
RESEARCH ARTICLE

The Results of Using the Method of Bipolar High-frequency Electric Welding to Close Defects of the Dura Mater in Frontal Sinus Tumors with Intracranial Spread, and its Comparison with the Standard Method

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ABSTRACT

The frequency of cerebrospinal fluid leak (CSFL) in the postoperative period after surgical interventions on the structures of the skull base reaches 6.2%, and after interventions on the structures of the anterior cranial fossa - 5.9%, middle cranial fossa - 6.4% and - 5.8% in all subtentorial interventions (Jamshidi, 2022; Rajendran, 2020). The aim of the study is to increase the effectiveness of surgical treatment of patients with tumors of the frontal sinuses with intracranial spread by using the method of high-frequency bipolar electric welding. Depending on the method of dura mater defect repair, patients were divided into 2 groups. The 1st group (control) included patients whose dura mater defect was connected according to the conventional method (suturing with polypropylene threads). In the 2nd group – the dura mater defect was connected by high-frequency bipolar electric welding. Patients of the 1st and 2nd groups were divided into 2 subgroups. Subgroups 1A and 2A included patients in whom the DM defect was up to 3 cm in diameter and linear; if necessary, a pericranium was used to close the DM defect. Subgroups 1B and 2B included patients in whom the connection of the defect was performed with the help of a fascia lata. As a result of the study, the authors proposed an effective method of connecting the dura mater defects after the removal of frontal sinus tumors spreading intracranially. Such methods include a high-frequency bipolar electric welding method, the use of which contributed to a minimal destructive effect on adjacent tissues but at the same time hermetically connected the dura mater. Presented data indicate that the use of high-frequency bipolar electric welding allowed to reduce the frequency of external CSFL by 2.2 times, compared to the use of suture material, and to reduce of hidden CSFL by 4.6 times, which indicates a statistically significant advantage of using high-frequency bipolar electric welding to close DM defects and prevent the occurrence of external and hidden CSFL in the postoperative period. In the presence of a DM defect of more than 3 cm and when it is closed with the fascia lata, it is possible to reduce the occurrence of external CSFL by 2.0 times compared to the control group. The use of high-frequency bipolar electric welding almost completely reduces the possibility of the formation of a meningeal scar in the postoperative period, which significantly accelerates the recovery of CSFL circulation and the recovery of brain tissue (due to the absence of factors that would irritate it), as a result of which the patient's rehabilitation and recovery are faster, compared to standard methods of connecting DM. The use of high-frequency bipolar electric welding was manifested by a faster recovery of normal intracranial pressure indicators - a faster recovery of fluid dynamics, a faster regression of inflammatory changes in the brain tissue and, as a result, a faster recovery of its functions, which indicates a higher quality of life of postoperative patients in the main group, compared to the control group.

KEYWORDS

Electrosurgery, frontal sinus tumors with intracranial spread, cerebrospinal fluid leak, dura mater defect, electric welding.

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1. Introduction

The frequency of cerebrospinal fluid leak (CSFL) in the postoperative period after surgical interventions on the structures of the skull base reaches 6.2%, and after interventions on the structures of the anterior cranial fossa - 5.9%, middle cranial fossa - 6.4% and - 5.8% in all subtentorial interventions [Jamshidi, 2022; Rajendran, 2020].

Nowadays, the connection of defects of the dura mater by applying a continuous wrapping suture with atraumatic non-resorbable polypropylene 5.0 threads with a suture step of 1.5-3.0 mm under the optical magnification of an operating microscope is

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standardized today [2,10]. However, this method has a significant number of disadvantages, and the most common is the occurrence of external and hidden CSFI, and as a result of the occurrence of infectious complications, such as meningitis and meningoencephalitis [Ivan, 2015; Caballero-García, 2019; Jennifer, 2020].

Violation of the integrity of the traditional connection of the dura mater (DM) with the suture material is associated with additional traumatization of the DM tissue during needle puncturing and the formation of many holes at the puncture sites, which reduces its tightness, the formation of scar tissue around the suture material, the development of intracranial granulations and the formation of a meningeal scar [4], the difficulties of sealing in the corners of the DM hole defect when it is non-linearly cut, stretching and expansion of DM defects in the area of needle punctures with an initial increase in pressure immediately after the patient is removed from anesthesia after surgery and a decrease in turgor and density of non-resorbable suture material in tissues after 3-6 months [Bonda, 2005; Kim, 2015].

Therefore, in order to achieve a more effective connection of the dura mater, we suggested the use of other seamless technologies. As a method of connecting the dura mater of a new type, we chose the technology of electric welding of living tissues, developed at the E. O. Paton Institute of Electric Welding of the National Academy of Sciences of Ukraine [Ivashchenko, 2017]. We have chosen it due to its ability to connect soft living tissues without the use of sutures, staples or other auxiliary materials.

2. Materials and methods

The authors of the study conducted an examination and postoperative follow-up of 78 patients with frontal sinus tumors with an intracranial spread in the period from 2018 to 2022 who were treated at the Romodanov Neurosurgery Institute of the National Academy of Medical Sciences of Ukraine and the Institute of Otolaryngology named after Professor O.S. Kolomyichenko of the National Academy of Medical Sciences of Ukraine. There were 34 women (43,6%) and 44 men (56,4%) aged from 18 to 80 years. Patients underwent basal subfrontal approaches or basal frontal, temporal approaches, depending on the location and spread of the tumour. Depending on the method of connection of the dura mater, patients were divided into 2 groups. The main group included 38 patients (48,7%), in whom the connection of the dura mater was performed using high-frequency bipolar electric welding on the convex surface of the brain. The control group included 40 patients who were diagnosed with a tumor of the frontal sinuses with intracranial spread, who subsequently underwent surgical treatment, closing the DM defects with suture material - polypropylene, size 4.5 according to Donati under the optical magnification of an operating microscope.

