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# INDIVIDUAL PLANNING OF SURGICAL APPROACHES IN SURGERY OF POSTERIOR CRANIAL FOSSA TUMORS

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**Abstract**

To optimize surgical interventions for tumors of the posterior cranial fossa (PCF), a method of individualized planning of surgical approaches was developed, taking into account the histological structure and tumor localization in various forms of the bone-dural framework. An analysis was conducted of 93 computed tomography (CT) and 48 magnetic resonance imaging (MRI) scans, as well as 72 CT and MR angiograms and sinusograms from patients with PCF tumors of varying locations, using a system of bony landmarks and projection lines. Variants of PCF anatomy were identified, and features of displacement of brain structures and neurovascular formations were analyzed depending on the tumor's location and the shape of the bone-dural framework. Based on the data obtained, an algorithm was developed for planning and calculating access parameters according to the individual topography of the tumor. The use of this individualized approach in 67 patients with PCF tumors improved surgical accuracy, reduced access-related trauma, shortened operation time, and decreased the frequency and severity of postoperative complications.

**Keywords:** posterior cranial fossa tumors, surgical approaches, planning.

**Annotatsiya**

Orqa bosh miya chuqurligidagi (OBMC) o‘smalarga operatsion aralashuvlarni optimallashtirish maqsadida, o‘simtaning gistologik tuzilmasi va joylashuvini hisobga olgan holda, suyak-parda karkasining turli shakllarida operatsion kirish yo‘llarini individual rejalashtirish usuli ishlab chiqildi. OBMC o‘smalari turlicha joylashuvga ega bo‘lgan bemorlarning 93 ta kompyuter tomogrammasi va 48 ta magnit-rezonans tomogrammasi, 72 ta kompyuter va magnit-rezonans angiogramma hamda sinusogramma tahlil qilindi. Tadqiqot suyak orientirlari va proyeksion chiziqlardan foydalangan holda o‘tkazildi. OBMC tuzilishining variantlari aniqlanib, o‘simta joylashuvi va suyak-parda karkasi shakliga qarab miya tuzilmalari va qon-tomir asab shakllanishlarining siljish xususiyatlari o‘rganildi. Olingan ma’lumotlarga asoslanib, o‘simtaning joylashuviga doir individual topografik xususiyatlarni hisobga olgan holda kirish parametrlarini rejalashtirish algoritmi ishlab chiqildi. Ushbu individualizatsiyalangan kirish uslubining 67 nafar OBMC o‘smali bemorlarda qo‘llanilishi operatsiya aniqligini oshirish, travmatiklikni kamaytirish, operatsiya vaqtini qisqartirish va operatsiyadan keyingi asoratlarning og‘irligi va sonini kamaytirishga imkon berdi.

**Kalit so‘zlar:** orqa bosh miya chuqurligi o‘smalari, operatsion kirish yo‘llari, rejalashtirish.

**Аннотация**

С целью оптимизации оперативных вмешательств к опухолям задней черепной ямки (ЗЧЯ) была разработана методика индивидуального планирования оперативных доступов с учетом

гистологической структуры и локализации новообразования в различных формах костно-оболочечного каркаса. Проведен анализ 93 компьютерных и 48 магнитно резонансных томограмм, 72 компьютерных и магнитно-резонансных ангиограмм и синусограмм пациентов с опухолями ЗЧЯ различной локализации с применением системы костных ориентиров и проекционных линий. Определены варианты строения ЗЧЯ, выявлены особенности смещений мозговых структур и сосудисто-нервных образований в зависимости от локализации опухоли и формы костно-оболочечного каркаса. Опираясь на полученные данные, разработан алгоритм планирования и расчета параметров доступа на основании индивидуальных особенностей топографии опухоли. Применение методики индивидуализации доступа у 67 пациентов с опухолями ЗЧЯ позволило увеличить точность, снизить травматичность доступа, уменьшить время операции, количество и тяжесть послеоперационных осложнений.
**Ключевые слова:** опухоли задней черепной ямки, оперативные доступы, планирование.

