Original article

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Plastic closure of bone defects of anterior cranial fossa floor in surgery of benign and malignant craniofacial tumors

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Objective: to analyze the results of using various methods of plastic closure of bone defects of the anterior cranial fossa (ACF) floor when removing craniofacial tumors of the ACF floor depending on the size of the defect.

Materials and methods. A retrospective analysis of treatment outcomes of 122 patients with craniofacial tumors of the ACF floor was carried out. According to the nature of the lesions malignant craniofacial tumors were detected in 98 (80.3%) patients, and benign ones in 24 (19.7%) patients. The following neurosurgical approaches to craniofacial tumors of the ACF floor were used: bifrontal - in 58 (47.5%) patients, subcranial - in 49 (40.2%), transbasal Derome - in 8 (6.5%), frontotemporal - in 4 (3.25%), expanded endoscopic - in 3 (2.45%). In 52 (42.6%) cases, endoscopic endonasal assistance was used, most often in the case of plasty of large ACF floor defects to revise the surgical defect, assess the sufficiency of plasty and tamponade of the nasal cavity with balloon catheters.

Results. Patients were divided into groups depending on the bone defect of the ACF floor: median - in 27 (22.1%), middle-expanded - in 71 (58.2%), middle-lateral - in 24 (19.7%). The following types of plasty of the bone defect of the ACF floor were used: pedicle flap - 83 (68.0%) cases, free flap - 22 (18.1%), pedicled periosteal flap with reinforcement - 17 (13.9%). Postoperative complications occurred in 17 (13.9%) patients: nasal liquorrhea in 10 (8.2%) patients (of which 6 underwent reoperation to eliminate it), in 7 patients it was complicated by meningoencephalitis, in other 7 (5.7 %) - meningoencephalitis without signs of nasal cerebrospinal fluid. Postoperative mortality was 0.71% (1 patient). The frequency of nasal cerebrospinal fluid in the group of plasty using a free flap was 13.6% (3 cases), meningoencephalitis - 4.5% (1 observation), in the group of plasty using pedicle flap - 4.8% (4 cases) and 6.0% (5 observations), in the group of plasty using a pedicle flap with reinforcement - 17.6% (3 cases) and 11.7% (2 observations). In 33 (27.1%) cases the use of the author's method of bone defect plasty of the ACF floor with duplication of complications were not registered.

Conclusions. Significant size and spread of bone defects of the ACF floor increase the risk of postoperative complications. The use of free flaps for plasty of the bone defect of the ACF floor is ineffective and is associated with a high risk of complications. The proposed method of plasty of the posterior parts of the ACF floor by duplication of the periosteal flap promotes the sealing of the posterior parts, where suturing causes certain difficulties. Reinforcement of plasty from the side of the nasal cavity due to endoscopic technique using tamponade or balloon catheters reduces the incidence of postoperative complications.

Key words*: craniofacial tumors; subcranial approach; plasty of the anterior cranial fossa floor; nasal cerebrospinal fluid*

Introduction

Benign and malignant craniofacial tumors of the floor of the anterior cranial fossa (ACF) are often large, it complicates the process of bone defect plasty during surgical removal, as well as increases the duration and complexity of surgery. Closure of the dura mater (DM) defects and bone defect plasty of the ACF floor is an important stage in the surgery of tumors of this location and is crucial in distinguishing between intracranial and extracranial regions [1].

With increasing radical removal of craniofacial tumors the plastic closure of defects of the ACF floor becomes relevant, most of which are large.

H. Nameki et al. (2005) classified four types of bone defects of the ACF floor depending on the size and location [2]:

Type 1 - giant-sized defects extending to the half of the ACF, as well as orbitomaxillary structures;

Type 2 - large defects extending to the anterior part of the ACF;

Type 3 - medium-sized defects (≤4 cm wide), which extending to the roof of the orbit, ethmoid labyrinth and / or sphenoid sinus;

Type 4 - small defects (≤15 mm).