For bipolar high frequency, electric welding 3 specially developed modes were used:

- dura mater between each other;
- dura mater and fascia lata or pericranium;
- if necessary – fascia lata between each other.

To close the dura mater defects, suture material was used without the use of other sealing solutions and materials. If possible, the edges of the dura mater were sutured together, and a hemostatic sponge moistened with lidase and dexamethasone was applied to the junction to avoid the formation of a rough scar and further formation of an epileptiform zone in this area. In the presence of a defect with the inability to bring the edges of the wound without tension, the fascia lata or pericranium was sewn to the dura mater as a method of additional autoplasty.



Figure 1. Our tools developed together with the Paton Electric Welding Institute of the National Academy of Sciences of Ukraine for high-frequency bipolar electric welding of dural defects

Source: compiled by the authors.

In all comparison groups, at the final stage of the operation, when applying a sealing suture to the dura mater or connecting it with high-frequency electric welding, intraoperative tightness control was performed using a modified Valsalva test by increasing the pressure in the respiratory circuit to 20 mm Hg. If areas with CSF leakage were detected, the corresponding areas were resealed using high-frequency electric welding (in group 1) and sutures (in group 2) until satisfactory results were obtained.

Further closure of the surgical wound was carried out according to the standard method in all groups: if necessary, cranioplasty with autobone, bone cement or titanium mesh was performed, pericranium was sutured, the skin was sutured with classical sutures or intradermal cosmetic suture. The quality of dural defect sealing was assessed based on the detection of postoperative cerebrospinal fluid leaks in patients.

The following criteria were chosen to compare the effectiveness of the applied methods:

- tightness of the suture by hemostasis, aerostasis and cerebrospinal fluid;
- time of complete healing of dura mater;
- dynamics of postoperative epidural exudation;
- presence/absence of complications of tightness of dura mater using computed tomography;
- term of removal of epidural drainages;
- total duration of postoperative treatment.

The effectiveness of the proposed method of connecting the dura mater was evaluated intraoperatively and in the dynamics of postoperative observation on the third and tenth day, one and six months after surgery. Statistical processing of the results was performed using a software package for statistical processing of biometric data WinPEPI. Student's t-test was used to assess the difference between groups. Differences between groups were considered reliable at $p < 0.05$.

Criteria for excluding a patient from the study:

- absolute - extremely severe general condition of the patient in combination with gross damage to the brain stem structures, severe damage to the cardiovascular, pulmonary, and urinary systems, significant decompensation due to diabetes, and mental disorders;
- relative (deferred in time) - the presence of local inflammatory processes on the scalp and neck, radiation therapy less than 9 months ago, catarrhal diseases of the respiratory tract, the presence of peritonitis, meningitis, encephalitis, etc. in the patient;

The complex examinations included clinical methods: the study of complaints and disease anamnesis; physical examination; instrumental methods of research: (endoscopy of ENT organs). Clinical and instrumental (general blood test with leukocyte formula, biochemical blood tests, general analysis of cerebrospinal fluid), radiological diagnostic methods (CT and MRI with and without IV contrast, angiography (if necessary), MRI-cisternography), consultations of related specialists (neurosurgeon, otoneurologist, neuroophthalmologist, therapist), morphological (pathomorphological studies of the material), statistical methods of evaluating treatment results and their reliability.

3. Results

A retrospective analysis of the results of DM sealing during surgery in patients with frontal sinus tumors with intracranial growth using the method of high-frequency bipolar electric welding in 1 group (38 patients) - the main group and the traditional method of suturing defects of the dura mater was carried out gold standard" today (40 patients) - a control group from 2018 to 2023.

The overall frequency of postoperative CSFL among all patients included in the study was 17.9% (14 cases out of 80 patients), including 5 cases (6.4%) with external CFSL and 9 cases (11.5%) with hidden CSFL with the formation of a pseudomeningocele without signs of cerebrospinal fluid effusion to the outside. In 64 cases (82.1%), there were no signs of CFSI.

The total postoperative mortality in the hospital was 2.6% (2 cases out of 78 patients), while the presence of CFSI significantly increased the risk of mortality compared to a favorable course of surgical intervention (without CFSI) - accordingly, 1 fatal case with the presence of external liquefaction is 7.1 % (1 case out of 14 patients with liquefaction in the postoperative period) and 1 fatal case is 1.6% (1 case out of 64 patients without liquefaction in the postoperative period), but this difference did not have sufficient statistical significance ($p=0.6197$).

The frequency of postoperative infectious complications was 9% (7 cases out of 78 patients), including 1 case (1.28%) with suppuration of the surgical wound and 6 cases (7.7%) of deep infection of the surgical site (meningitis, meningoencephalitis). When analyzing the effect of postoperative CSFI on the risk of purulent-inflammatory complications, it was established that in the presence of external or hidden CSFI, infectious complications developed in 35.7% (5 cases out of 14), which accounted for 6.4% (5 cases out of 78 patients) of the total number of patients.