**Introduction.** Planning of surgical access is an effective way to reduce the trauma of surgical intervention and ensure maximum radicality of tumor removal with minimal damage to brain structures and vascular-nerve formations [3]. The literature discusses the technique of computer 3D reconstruction of patient tomograms for individualization of the relative positions of bone landmarks and sinuses of the dura mater (DMA) when planning lateral suboccipital access [8] and in skull base surgery [9]. According to a number of authors, the computer neuronavigation system is the most effective method for planning and implementing surgical access in surgery of deep brain formations [1, 5, 6]. There are isolated publications on the use of this method in calculating the volume of resection of the posterior wall of the internal auditory canal when removing vestibular schwannomas [7] and in planning access to hematomas of the cerebellar hemispheres with preliminary installation of radiopaque markers [2]. Modern development of surgery of tumors of the posterior cranial fossa (PCF) places increased demands on the accuracy and adequacy of surgical approaches, which makes it relevant to further develop methods for planning surgical approaches using computer neuronavigation systems and other anatomically sound methods.

The aim of the study was to optimize surgical interventions for tumors of the PCF of various localizations by planning surgical access based on the individual characteristics of the relative position of the neoplasm with brain structures and vascular-nerve formations in various forms of the bone-shell framework.

**Materials and methods.** An analysis of 93 computed tomograms, 48 magnetic resonance tomograms, 72 computed and magnetic resonance angiograms and sinusograms of patients with tumors of the PCF of various localizations and histological structures was performed. On CT scans in the bone window and multiplanar mode, linear and angular parameters of the internal, external base of the PCF, temporomastoid region were measured, and structural features and spatial orientation of the clivus, pyramid of the temporal bone, mastoid process, squama of the occipital bone were noted.

Features of displacements of brain structures, arteries and veins in patients with PCF tumors of various localizations depending on the shape of the bone-shell framework were studied using a system of projection lines and bone landmarks, which was subsequently used for planning approaches.

When performing statistical calculations, the computer program "Microsoft Excel Office 2007" was used. The critical level of significance when testing statistical hypotheses in this study was taken to be "0.05".

Results of the study and discussions. Generalization of the main linear craniometric parameters of the PCF - length, width, depth allowed us to identify 8 forms of the structure of its bone base based on the variants of combinations of these indicators. These forms differed visually in the 3D model and had a certain characteristic according to linear and angular parameters.
Spiral computed tomograms in the bone window and multiplanar mode revealed the features of the structure and spatial location of the pyramid of the temporal bone, internal auditory canal, mammillary processes, sigmoid sinus, which depended on the shape of the PCF.
The data obtained formed the basis for planning surgical access in terms of determining the volume of resection of bone structures, taking into account the thickness of the bone, the severity of air cavities, the location of bone canals and openings on the base of the skull. The use of a system of projection lines and bone landmarks in the analysis of computer tomograms made it possible to identify the features of displacements of brain structures and vascular-nerve formations caused by a tumor of the PCF of various localizations in terms of severity and rate of development in various forms of the bone-shell framework.
Generalization of the results of the clinical and anatomical studies made it possible to develop a technique for individual planning of surgical approaches to tumors of the PCF.
The access planning algorithm included:
1. Measuring the craniometric parameters of the PCF, determining its individual configuration and having significance when performing access in terms of determining the conditions of craniotomy.
2. Determining the most adequate access option depending on the configuration
of the PCF, the nature and localization of the tumor. Selecting the bone landmarks and projection lines necessary for access planning.
3. Fixing the location of bone landmarks and projection lines on computer tomograms in multiplanar mode, using the bone window and ruler in the tomogram viewing program window.
4. Determining the nature and degree of displacement of the structures of the PCF relative to bone landmarks and projection lines depending on the location, size and direction of tumor growth. Determining surgical risk zones at the border of the tumor node (intimate location of venous collectors, sinuses, large arterial vessels and cranial nerves).
5. Measuring the depth of the tumor, determining the optimal entry point (the closest distance to the tumor border) and recording its location relative to projection lines and bone landmarks.
6. Calculating access parameters relative to projection lines and bone landmarks: determining the optimal access axis (outside important anatomical structures), access depth, and angle of surgical action. Recording the access parameters in the protocol.
7. Determining the location, size of the trepanation window, volume of resection of bone structures taking into account the access parameters and the need for traction of the cerebellar hemisphere.
8. Graphic design of the access plan on a drawing or 3D model of the patient's head with the application of the skin incision line, trepanation window boundaries, tumor contours and other necessary information. When planning surgical access, the Stealth Station/S7 computer neuronavigation system (Medtronic, USA) was used.
At the stage of preparation for access planning, the patient's CT scan data were transferred from a digital medium (CD, flash card) to the computer neuronavigation system. Then, two-dimensional CT images were adjusted by changing the density characteristics, achieving maximum display of the tumor boundaries and other structures. Depending on the nature and location of the tumor, 3D models of the patient's head were created with the tumor contours and cerebrospinal fluid spaces highlighted. By analyzing the patient's CT in multiplanar mode, the relationship of the tumor with the arteries, veins and sinuses of the dura mater was clarified. Based on the obtained data, the