I.V. Reshetov et al. [3] classified bone defects of the ACF floor into three groups:

I - defects of the midline structures of the skull base (according to localization: defect of the frontal sinus, defect of the ethmoid labyrinth (on one or both sides), defect of the ethmoid and sphenoid sinuses, defect of the ethmoid sinus and the roof of the orbit, defect of the ethmoid sinus and medial wall of the maxillary sinus);

II - defects of the lateral parts of the skull base (according to localization: defect of the lateral parts of the frontal sinus, defect of the upper lateral parts of the maxillary sinus, defect of the lateral wall of the sphenoid sinus, defect of the lateral parts of the maxillary and sphenoid sinuses);

III - combined defects (occur after removal of craniofacial tumors that spread to both the midline and lateral structures of the skull base).

Both a bone defect and a DM defect can occur simultaneously, but a bone defect is not always accompanied by a DM defect [7]. Such defects of varying severity can occur in malignant and benign craniofacial tumors of the ACF floor with intracranial and extracranial growth [4–6].

Plastic closure of the ACF floor defects in combination with additional plastic surgeries promoted the reliability of plastic surgery, but increased trauma and duration of surgery, reduced the quality of life of the patient (additional operating field, use of muscles from other areas (temporal, pterygopalatine fossae) and, as a result the formation of defect in new areas) [8]. A.S. Ketcham (USA), was the first to perform plasty of large defects of the ACF floor who suggested using periosteal pedicled flap from the frontal area. It was lined widely on orbits and thus separated the nasal cavity from the intracranial parts [9]. Periosteal flap is still widely used due to its hermetic properties, but its mechanical properties are often insufficient, especially in the early postoperative period [6,10,11].

Later, it was proposed to use the vascularized tissue transfer. In particular, the muscular and skin-aponeurotic pedicled flaps were isolated in one block, and the vascular pedicle was sutured into the common carotid artery system in the neck. The advantages of this flap formation technique are the possibility of closing large surgical defects and reducing the healing time by improving the blood supply of the autograft, the disadvantages are additional surgical trauma in the area of autograft, an increase in the duration of surgery, the need for additional surgical team. Such features have limited the use of this technique. It is usually used for large repeated defects [12]. Locally transferred tissues are also used, including the temporalis and pterygoid muscles, the pedicled skin flaps from the frontal area. Transferred temporalis or pterygoid muscles are effective methods for closing the defects of the ACF floor due to massive muscle tissue rich in blood vessels which have sufficient mechanical features, but are not without drawbacks (an additional traumatic factor for masticatory muscles, cosmetic defect, an increase in the duration of surgery) [13,14]. Another method is the use of a pedicled flap of the skin, but the small size of the skin flap limits its use for closing large ACF floor defects, although the method has the advantage of sufficient mechanical features. Free flaps (adipose tissue, fascia, artificial DM) are also used [12,15,16]. The flap can be fixed with or without adhesive mixtures [17].

With the development of less traumatic and minimally invasive approaches (Keyhole-surgery, endoscopic endonasal, subcranial surgery) it becomes relevant to use minimally invasive methods of closing defects of the ACF floor, which can provide good mechanical features, ensure the sealing of closure both in the early and long-term postoperative period that will improve the quality of life of patients after surgery.

Objective: to analyze the results of using different methods of plastic closure of bone defects of the anterior cranial fossa floor when removing craniofacial tumors of the anterior cranial fossa floor depending on the size of the defect.

Materials and methods

Diagnostic findings and treatment of 122 patients with craniobasal bone defects of the ACF were analyzed.

Inclusion criteria:

1. Patients with craniofacial tumors of any gender and age who underwent inpatient treatment at the Institute of Neurosurgery named after Acad. A.P. Romodanov, Ukraine and the Institute of Otolaryngology named after Prof. O.S. Kolomiychenko, Ukraine in the period from 2001 to 2021.

2. Intra- and extracranial spread of the tumor with the destruction of the ACF floor.

3. The diagnosis was verified histologically and / or using neuroimaging technologies.

Study design

The extent of resection of the ACF floor was determined by the advisability during surgery, invasion and destruction of the tumor of the ACF floor. Resection of bone structures took place within healthy tissues. The extent of resection of the ACF floor was planned before surgery to determine the type and size of plastic closure of the ACF floor, as well as bone craniofacial defect. With increasing size of the bone defect the risk of postoperative complications increases, including cerebrospinal fluid, prolapse of the frontal lobes into the nasal cavity, therefore the resection of the ACF floor was performed along the border with healthy tissues. Median resection of the ACF floor does not cause difficulties with plastic closure. Middle-expanded defects are more complex in this regard and require additional surgical approach. Middle-lateral bone defects are large and threaten the prolapse of the frontal lobes into the nasal cavity. To determine the possibilities for improving the

This article contains some figures that are displayed in color online but in black and white in the print edition

surgical treatment of the pathology of this location, reducing the number of postoperative complications associated with plasty of the skull base, the effectiveness of various methods of plasty of bone defects of the ACF floor was compared.