With a favorable course of the postoperative period (without the presence of CSFI), the incidence of infectious and inflammatory complications was 3.13% (2 cases out of 64), which was 2.6% (2 cases out of 78) of the total number of patients. Thus, postoperative CSFI, including pseudomeningocele, contributes to a 2-fold statistically significant increase in the risk of developing infectious and inflammatory complications in the postoperative period ($p < 0.0001$).

In all patients with existing external CSFI, when conservative methods of treatment of postoperative CSFI aimed at reducing CSF pressure were ineffective (dehydration therapy, elevated head position, antitussive drugs, lumbar punctures with reduction of CSF pressure to the target value of 100 mmHg) were revised surgical wound, closure of CSF fistula and layer-by-layer sealing of the wound in 5 cases (35.7% of the number of patients with CSFI in the postoperative period), which is 6.4% of the total number of patients.

The median of the duration of postoperative hospital treatment of patients who had postoperative CSFI was 17 days (SAZ from 12 to 26 days), while with a favorable course of the postoperative period, the median duration was 9 days (SAZ from 8 to 13 days), which is statistically significantly less ($p < 0.05$ according to the Mann-Whitney U-test) and indicates the significant expediency of correct hermetic and timely closure of DM defects from a clinical and economic point of view.

4. Discussion

4.1 Factors of the development of CSFL

For the completeness of our data analysis, according to modern literary sources, which describe the factors of the development of CSFL in the postoperative period after the removal of brain tumors of the anterior cranial fossa, we analyzed the impact on the frequency of development of this complication of the following factors:

- 1) The presence of a significant volumetric resection cavity after tumor removal or brain excavation in the projection of the incision and DM defect;
- 2) Impossibility of reducing the edges of the defects of DM;
- 3) The size of the DM defect and the shape of the DM section after tumor removal;
- 4) Additional opening of the air-containing cavities of the skull base (except for the frontal sinus), especially cells of the ethmoidal sinus and cells of the mastoid process);
- 5) Wide opening of the cisterns of the base and ventricles of the brain during surgery [Abergel et al., 2010].

Out of 78 observations, in 34 (43.6%) cases during surgical intervention, air-containing cavities of the skull base (without including the frontal sinus) were opened, namely cells of the ethmoidal sinus - 32 cases (41%), cells of the mastoid process 2 cases (2, 6%). In general, when analyzing the probability of detection of the total set of complications, including pseudomeningocele and external CSFL, a statistically significant tendency to increase the risk of complications in such patients is determined ($p = 0, 1779$) (table 1).

At the same time, this factor increases the chances of developing external (including nasal) CSFI in the postoperative period by almost 3 times (the complication developed in 5 cases (6.4%)) compared to surgical intervention, without revealing cells of the ethmoidal sinus or cells of the mastoid process), which was caused by the iatrogenic formation of the path of outflow of cerebrospinal fluid to the outside. This relationship was statistically significant ($p = 0.0182$).

Extensive rupture of cerebrospinal fluid-containing spaces of the brain (cisterns of the skull base and/or cerebral ventricles) during surgical intervention, which was observed in 8 cases (10.2%) - more than doubled the frequency of postoperative cerebrospinal fluid effusion in 3 cases - (37.5%) against 11 cases (15.2%) out of 72 without opening of liquid-containing spaces. The influence of this factor is also statistically significant ($OR = 3.7840$, $p < 0.0001$).

The factor of free space under the DM (the presence of a porencephalic cyst) was analyzed; for example, after resection of a large tumor, this caused direct contact of the connected area or the DM suture with the circulating cerebrospinal fluid. This risk factor occurred in 21 cases (26.9% of the total number of observations).

CSFI developed in 9.5% (2 out of 21 cases of removal of large and giant tumors), while in the absence of a porencephalic cyst or brain excavation in the suture area, cerebrospinal fluid effusion occurred in 18.1% (12 out of 66 cases), which indicates a statistically

insignificant influence of this risk factor on the course of the postoperative period in patients with neoplasms that spread to the Anterior Skull base or intra-extracranial Anterior Skull base tumors (OR=3.7840, $p < 0.0001$).

A very important factor is the size and shape of the DM defect after tumor removal influence on the frequency of postoperative CSFL. In 44 cases (56.4%), the size of the defect was up to 3 cm in diameter, the joining was performed using a linear connection, and if necessary, the pericranium was used. In 32 cases (41%), the size of the DM defect reached more than 3 cm in diameter, and the fascia lata was used as an autograft. In all cases when the DM section was not linear - the shape of the defect was rounded or oval because, according to modern world research, the shape of the DM defect, which is closed with a graft, should not have sharp edges because it is precisely in the area of sharp edges and the juxtaposition of tissues in these zones that there is the greatest probability of postoperative CSFL; therefore it is recommended to cut out the shape of the defect so that it is not square, not rectangular, but O – similar. Leakage of the restored DM in the postoperative period was observed in 1 case (20% of all linear DM cuts), which did not require additional plasticity with autografts; in 4 (80% of all CSFL) cases, the DM defect was closed with fascia lata [15,16]. Thus, it can be concluded that the size of the DM defect is more than 3 cm, and the usage of an autograft has a statistically significant effect on the risk of postoperative CSFL ($p=0.0293$).

The connection between the material used to close the bone defect after surgery and the presence of a cavity above the closed DM defect after tumor removal for the presence of CSFL in the postoperative period is important. Among 78 patients, in 16 (20.5%) cases, at the final stage of the operation, primary cranioplasty was performed with autobone, autobone with bone cement in 42 (53.8%), titanium perforated plate in 7 (8.9%), there was an unreplaced bone defect in 13 (16.7%).