optimal access trajectory was selected: to the tumor center for intracerebral processes, along the matrix for meningiomas, to the internal auditory canal for acoustic neuromas.
In the layer-by-layer movement simulation mode along the access trajectory, the safety of the selected trajectory was checked, taking into account the presence of large vessels, cranial nerves, and functionally significant brain structures along its course. After selecting the access trajectory, the entry point was marked on the surface of the 3D model of the patient's head and fixed in the projection scheme relative to the selected projection lines and bone landmarks.
Access parameters were calculated relative to the access trajectory. The access depth was determined along the axis from the inner surface of the bone in the area of the proposed resection to the most distant pole of the tumor. The axis of the surgical attack should approach the bisector of the selected angle of the surgical action. The angle of the surgical action was calculated relative to the tumor boundaries with the maximum possible exposure of the tumor node with possible traction of the brain structures relative to the access axis within 10° and displacement of the tumor node during isolation relative to the initial boundaries up to 1 cm.
The measurement results were recorded in the protocol. Based on the calculated access parameters, the craniotomy site, volume and direction of bone resection were determined. The trepanation window was planned in the optimal place relative to the entry point of the access trajectory to create the possibility of dissection of the dura mater, taking into account the location of the sinuses. The size and shape of the trepanation window should provide comfortable conditions for the surgeon during manipulations within the angle of the surgical action. For this purpose, the direction of preferential bone resection was selected taking into account the shape of the PCF and the selected approach.
The site of dura mater dissection was marked relative to the entry point of the access trajectory. By measuring the distance from this place to several points of the tumor borders, the boundaries and shape of the membrane dissection were determined to ensure maximum exposure of the tumor.
Depending on the size of the trepanation window, the skin incision line was marked. The skin incision should provide sufficient bone exposure for comfortable trepanation; the skin edges should not be subject to excessive stretching when the retractor is inserted.
The use of linear and arcuate skin incisions in posterior cranial fossa surgery is optimal and has been proven over time. The average length of the skin incision should be 2.5 times greater than the longitudinal size of the trepanation window.
The access plan was graphically designed on a 3D model of the patient's head. The access diagram was applied with multi-colored marks, the entry point, access axis, trepanation window boundaries, skin incision line, and other necessary landmarks were noted.
When using a computer neuronavigation system for planning and implementing surgical access, it is necessary to consider the possibility of using it only as an auxiliary tool during surgical interventions. The system does not replace the surgeon's knowledge, experience, and decisions made by him. If the system does not provide the ability to accurately navigate and its accuracy cannot be restored, the system should be stopped (Synergy® AXIEM Cranial Application Quick Start Guide, Medtronic Navigation, Inc. 9733792RU, Revision 4 08/2011).
In the absence of a computer neuronavigation system, surgical intervention planning can be performed on a personal computer using a program for analyzing computer and magnetic resonance tomograms with the ability to view tomograms in a multiplanar mode in one working window.
In our study, surgical intervention planning was performed on a VAIO VGN-FS laptop (Sony Corp.) with the Windows XP, Home Edition (Microsoft Corp., 2002) operating system using the eFilm

Workstation 1.8.3 computer and magnetic resonance tomogram analysis program (eFilm Medical Inc., Canada).

Access planning was performed according to the algorithm described above. Features of the tumor topography - its location relative to important anatomical structures were studied by changing the density characteristics of the image. When planning access to nodular tumors of the PCF, angiograms and sinusograms were additionally analyzed, which made it possible to obtain additional information about the sources of blood supply to the tumor and the relationship with the main veins and sinuses. The access scheme was applied to the head drawing using a system of projection lines and bone landmarks. The entry point, access axis, trepanation window boundaries, skin incision line and other necessary points for control measurements were marked.

Planning of the median and paramedian access to tumors of the hemispheres, cerebellar vermis and the fourth ventricle was carried out taking into account the individual features of the structure of the cervico-occipital junction, the configuration of the squama of the occipital bone and its location in relation to the base of the skull.