To assess the effectiveness of the ACF floor plasty after craniofacial tumors removal, complications were analyzed depending on the type of DM plasty used and the ACF floor bone defect, taking into account the absence of DM plasty and / or the bone defect of the ACF floor. Data on complications depending on the type of plasty of the bone defect of the ACF floor are statistically significant (p <0,0500, γ-statistics). Complications most often occurred after using a free flap.

Characteristics of the research group

There were 50 men (40.9%) and 72 women (59.1%). The age of patients was from 21 to 74 years, mean age was (52.67 ± 11.3) years.

According to the nature of the lesions in 98 (80.3%) patients malignant craniofacial tumors were detected, in 24 (19.7%) - benign ***(Tables 1 and 2)***. A considerable predominance of malignant craniofacial tumors in the sample, in our opinion, suggests a high level of destruction of the skull base, as well as a significant invasion of malignant tumors of the ACF floor.

Cancers such as adenocarcinoma, basal cell carcinoma, transitional cell carcinoma, squamous cell carcinoma with/without keratinization, anaplastic cancer, adenocystic cancer, cancer without detail, as well as sarcomas (leiomyosarcoma, rhabdomyosarcoma, angiomyosarcoma, lymphosarcoma, polymorphocellular, reticulocellular) were diagnosed.

Bifrontal approach was performed in almost half of the cases - 58 (47.5%), subcranial approach was used in 49 (40.2%) cases, Derome transbasal approach - in 8 (6.5%) cases, frontotemporal approach - in 4 (3, 25%), extended endoscopic approach - in 3 (2.45%). In 52 (42.6%) cases endoscopic endonasal assistance was used, most often in the case of plasty of large defects of the ACF floor for revision of the surgical defect, sufficiency of plasty and tamponade of the nasal cavity with balloon catheters.

All patients gave written consent to the examination and use of data from the medical history in scientific research. The study was approved by the Committee on Ethics and Bioethics of the Institute of Neurosurgery named after acad. A. P. Romodanov, Ukraine (Minutes №6 dated December 22, 2015)

Statistical analysis

Statistical data processing was performed using the Statistica 10.0 StatSoft Inc. statistical software package (USA). All accumulated material is standardized, entered into a database and subjected to statistical processing using methods of descriptive and non-parametric statistics. Pearson's chi-squared test was used to compare the frequencies of independent categorical features in contingency tables. Non-parametric criteria were used. The results were considered statistically significant provided that the level of statistical significance was (p) <0.05.

Results and discussion

The possibility of plastic closure of the bone defect of the ACF floor was assessed at the preoperative stage. The optimal method was chosen. Bone defects of the ACF floor, formed by the tumor or during tumor removal by resection of bone structures, are divided into three types to determine the volume of plastic closure:

- median - defect of the cribiform plate on one or two sides. The anterior and posterior border of the defect

Table 1. Histological distribution of benign craniofacial tumors

Histological diagnosis	Abs.	%
Osteoma	10	8,2
Meningioma	8	6,5
Tumor of vascular origin (angioleiomyoma, hemangioma, angiofibroma)	5	4,2
Cholesteatoma	1	0,8
Total	24	19,7

Table 2. Histological distribution of malignant craniofacial tumors

Histological diagnosis	Abs.	%
Cancer	65	53,2
Sarcoma	11	9,1
Esthesioneuroblastoma	9	7,3
Tumors of vessels or lymphoid tissue (hemangiopericytoma, lymphoma)	6	4,9
Tumors of bone and cartilage origin (osteosarcoma, chondrosarcoma)	5	4,2
Malignant epithelial odontogenic tumor	1	0,8
Malignant mesenchymoma	1	0,8
Total	98	80,3

was determined by the anteroposterior size of the tumor. Such defects can be located from the anterior wall of the frontal sinus to the posterior cribiform plate or spread further to the site of the main bone, tuberculum or diaphragm of sella turcica ***(Fig. 1A)***;

- middle-expanded bone defect of the ACF floor, which, in addition to the above defects, includes a defect of medial parts of the orbital roof and the medial walls of the orbit on one or two sides ***(Fig. 1B)***;

- middle-lateral bone defect of the ACF floor, which, in addition to the above defects, includes a defect of the roof of the orbit ***(Fig. 1C)***. It occurs both after and without orbital exenteration.