In patients who had signs of osteomyelitis of the bone or signs of infectious and inflammatory complications of the Anterior skull base tissues - the bone defect was not replaced; the surgical intervention was carried out in 2 stages - where the 1st stage - removal of the tumor, sealing of the DM, cranialization of the frontal sinus, removal of the focus of infectious inflammatory changes, 2nd remote stage - reconstructive plastic surgery of the skull. 5 patients (6.4%) had external CSFL, and 9 patients had pseudomeningocele (11.5% of the total number of patients).

In 7 patients in whom the bone defect was closed with a titanium perforated plate - 4 cases of CSFL (2 hidden, 2 cases of external liquefaction) (57.1% of all patients with closure of the bone defect with titanium); thus, it was found that CSFL occurs more often in the presence of a cavity formed above the DM due to the difference in the thickness of the edges of the bone defect and plastic material - in patients whose bone defect was closed with a titanium perforated mesh (57.1% of postoperative CSFs), compared to patients in whom the bone defect was closed with autobone and/ or bone cement (10 total, 3 external, 7 hidden CSFL) (12.8% of all patients with non-titanium closure of the defect).

Postoperative CSFL was not observed in patients with primary autoosseous cranioplasty and with an unreplaced bone defect. The indicated difference is statistically significant (OR=2.1944, $p=0.0104$), which indicates the expediency of filling the cavity above the restored DM during cranioplasty with thin materials (titanium mesh), for example, with the help of additional excess application of collagen porous materials.

Subperiosteal abscess occurred in 10 patients in the postoperative period, occurred in 4 (30.7% of 13) patients with unreplaced bone defect, in 1 (14.2% of 7) patients with titanium plate replacement, in 3 (18.8% of 16) patients with cranioplasty exclusively using autoplasty. No subperiosteal abscesses occurred in the postoperative period in patients with replacement of the bone defect with autobone with bone cement.

Thus, it can be concluded that the method of closing the bone defect affects the risk of subperiosteal abscess formation in the presence of gaping bone fissures and in the case of a discrepancy between the edges of the thickness of the bone defect and the plastic material, however, due to the significant difference in the number of patients in the groups, it is not statistically significant (OR=1.7325, $p=0.0293$).

Table 1 Presence of CSFL in postoperative period in all patients with risk factors

Nº	Risk factor	N(%)	p
1	The presence of a significant volumetric resection cavity after tumor removal or brain excavation in the projection of DM defect;	2 (9.5% of all patients who had this risk factor)	0,0182
2	The size of the DM defect is up to 3 cm;	1 (2.2% of all patients who had this risk factor)	0,0104

3	The size of the DM defect is more than 3 cm, and the reconstruction of the DM defect using the fascia lata;	4 (12.5% of all patients who had this risk factor)	<0,0001
4	Additional opening of the air-containing cavities of the skull base (except for the frontal sinus), namely cells of the ethmoidal sinus, cells of the mastoid process);	5 (14.7% of all patients who had this risk factor)	0,005
5	The wide opening of the cisterns of the base and ventricles of the brain during surgery.	3 (37.5% of all patients who had this risk factor)	0,0293
6	The presence of a cavity formed above the DM due to the difference in the thickness of the edges of the bone defect and plastic material at the final stage of the operation	2 (16.7% of all patients who had this risk factor)	<0,0001

Source: compiled by the authors.

4.2 Comparison of the effectiveness of sealing the dura mater using the method of high-frequency bipolar electric welding with the traditional method of suturing dura mater defects, taking into account the risk factors for the development of postoperative CSFL

The overall frequency of postoperative CSFL among patients of the 1st group (main) was 3 cases (7.8%) of 38 patients included in the first group, of which 1 case (2.6%) had external CSFL and 2 cases (5.3%) of hidden leakage with the formation of a pseudomeningocele without signs of exusion of the CSF to the outside. In 35 cases (92.1% of all patients in the main group), there were no signs of postoperative CSFL.

Among the patients of the 2nd group (control), there were 11 cases (27.5%) of the 40 patients included in the second group, of which there were 4 cases (10%) with the presence of external CSFL and 7 cases (17.5%) of hidden CSFL with the formation of a pseudomeningocele without signs of exusion CSF to the outside, in 29 cases (72.5% of all patients of the control group), no signs of postoperative CSFL were observed.

Since the size of the DM defect plays a significant role in the occurrence of CSFL and other complications in the intra- and postoperative period, sometimes there is a need to close the defect with the help of autografts - the fascia lata and the periosteum from the convexity surface of the brain stem. Therefore, to assess the quality of DM defect closure after tumor removal in the postoperative period, patients of the 1st and 2nd groups were divided into 2 subgroups. Subgroups 1A and 2A included patients in whom the DM defect was up to 3 cm in diameter and linear; if necessary, a pericranium was used to close the DM defect. Subgroups 1B and 2B included patients in whom the connection of the defect was performed with the help of a fascia lata of the thigh when the edges of the DM defect could not be reduced without tension and compression of the brain tissues.

