	4.26	4	4.26
		On the right	15-24	multichamber			1	0.71
	MCA on the left	4-14	single-chamber				1	0.71
AA clipping. Blood washing from the basal cisterns. Decompressive craniotomy.	ACA-AcomA on the right	4-14	single-chamber		1	0.71	1	0.71

Surgical interventions for 4-7 days after AA rupture - 34

Operation	AA localization	AA size (mm)	The presence of diverticula, q-ty of chambers		Number of patients			
					Ab.	%	Ab.	%
AA clipping. Rehabilitation of basal cisterns	ACA-AcomA	On the left	15-24	single-chamber	24	17.02	1	0.71
				multichamber			1	0.71
			4-14	single-chamber			5	3.55
			up to 3	single-chamber			1	0.71
		On the right	15-24	multichamber			2	1.42
			4-14	multichamber			1	0.71
				single-chamber			4	2.84
			up to 3	single-chamber			1	0.71
	MCA	On the left	15-24	multichamber			1	0.71
		On the right	4-14	single-chamber			1	0.71
	ICA	On the left	giant	multichamber			1	0.71
			4-14	single-chamber			2	1.42
		On the right	15-24	multichamber			1	0.71
			4-14	single-chamber			2	1.42
AA clipping. Sanitation of the basal cisterns. Removal of I/M stroke-hematoma.	ACA-AcomA	On the left	4-14	single-chamber	9	6.38	2	3.62
		On the right	Up to 3	single-chamber			1	0.71
			4-14	single-chamber			1	0.71
	MCA	On the right	4-14	single-chamber			2	1.42
	ICA	On the left	4-14	single-chamber			2	1.42
		On the right	Up to 3	single-chamber			1	0.71

AA clipping. Drainage of the ventricular system.	MCA on the left	4-14	single-chamber	1	0.71	1	0.71	

Surgical interventions on the 8-14th day -14 (9,93%)

Operation	AA localization	AA size (mm)	The presence of diverticula, q-ty of chambers		Number of patients			
					Ab.	%	Ab.	%
AA clipping. Rehabilitation of basal cisterns	ACA-AcomA	On the left	4-14	single-chamber	12	8.51	1	0.71
				multichamber			1	0.71
		On the right	4-14	single-chamber			2	1.42
			up to 3	double chamber			1	0.71
	MCA	On the left	4-14	single-chamber			1	0.71
		On the right	15-24	multichamber			1	0.71
			4-14	multichamber			1	0.71
	ICA	On the left	4-14	multichamber			1	0.71
				single-chamber			1	0.71
		On the right	Up to 3	single-chamber			2	1.42
AA clipping. Sanitation of the basal cisterns. Removal of I/M stroke-hematoma.	ACA-AcomA	On the left	4-14	double chamber	2	1.42	1	0.71
		On the right	15-24	multichamber			1	0.71

Surgical interventions on the 15-21 day -11 (7,8%)

Operation	AA localization	AA size (mm)	The presence of diverticula, q-ty of chambers		Number of patients			
					Ab.	%	Ab.	%
AA clipping. Rehabilitation of basal cisterns	ACA-AcomA	On the left	15-24	multichamber	10	7.09	1	0.71
			4-14	single-chamber			2	1.42
				multichamber			1	0.71
			up to 3	single-chamber			1	0.71
		On the right	4-14	Single-chamber			1	0.71
	MCA on the right	4-14	Single-chamber				1	0.71
	ICA	On the left	4-14	multichamber			1	0.71
		On the right	4-14	single-chamber			2	1.42
AA clipping. Blood washing from the basal cisterns. Decompressive craniotomy.	ICA on the left	4-14	single-chamber	1	0.71		1	0.71

Surgical interventions after 21 days-13 (9,22%)

Operation	AA localization	AA size (mm)	The presence of diverticula, q-ty of chambers		Number of patients			
					Ab.	%	Ab.	%
AA clipping. Rehabilitation of basal cisterns	ACA-AcomA	On the left	15-24	multichamber	13	9.22	1	0.71
			4-14	single-chamber			3	2.17
			Up to 3	single-chamber			1	0.71
		On the right	4-14	single-chamber			1	0.71
				multichamber			1	0.71
	MCA	On the left	4-14	multichamber			1	0.71
		On the right	4-14	single-chamber			1	0.71
	ICA	On the left	4-14	multichamber			1	0.71
				single-chamber			1	0.71
		On the right	4-14	single-chamber			2	1.42

Summary

1. The frequency of IORA in B AA clipping operations was 9.73% (141 patients) in a series of observations 1441 (100%). According to our observations, most often IORA-141 (100%) was registered in operations pf clipping of AA complex ofACA-AcomA (86 (61%) cases out of 141 (100%)).

2. IORA is possible at different stages of the aneurysm clipping operation with a maximum frequency of contact breaks -135 (95.74%): at the stage of AA isolation (119 cases-84.40%), with the imposition of a clip on the neck of AA - 7 (5.07%), with the isolation of the artery affected by aneurysm 6 (4.26%) and with arachnoid dissection – 3 (2.17%). Non-contact IORA (at the stage of craniotomy) was recorded less often-6 (4.26%).

3. The most common risk factors for IORA were: cerebral edema, large AA, atherosclerotic changes in the aneurysm-affected artery segment and cervical aneurysm sites, high blood pressure during surgery, adhesions arachnoid changes.

4. At the time of discharge from the hospital, according to the Glasgow results scale: 69 (48.94%) full or partial restoration of labor activity, 18 (12.77%) had limited daily activities without the need for outside assistance, 37 (26 24%) deep disability) Deaths were in the group of "contact" IORA - 17 (12.06%). At 6 (4.26%) of "non-contact" IORA, a deepening of initial neurological symptoms was recorded with a suppression of the level of consciousness, the addition of pyramidal insufficiency, speech impairment and psycho-organic syndrome, and a deepening of the phenomena of initial cerebral arterial vasospasm.

Abbreviations

AA – arterial aneurysm; SA– sacculated aneurysm; IOC – intraoperative complications; SAH – subarachnoid hemorrhage; BP – blood pressure; IORA– intraoperative aneurysm rupture; TC – temporary clipping; ACA-AcomA– anterior cerebral - anterior communicating artery; MCA– middle cerebral artery; ICA – internal carotid artery; PICA– posterior inferior cerebellar artery; IAH – induced arterial hypotension; H-H – Hunt-Hess scale; GCS – Glasgow coma scale; CAG – cerebral angiography; MSCT – multispiral computed tomography.

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