The type of bone defect and the size (transverse and anteroposterior) were determined at the stage of preoperative planning according to the data of magnetic resonance and spiral computed tomography of the brain ***(Table 3)***, as well as intraoperatively and postoperatively (on the 1st – on the 3rd day) according to spiral computed tomography of the brain.

According to ***Table. 3***, middle-expanded bone defect prevailed (71 (58.2%)). Median bone defects most often had a transverse / anteroposterior size of 3/4 cm (9 (7.3%)), middle-expanded - 4/5 cm (47 (38.5%)), middle-lateral - 6/6 cm (14 (11.5%)). It was found that in the case of a large bone resection of the ACF floor defects (tumor removal was performed within healthy tissues), the transverse size of the defect was from 4 to 8 cm. It is the transverse size that determines the possible descent of the frontal lobes into the bone defect.

The group of patients in whom pedicle flaps were used during the operation was the largest - 83 (68.0%). For pedicle flaps the periosteum from the frontal area was used in 67 (54.9%) cases, the temporalis muscle - in 10 (13%) cases. In 33 (27.1%) cases, the author's method of plasty of the bone defect of the ACF floor with the periosteal flap with duplication was used ***(Table 4)***.

In the group of patients with plasty of the median bone defects of the ACF floor, a free flap was used in 18 (66.6%) cases, a vascular pedicle flap - in 9 (33.4%) cases. The choice of tactics is determined by the size of the defect (the transverse size of the defect did not exceed 4 cm, anteroposterior - 3 cm), in the group of patients with plasty of middle-expanded bone defects of the ACF floor - a free flap was used in 4 (5.6%) cases, a vascular pedicle flap - in 64 (90.1%) patients, a pedicle flap with reinforcement- in 3 (4.3%) patients, in the group of patients with plasty of middle-expanded bone defects of the ACF floor - a vascular pedicle flap - in 10 (41.6 %) cases, a pedicle flap with reinforcement - in 14 (58.4%).

Postoperative complications associated with plasty of the ACF floor occurred in 18 (14.7%) patients ***(Table 5)***: 10 (8.2%) had nasal cerebrospinal fluid (CSF) leak (of which 6 underwent reoperation to eliminate it), 7 patients had complications of meningoencephalitis, 8 (6.6%) had meningoencephalitis without signs of nasal cerebrospinal fluid. Postoperative mortality was 0.71% (1 patient). Significant prolapse (> 1.5 cm) of the frontal lobes in the early and late postoperative period, according to magnetic resonance imaging of the brain, occurred in 18 (14.7%) patients, in all cases clinically insignificant.

Postoperative complications were most often registered in the group of patients with plasty of bone defects of the ACF floor with a pedicle flap with reinforcement (nasal cerebrospinal fluid in 3 (17.6%) cases and meningoencephalitis in 2 (11.7%) cases),

Table 3. Types and sizes of bone defects of the anterior cranial fossa floor (intraoperative data after the stage of tumor removal)

Type of bone defects	Bone defect size	Number of patients
median bone defect – 27 (22,1%)	1/1	2 (1,6%)
	1/2	5 (4,1%)
	2/2	3 (2,5%)
	2/3	2 (1,6%)
	2/4	1 (0,8%)
	2/5	4 (3,6%)
	3/4	9 (7,3%)
	3/5	1 (0,8%)
middle-expanded bone defect – 71 (58,2%)	4/4	5 (4,1%)
	4/5	47 (38,5%)
	4/6	4 (3,3%)
	4/7	12 (9,8%)
	4/8	3 (2,5%)
middle-lateral bone defect – 24 (19,7%)	5/7	7 (5,7%)
	6/6	14 (11,5%)
	8/6	2 (1,6%)
	8/8	1 (0,8%)
Total	—	122 (100,0%)