In all comparison groups, at the final stage of the operation, when applying a sealing seam on the DM or connecting the DM with the bipolar high-frequency electric welding, intraoperative tightness control was performed by performing a modified Valsalva test by increasing the pressure in the respiratory circuit to 20 mmHg. When areas with leakage of cerebrospinal fluid were detected, the corresponding areas of the DM were re-sealed, respectively, with the help of bipolar high-frequency electric welding (in 1 A, B group) and sutures (in 2 A, B groups) until a satisfactory result was obtained.

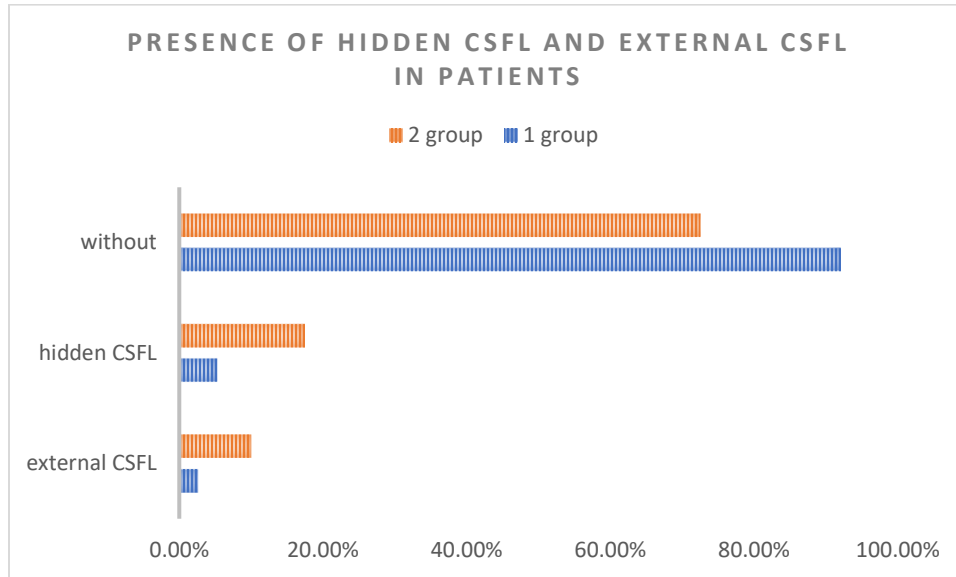


Fig.2 The presence of external and hidden CSFL in patients of both comparison groups

Source: compiled by the authors.

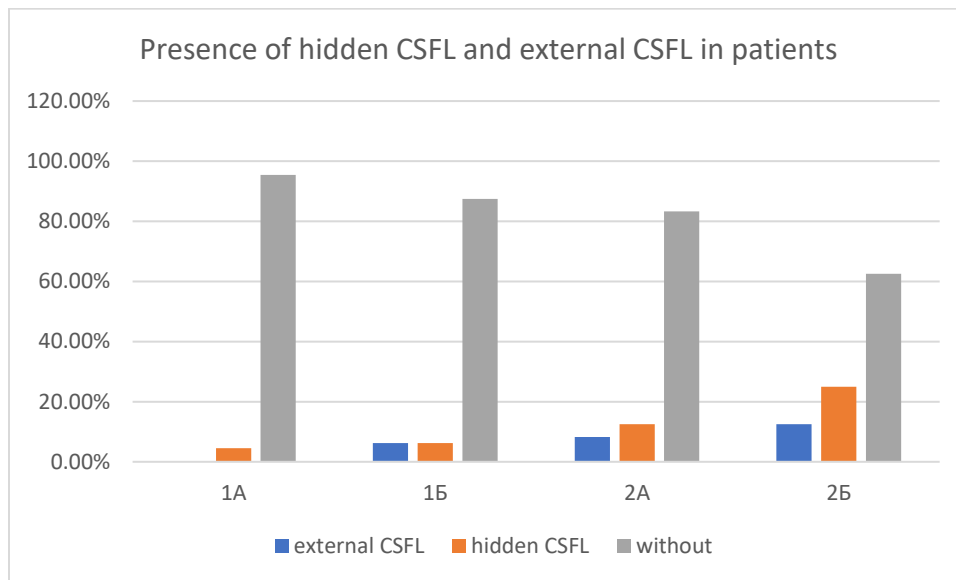


Fig.3 Distribution of the presence of external and hidden CSFL in comparison subgroups

Source: compiled by the authors.

The patients whose DM defects after radical removal of frontal sinus tumors with intracranial growth were connected using bipolar high-frequency electric welding have statistically significantly fewer external and hidden CSFL in the postoperative period, compared to patients in whom DM defects were closed using suture material - 7.9% to 27.5%, respectively.

It is statistically significant that the presence of large defects of more than 3 cm and their closure with autografts (fascia lata) contributes to the more frequent development of CSFL - in the 1B group (connection using bipolar high-frequency electric welding) - 12.5% of the occurrence of postoperative CSFL, in the 2B group (control) - 42.8% respectively.

For a more detailed analysis of postoperative CSFL and evaluation of the effectiveness of bipolar high-frequency electric welding application, the risk factors were analyzed for each comparison group.