When planning the retrosigmoid access, the distances between the bone landmarks of the occipital region were measured (the external occipital eminence, the posterior edge of the foramen magnum, the junction of the parietal, temporal and occipital bones, the posterior base of the mastoid process). Depending on the longitudinal-latitudinal characteristics of the occipital bone, the volume and direction of resection were selected to ensure the calculated access parameters. Transpyramidal approaches were used as additional stages of the retrosigmoid approach when it was necessary to expose the dura mater in the medial parts of the temporal bone pyramid and provide a multiaxial approach to the internal auditory canal. The volume of resection of various parts of the temporal bone pyramid was determined depending on the localization of the tumor matrix, the direction of growth and the shape of the PCF. When planning the resection of parts of the pyramid, the features of the location of bone formations in the temporomastoid region and the openings of the skull base were taken into account depending on the shape of the PCF. Combined transpyramidal transtentorial approach was used to approach the notch of the tentorium cerebelli, the petroclival region, and the upper parts of the clivus in large meningiomas with a wide matrix zone. When planning the approach, the craniometric parameters of the temporomastoid and petroclival regions of the patient's skull were measured. When drawing up the access scheme, the features of the transverse and sigmoid sinuses, the location of the notch and the height of the tentorium cerebelli were assessed relative to the bone landmarks and projection lines. The access plan was implemented according to the protocol. The patient was placed on the operating table and the head was fixed in a Mayfield clamp.

When implementing the access plan using the computer neuronavigation system, after registering the patient in the system, the registration probe transferred the access scheme from the 3D model to the patient's scalp using color marks. In the absence of a navigation device, the access scheme was applied to the patient's scalp using bone landmarks and projection lines, using a metal ruler, Weber compass, caliper, protractor, and a graduated needle for ventricular puncture for the necessary measurements. After dissecting the skin and periosteum, skeletonizing the bone and installing the retractor, the entry point, boundaries of the trepanation window, and projection lines were applied to the bone using the registration probe or sterile measuring instruments. After performing a craniotomy, the intersection points of the projection lines with the edges of the bone defect were used during the operation as points of control changes to correct the access trajectory relative to the bone landmarks and projection lines, using sterile measuring instruments. The method of individual access planning was used in the surgical treatment of 67 patients with tumors of the posterior cranial fossa in the neurosurgical department of the State Healthcare Institution "Orenburg Regional Clinical Hospital". Surgical interventions were performed using the Pentero 900 surgical microscope (Carl Zeiss Meditec AG, Germany), the Stealth Station S7 computer neuronavigation system (Medtronic, USA), and the Sonoca ultrasonic disintegrator (Söring, Germany). Patients with tumors of the cerebellar vermis and the fourth ventricle (11) underwent midline upper or lower suboccipital craniectomy. When removing tumors of the cerebellar hemispheres, paramedian suboccipital craniectomy was used, fluorescence microscopy and an ultrasonic aspirator were used. Total tumor resection was performed in 10 of 13 patients (77%) with tumors of the cerebellar hemispheres, subtotal tumor resection was performed in 3 (23%) patients with tumors of the cerebellar hemispheres and in 8 (73%) of 11 patients with tumors of the cerebellar vermis and the fourth ventricle.

Patients with acoustic neuromas (7), meningiomas of the cerebellopontine angle (10), posterior border of the petrous temporal bone (9), tentorium cerebelli (6), cerebellar fossa and posterolateral parts of the foramen magnum (1) were operated on using an optimized retrosigmoid approach. Patients with meningiomas of the petroclival region (9), acoustic neuromas growing into the notch of the tentorium cerebelli (1), large meningiomas of the cerebellopontine angle (2) were operated on using a combined suboccipital subtemporal transpyramidal transtentorial approach using the individual planning technique. Meningiomas of the cerebellopontine angle (12) were removed radically in 10 (83.3%) patients, partial removal of the tumor was performed in 2 (16.7%) patients. Petroclival meningiomas (9) in 4 (44.4%) patients were removed radically in 4 patients. The tumor was partially removed in 5 (55.6%) patients. Meningiomas of the posterior edge of the petrous temporal bone and posterolateral parts of the foramen magnum were removed radically in all 10 patients. Meningiomas of the tentorium cerebelli were removed radically in all 6 patients. Acoustic neuroma (8) with the capsule was removed radically in 6 (75%) patients, intracapsular removal with a significant volume of the capsule was noted in 2 (25%) patients.

In the group of patients with intracerebral tumors, postoperative mortality was 8.3%, among patients with nodular tumors of the PCF - 4.7%.

**Conclusion.** The technique of planning surgical intervention based on the individual structural features of the PCF using modern visualization tools and a computer neuronavigation system is a way to prepare the surgeon for special conditions of access, simulate possible options for approaching the tumor, thereby increasing accuracy, reducing the trauma of access, the number and severity of postoperative complications.

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