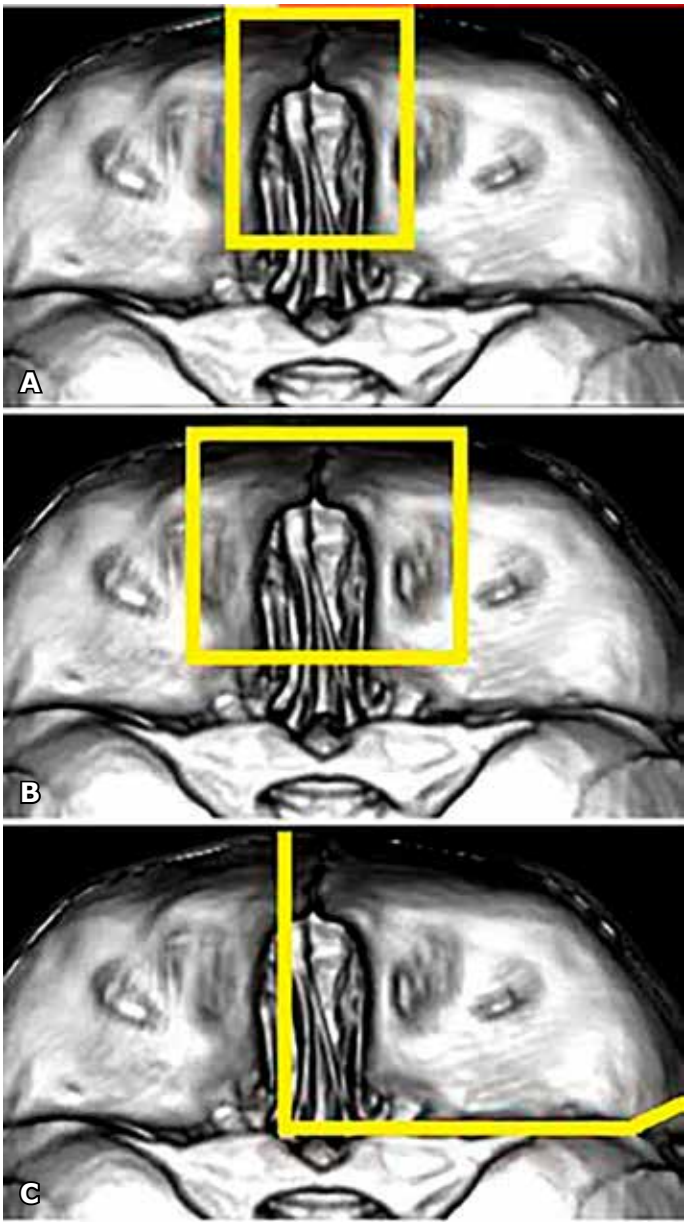

Fig. 1. Types of bone defects of the anterior cranial fossa: A - median defect; B - middle-expanded defect; C - middle-lateral defect

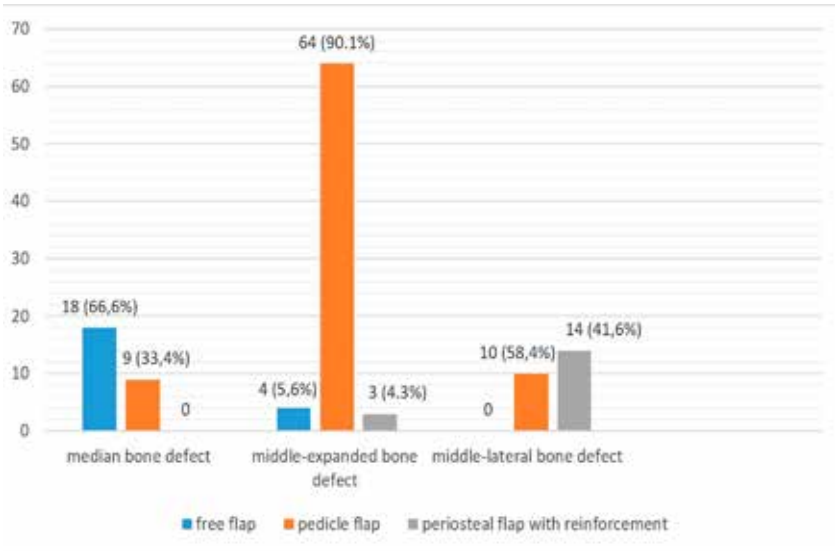

Fig. 2. Distribution of patients by type of bone defect of the anterior cranial fossa floor and type of plasty