Table 2. Presence of risk factors in each comparison subgroup

Nº	Risk factor	N from all cases	1A	1B	2A	2B	p
1	The presence of a significant volumetric resection cavity after tumor removal or brain excavation in the projection of DM defect;	21 cases	-	12	-	10	0,0182
2	The size of the DM defect is up to 3 cm;	44	22 (100%)	-	24 (100%)	-	0,0104
3	The size of the DM defect is more than 3 cm, and the reconstruction of the DM defect using the fascia lata;	32	-	16 (100%)	-	16 (100%)	<0,0001
4	Additional opening of the air-containing cavities of the skull base (except for the frontal sinus), namely cells of the ethmoidal sinus, cells of the mastoid process);	34	5	14	4	11	0,005
5	Wide opening of the cisterns of the base and ventricles of the brain during surgery.	8	1	4	0	3	0,0293
6	The presence of a cavity formed above the DM due to the difference in the thickness of the edges of the bone defect and plastic material at the final stage of the operation						
	1. Cranioplasty only with autobone	16	6	2	5	3	<0,0001
	2. Cranioplasty with autobone with bone cement	42	5	13	7	16	0,005
	3. Cranioplasty with a titanium perforated plate	7	2	2	0	3	0,0027
	4. Unreplaced bone defect	13	2	6	1	4	0,001

Source: compiled by the authors.

Evaluating the factor of the size of the DM defect and the method of its connection after removal of the tumor on the frequency of postoperative CSFL, dividing patients into subgroups, it can be concluded that in patients whose DM defect closure was carried out with suture material, and not with bipolar high-frequency electric welding, the occurrence of postoperative CSFL was observed 3,7 times more often when the size of the DM defect was up to 3 cm ($p < 0.05$) and 3 times more often when the DM defect was more than 3 cm and the autografts, that were used – fascia lata (Table 3).

Table 3. Dependence of the size of the DM defect and the method of its reconstruction before the occurrence of postoperative CSFL in all comparison groups.

The size and shape of the DM defect	Number of cases from all	Number of cases in patients of group 1	Number of cases in patients of group 2	The presence of postoperative CSFL in patients of group 1 (main) - connection with the help of bipolar high-frequency electric welding	The presence of postoperative CSFL in patients of group 2 (control) - connection with suture material	p

The Results of Using the Method of Bipolar High-frequency Electric Welding to Close Defects of the Dura Mater in Frontal Sinus Tumors with Intracranial Spread, and its Comparison With the Standard Method

The size of the defect is up to 3 cm in diameter	46 (59%)	22	24	1 (4.5% of all patients of group 1A)	4 (16.6% of all patients of group 2A)	p < 0.05
The size of the defect is more than 3 cm in diameter, DM reconstruction with the fascia lata	32 (41%)	16	16	2 (12.5% of all patients of the 1B group) - of them 1 (6.25%) - external CSFL, 1 hidden CSFL(6.25%)	6 (37.5%) from all patients of the 2B group) - of them, 2 (12.5%) - external CSFL, 4 cases of hidden CSFL (25%)	p < 0.05

Source: compiled by the authors.

Evaluating the factor of the additional opening of the air-containing cavities of the skull base (without including the frontal sinus), namely cells of the ethmoid sinus - 32 cases (41% of all cases of neoplasms of the frontal sinuses with intracranial growth), cells of the mastoid process 2 cases (2.6% of all cases of neoplasms of the frontal sinus with intracranial growth). In the presence of this factor, 1 external CSFL occurred in the 1B group (6.25%), and neither external nor hidden CSFL occurred in the 1A group (0%). In the 2A group, 2 external (8.3%) and 1 hidden CSFL (4.1%) occurred; in the 2B group – 1 external (6.25%) and 2 hidden CSFL (12.5%).

Thus, a statistically significant tendency to increase the risk of CSFL in such patients is determined (OR=1.6232 (95% CI 0.8045-3.2348), p=0.1779). This factor occurs with the same frequency in all comparison groups (Table 2). At the same time, in the groups where the DM defects were connected with the help of suture material instead of high-frequency bipolar electric welding, the frequency of the development of external (including nasal) CSFL in the postoperative period occurred 2.23 times more often (OR=2.9353 (95% CI 1.2008-7.1748), p=0.0182), and hidden liquefaction is 4.6 times more frequent, which indicates a statistically significant advantage of the use of VKZV for closing DM defects and preventing the occurrence of external and hidden liquefaction in the postoperative period.

Wide rupture of cerebrospinal fluid-containing spaces (cisterns of the skull base and/or ventricles of the brain) during surgery occurs with the same frequency in both comparison groups, except for the 2A group (Table 2), while in the postoperative period, there was not a single case of hidden, no external CSFL in patients of groups 1A and 1B, but 1 external (6.25%) and 2 hidden CSFL (12.5%) occurred in patients of group 2B.

It is important to note that in groups 1B and 1A, in the presence of a cistern/ventricle defect, we used high-frequency bipolar electric welding to weld its defect, and in group 2B - connected with suture material. Thus, it can be concluded that the use of high-frequency bipolar electric welding to close defects of the DM, the walls of the perforated ventricle/cistern reduces the likelihood of postoperative CSFL by 3 times, compared to closing defects with suture material (OR=3.7840 (95% CI 2.3794 -6.0179), p<0.0001).

The most dangerous life-threatening complication of postoperative CSFL is meningitis and meningoencephalitis, the frequency of bacterial meningitis after planned intracranial neurosurgical interventions are 5%, and the frequency of nasocamial meningitis is 2.3%, which is associated with a violation of the integrity of the meninges and due to iatrogenic defects of the DM, penetration and colonization of microorganisms causing nosocomial meningitis [Hernández, 2018].

During the study of the comparison groups, it was established that in the 1A group, there was only 1 case of meningism (4.5%), in the 1B group, there was 1 case of meningism (6.25%), and 1 case of meningitis (6.25%), in the 2A group - 1 case of meningitis (4.2%), 1 case of meningoencephalitis (4.2%), in group 2B 1 case of meningism (6.25%), 2 cases of meningitis (12.5%) and 1 case of meningoencephalitis (6.25%).

Thus, it can be concluded that since the use of high-frequency bipolar electric welding to close DM defects statistically significantly reduces the occurrence of postoperative CSFL, it leads to a 1.9-fold decrease in the occurrence of infectious-inflammatory membrane complications compared to the use of suture material to close DM defects.

According to the research of Nittby et al. established that after lymphorrhoea and related infectious-inflammatory complications (meningitis, meningoencephalitis) - the most formidable complication after neurosurgical interventions - is the occurrence of postoperative intracerebral and meningeal hematomas, their frequency of occurrence is 6.6% and is associated with thus the mortality rate reaches 32% [Nittby, 2016].

Patients of group 1A had 1 epidural hematoma (4.5%), patients of group 1B had 1 subdural hematoma (6.25%), patients of group 2A had 1 epidural (4.2%) and 1 subdural (4.2%), in patients of group 2B - 2 subdural (12.5%), 1 epidural (6.25%) and 1 contralateral subdural (6.25%). Thus, it can be concluded that the use of high-frequency bipolar electric welding to close DM defects statistically significantly reduces hemorrhagic membrane complications by 2.5 times, compared to suture material, which is associated with the coagulation effect on the vascular wall of diploic and emissary veins, venous lacunae, which contains DM, and thus significantly reduces the risk of such life-threatening complications.

Vasogenic and hydrocephalic types predominated in both comparison groups in the presence of signs of cerebral edema-swelling in the pre- and postoperative periods. The vasogenic type occurred in the event of a violation of the functions of the blood-brain barrier, as a result of which there was an increase in the hydration of glia; the causes of this type of edema were metabolic disorders of the transport systems of the endothelium, arterial hypertension, neovascularization of the tumor bed, and the hydrocephalic type occurred when the outflow tracts of the cerebrospinal fluid were blocked, the causes of which were Capacitive intracranial processes that caused deformation of the brain and ventricles.

It was found that in groups 1A and 1B, the signs of edema and swelling in the postoperative period disappeared 1.9 times earlier, compared to groups 2A and 2B, because the use of high-frequency bipolar electric welding is more physiological, compared to suture material, because with high-frequency bipolar electric welding in the area of the weld, DM performs its liquid resorptive functions (due to the preservation of Pacchioni's granulations and venous pial and cortical vessels of the DM), reduction of the operation time in the case of high-frequency bipolar electric welding, compared to the use of suture material, also significantly contributes to the faster regression of edema-swelling of the brain in the postoperative period.

Among both groups, only 3 patients (3.8% of all patients) developed a meningeal scar in the postoperative period. No patients from the 1A, 1B groups, 1 patient from the 2A group (4.2%), 2 patients from 2B group (12.5%). During MRI, these patients visualized in the region of the junction of the TMO different in size, mosaic in density, with a predominance of the hyperdense component - areas of cords between the brain tissue and the DM, which in the postoperative period were manifested by epileptic seizures, cephalic syndrome, psychopathization, characteristic changes on the EEG, in later, reoperation was performed, due to the fact that there was an increase in the dynamics of epi-attacks and signs of CSF circulatory disorders.

Thus, it can be concluded that the use of high-frequency bipolar electric welding practically completely reduces the possibility of the formation of a meningeal scar in the postoperative period, which significantly accelerates the restoration of CSF circulation and the restoration of brain tissue (due to the absence of factors that would irritate it); as a result, faster rehabilitation of the patient and its recovery, compared to standard DM connection techniques.

An important indicator is the term removal of epidural drains. They were removed 1.4 times in the main group (1A and 2A) compared to the main group (2A, 2B) ($p < 0.05$). In the main group, the average indicator was (5th day + 1.7 days); in the control group - lumbar drains were removed on average on (7th day + 2.3 days) ($p < 0.05$). This is due to faster recovery of DM tissue and, recovery of CSF circulation, faster normalization of intracranial pressure when using high-frequency bipolar electric welding, compared to standard methods of closing DM defects with suture material.

The total duration of postoperative treatment was determined both by the duration of its stages and by the complications that arose and measures for their treatment. In the comparisons, the duration of postoperative treatment with the use of high-frequency bipolar electric welding provided a reduction in the duration of postoperative treatment from (20.3 + 4.3) days in the control groups (2A, 2B) to (16.1 + 1.9) days in the main group (1A, 1B) ($p < 0.01$). In general, with the application of high-frequency bipolar electric welding, a faster course of the stages of the postoperative period was observed compared to traditional methods of suturing DM defects in the main group.

The results of surgical treatment in the early postoperative period were evaluated according to the scale of radicality and neurological assessment in neuro-oncology (The neurologic assessment in neuro-oncology, NANO, USA, Boston, 2001), which is used to predict survival, where 0 points are unsatisfactory, 1 point are acceptable, 2 points - satisfactory, 3 points - good, 4 points - high quality. According to the results we obtained, there is a statistically significant predominance in the main group (with high-frequency bipolar electric welding) with a result of 3 points ("good results") and 4 points ("high quality"), compared to the predominance of 2 points - "satisfactory" and 3 points "good" in the main group. The predominance in the main group, according to the indicator "good results", is 1.9 times higher, according to the indicator "high-quality" - 2.17 times, compared to the control group. (OR=1.7325 (95% CI 1.0567-2.8405), $p=0.0293$).