Table 4. Distribution of patients depending on the type of plasty of the bone defect of the anterior cranial fossa floor

Tissues for plasty of the bone defect of the ACF floor	Number of patients
Free flap: • - Temporalis muscle • - fat	22 (18,1%) 10 (8,2%) 12 (9,8%)
Pedicle flap: • - periosteal flap • - muscle flap	83 (68,0%) 67 (54,9%) 16 (13,1%)
Periosteal flap with reinforcement: • - titanium "Conmet" • - protacryl • - hydroxyapatite	17 (13,9%) 9 (7,4%) 4 (3,8%) 4 (3,8%)
Total	122 (100,0%)

Table 5. Postoperative complications in groups of patients with different types of plasty of bone defects of the anterior cranial fossa floor

Type of plastic surgery	Nasal CSF leak	Meningoencephalitis
Free flap (n=22)	3 (13,6%)	1 (4,5%)
Pedicle flap (n=83)	4 (4,8%)	5 (6,0%)
Pedicle flap with reinforcement(n=17)	3 (17,6%)	2 (11,7%)
Total	10 (8,2%)	8 (6,6%)

which, in our opinion, is primarily due to the large size of the intraoperative bone defect (in all cases - middle-lateral defect with anteroposterior / transverse size> 5/7 cm), while the number of nasal CSF leak (3 (13.6%)) in the group of patients with plasty using a free flap is due to insufficient mechanical properties of the autograft. In 33 (27.1%) cases the use of the author's method of bone defect plasty of the ACF floor with duplication, complications were not registered.

Technique of plasty of a bone defect of the ACF floor using a periosteal flap with duplication ***(Fig. 3)***

After the skin-aponeurotic flap is formed, the periosteal flap of the frontal area (in width between the upper temporal lines of the temporal bone, sometimes unilateral) is formed on a broad base, allocated to the basal areas (10–12 cm high) ***(Fig. 4A)***. After completion of the intracranial and facial stages of the operation, a postoperative bone defect of the ACF floor (of different size and location (median and middle-lateral)) is assessed ***(see Fig. 3)***. It is closed with a periosteal flap with capturing the roof of the orbit on both sides, a duplication of a periosteal flap is formed in the posterior parts of the defect with an approach to the site of the main bone. If necessary, a prolene mesh is applied on the periosteal flap, which should extend beyond the perimeter of the bone defect. After that, the basal parts of the DM, or rather its substitute (in the case of DM plasty) - the fascia lata are placed on a prolene mesh (so its posterior parts form a duplication to connect with the duplication of the periosteal flap). Nasal tamponade is performed using endoscopic assistance. Descent of frontal lobes have a compressive effect, especially on the posterior parts of the plasty in the area of duplication. The tampon is kept in the nasal cavity for 7-10 days.

Conclusions

1. To prevent possible postoperative complications of plasty of the anterior cranial fossa floor, the bone defect plasty is decisive.

2. The large size and spread of the bone defect of the anterior cranial fossa floor increase the risk of complications in the postoperative period.

3. The use of free flaps for plasty of a bone defect of the anterior cranial fossa floor is associated with a high risk of complications.

4. Our proposed method of plasty of the posterior parts of the anterior cranial fossa floor by duplication of the periosteal flap promotes the sealing of the posterior parts, where suturing entails certain difficulties.