The results of surgical treatment in the distant postoperative period were also evaluated according to the scale of radicality and further neurological assessment in neuro-oncology (The neurologic assessment in neuro-oncology, NANO, USA, Boston, 2001), which is used to predict survival. According to the results we obtained in the main group (with high-frequency bipolar electric welding), the results of 3 points ("good results") are almost completely identical to the corresponding results in the main group,

and in the group of 4 points ("high-quality"), there is a predominance in the main group compared to the control group by 1.45 times. (OR=1.3933 (95% CI 0.3759-5.1649), p=0.6197).

According to the evaluation of the general condition of the neuro-oncology patient before surgery - the Karnovsky scale, in all groups, the patients are equally distributed according to the severity of the condition, which confirms the correct randomization of the studied comparison groups. (OR=20.9193 (95% CI 8.6806-50.4132). Before the surgical intervention, there was no difference between the average score of the Karnovsky scale between the groups (p=0.22 according to ANOVA analysis of variance).

3 months after the surgical intervention, according to the assessment of the general condition of the neuro-oncology patient - the Karnovsky scale, in the specified groups, the number of patients in the main group with indicators of 60%-70% of the points - 27 patients (34.6%), and in the control group only 19 patients (24.3%) (p<0.05), which indicates that the use of high-frequency bipolar electric welding contributes to faster rehabilitation of patients.

6 months after the surgical intervention, according to the assessment of the general condition of the neuro-oncology patient - the Karnovsky scale, in the specified groups, the number of patients in the main group with indicators of 70%-80% is 21 patients (55.2%), and in the control group only 15 patients (37.5%) (p<0.05).

After 12 months, according to the assessment of the general state of the neuro-oncology patient - the Karnovsky scale in the specified groups, the number of patients in the main group with indicators of 90%-100% is 31 patients (39.7%), and in the control group only 25 patients (30.7%) (p<0.05), indicating a higher quality of life index in the long-term postoperative period in patients in whom TMO defects were closed using bipolar high-frequency electric welding.

5. Conclusion

Thus, the main factors that contribute to the development of postoperative complications in patients with tumors of the frontal sinuses with intracranial spread, in addition to the recurrence of the tumor and its continued growth, have been identified.

When the size of the DM defect is up to 3 cm (p < 0.05), the use of high-frequency bipolar electric welding allowed to reduce of the frequency of external CSFL by 2.2 times, compared to the use of suture material and to reduce of hidden CSFL by 4.6 times, which indicates a statistically significant the advantage of using high-frequency bipolar electric welding to close DM defects and prevent the occurrence of external and hidden CSFL in the postoperative period.

In the presence of a DM defect of more than 3 cm and when it is closed with the fascia lata, the use of high-frequency bipolar electric welding makes it possible to reduce the occurrence of external CSFL by 2.0 times, compared to the control group, in which the DM defects were closed with the help of suture material, and in 3.5 times to reduce the occurrence of hidden CSFL compared to the control group.

With a wide opening of the air-containing cavities of the skull base (not including the frontal sinus), namely the cells of the ethmoidal labyrinth, the cells of the mastoid process, in the main group, external CSFL in the postoperative period occurred 2.23 times less often than in patients of the control group, and hidden CSFL - in 2.9 times less often than in patients of the control group, which indicates a statistically significant advantage of the use of high-frequency bipolar electric welding for closing DM defects.

In the case of extensive dissection of the cerebrum-containing spaces (cisterns of the base of the skull and/or ventricles of the brain) during surgery, the use of high-frequency bipolar electric welding reduces CSFL by 3.1 times, compared to closing defects with suture material, because it allows effectively connect the defects of the DM and also weld and thus perform reconstructive surgery of the walls of the perforated ventricle/cistern.

The use of high-frequency bipolar electric welding to close DM's defects statistically significantly reduces the occurrence of infectious and inflammatory complications by 1.9 times, compared to the use of suture material to close DM defects, namely meningitis and meningoencephalitis.

The use of high-frequency bipolar electric welding almost completely reduces the possibility of the formation of a meningeal scar in the postoperative period, which significantly accelerates the recovery of CSFL circulation and the recovery of brain tissue (due to the absence of factors that would irritate it), as a result of which the patient's rehabilitation and recovery are faster, compared to standard methods of connecting DM.

According to the Anterior Skull Base questionnaire and the Karnovsky scale for assessing the quality of life of cancer patients, the use of high-frequency bipolar electric welding was manifested by a faster recovery of normal intracranial pressure indicators - a faster recovery of fluid dynamics, a faster regression of inflammatory changes in the brain tissue and, as a result, a faster recovery its functions, which indicates a higher quality of life of postoperative patients in the main group, compared to the control group.

This study has two limitations. Firstly, it is impossible to examine histological changes in the area of the junction of the dura mater in the postoperative period because it is necessary to perform a repeated craniotomy and durotomy at the junction of DM. Second, there was a limitation in a sufficient number of experimental studies using the human dura mater (porcine dura mater was used as a biosimulator in the experiments). Therefore, future studies can develop a thermistor that will automatically turn off the clamp of bipolar high-frequency electric welding when the temperature rises above 40 degrees Celsius and causes the threat of thermal damage and vaporization of brain tissue.

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List of abbreviation

DM- dura mater

CSFL - Cerebrospinal fluid leak

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