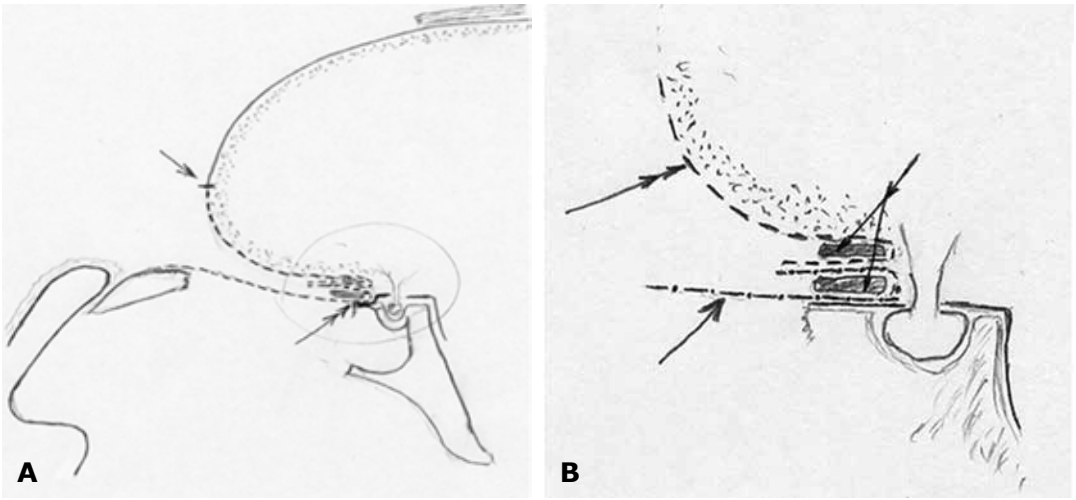

Fig. 3. Schematic illustration of the plasty of a bone defect of the anterior cranial fossa floor with the periosteal flap with duplication: A - plasty of the dura mater is shown by arrows. Plasty of the bone defect of the anterior cranial fossa floor (dashed line) with the laying of the periosteal flap of the frontal area on the residual bone structures of the floor; B - plasty of the posterior parts of the floor of the anterior cranial fossa by laying duplications of the posterior parts of the dura mater and posterior parts of the periosteal flap with introversion

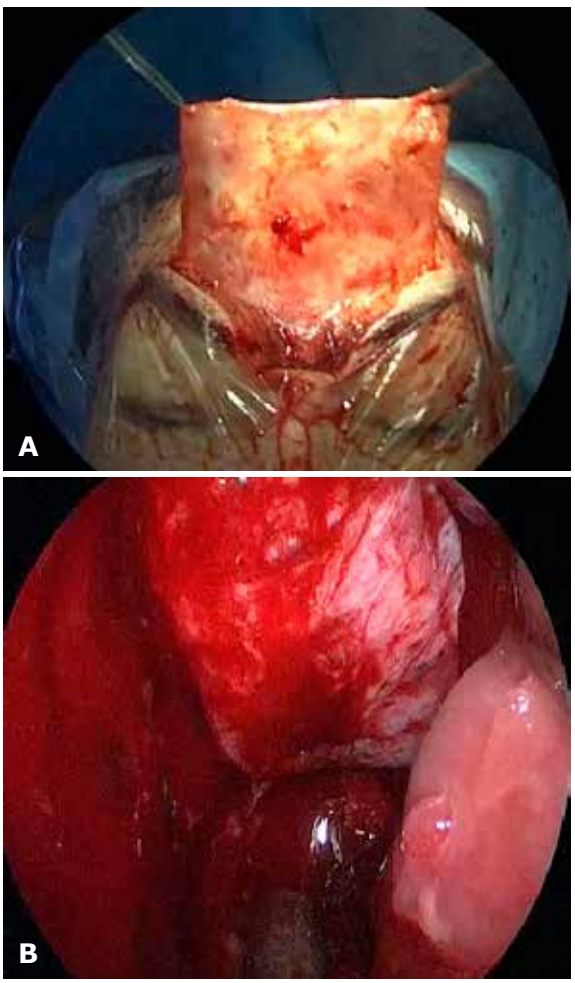

Fig. 4. Stages of formation and plastic closure of the floor of the anterior cranial fossa with the periosteal flap from the frontal area: A – periosteal flap formed from the frontal area; B - view of the plasty of the floor of the anterior cranial fossa with the periosteal flap from the nasal cavity

5. Reinforcement of plasty of the nasal cavity due to endoscopic technique using tamponade or balloon catheters reduces the level of postoperative complications.

Information disclosure

Conflict of interest

The authors declare no conflict of interest.

Ethical approval

All procedures performed in studies involving human participants were in accordance with the ethical standards of the institutional and national research committee and with the 1964 Helsinki declaration and its later amendments or comparable ethical standards.

Informed consent

Informed and voluntary written consent to participate in the study was obtained from each patient.

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