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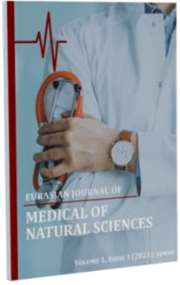

MODERN TECHNOLOGIES IN SURGICAL TREATMENT OF THE CONSEQUENCES OF SKULL AND BRAIN TRAUMA

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ABSTRACT

The article presents the main surgically significant forms of post-traumatic pathology in 4136 patients with defects and deformities of the bones of the arch, base of the skull and facial skeleton, recurrent liquorrhea, arteriosine fistula, true and false aneurysms, etc. A classification of the consequences and complications of traumatic brain injury, as well as a periodization of its clinical course, has been developed. The possibilities of modern neuroimaging technologies for recognizing and investigating the pathogenesis of consequences and complications of traumatic brain injury are revealed. Special attention is paid to reconstructive and minimally invasive surgery, and the method of computer modeling and subsequent stereolithographic laser reproduction of full-scale copies of the skull, its defects and implants is described in detail, which is especially important for extensive and complex craniobasal and craniofacial injuries. The differentiated use of intracranial and эндоназальныхendonasal approaches for closing chronic CSF fistulas is justified. Together with the method of endovascular reconstruction of main vessels using balloon catheters developed by F. A. Serbinenko for the first time at the N. N. Burdenko Research Institute of Neurosurgery, new approaches based on modern technologies using stents, microspirals and embolizing compositions are presented.

Introduction of the principles of microsurgery, minimally invasive endoscopic and endovascular interventions, reconstructive operations using computer modeling and stereolithographic prototyping of damaged structures and implants, as well as the use of modern methods of neuroimaging, pathogenetically based adequate resuscitation and intensive care, and programmable CSF bypass systems have made it possible in recent years not only to reduce the mortality rate in severe traumatic brain injury, but also to reduce the degree of disabling consequences [1-9]. The main types of post-traumatic pathology were defects and deformities of the cranial vault and base with damage to the brain and its membranes, including those accompanied by basal liquorrhea and / or hydrocephalus, as well as damage to intracranial vessels with the formation of carotid-cavernous fistulas, false aneurysms, chronic hematomas, etc..

Reconstructive surgery of cranial arch and base defects

Despite its long history, the problem of restoring the integrity of the skull after depressed fractures, decompressive trepanations, fire стрельныхwounds, removal of tumors affecting the bones of the arch and base of the skull, as well as other pathological processes is still relevant [2, 3, 8, 10-13]. The number of victims with bone defects is constantly increasing due to the increase in cases of severe traumatic brain injury and surgical activity, the expansion of indications for decompression trepanation of the skull not only for trauma, but also for vascular diseases. At the дегерметизациязame time, skull depressurization, in addition to complications in the postoperative period, leads to the formation of a new pathological condition, which is called "trepanated syndrome" [14]. The pathophysiological mechanisms of the development of this syndrome are quite diverse and are currently being discussed [7, 15]. Improvement of neurological functions after cranioplasty and skull sealing, associated with changes incerebrospinal fluid and hemodynamics, allows us to consider the reconstruction of bone defects as a necessary condition in the rehabilitation of patients with the consequences of severe craniocerebral lesions and decompression operations [2, 3, 15]. It is considered optimal to perform reconstructive operations in the period from 1 to 6 months after the injury [2, 3, 12]. However, the possibility of performing reconstructive operations at an early stage depends on many factors: the rate of regression of cerebral edema and intracranial hypertension, the presence of extra - and intracranial complications, the development of hydrocephalus, etc. In our study, 186 patients with post-traumatic hydrocephalus, including after decompression trepanations (Figure 1), underwent bypass surgery followed by closure of the bone defect. In 68 of them, programmable systems were used with a significant reduction in the frequency of bypass graft dysfunction in the postoperative period. One of the main problems of reconstructive surgery is the choice of plastic material. The range of materials used for cranioplasty is huge and constantly expanding. Biological compatibility, lack of tissue reactions, and high regenerative abilities are the main advantages of auto-materials, but they also have significant limitations [2, 3, 16]. Modern xenomaterials (polymethylmethacrylates, titanium, hydroxyapatite, etc.) serve as an alternative to bone implants and in some cases have certain advantages. The search continues for materials for cranioplastythat can not only provide sealing of the skull, but also contribute to the processes of osteoconduction and osteoinduction. In our clinic, the following main types of plastic materials have been used in the reconstruction of bone defects in the cranial vault in recent years: autocost (split bone, bone fragments, etc.), allocost (formalized, lyophilized bone tissue) and xenoimplants (methyl methacrylates, titanium, etc.).

From our point of view, auto-tissues have the greatest advantage, but structural changes in bone tissue, its frequent resorption (with an auto-tissue size of more than 30.0 cm2, the risk of resorption is significantly higher), and technical difficulties of sampling, especially large bone flaps, limited their use. The use of auto-tissues is most preferable in children, as well as in small bone defects. The use of allogeneic materials is currently being reviewed due to the risk of transmission of vector-borne infections [2]. Computer modeling and laser stereolithography An important task of cranioplasty is the aesthetic perfection of reconstructive surgery, especially for extensive defects of complex fronto-orbital and craniobasal localization. Rapid development of neuroimaging methods with the construction of three-dimensional virtual models and the possibility of computer simulation of operations has radically changed the technology and quality of reconstructive surgery for traumatic, tumor, and congenital cranial defects and deformities, as well as after resection and decompression operations. The first systematic three-dimensional computed tomography (CT) studies at the N. N. Burdenko Research Institute of Neurosurgery began in the 90s in patients with craniobasal and craniofacial injuries in order to plan operations to remove foreign bodies of complex configuration and virtual modeling of reconstruction of cranial defects[2, 3, 17, 18]. Computer modeling allows you to edit CT models with the restoration of missing fragments and the creation of virtual individual implants. Implants are manufactured using various methods of prototyping three-dimensional objects based on CAD / CAM technologies [15, 19-21]. In Russia, this method was developed at the Institute of Laser and Information Technology Problems of the Russian Academy of Sciences (IPLIT, Shatura, Moscow Region) under the supervision of Academician of the Russian Academy of Sciences V. Ya. Panchenko, it was first used in forensic medical practice to verify the remains of the Romanov family [1-3, 19, 21]. Computer modeling and laser stereolithography in reconstructive operations at the N. N. Burdenko Research Institute of Neurosurgery has been used since the late 90s, and the first publications date back to the early 2000s [3, 7, 16]. From 1999 to 2011, in the Department of neurotrauma of the N. N. Burdenko Research Institute of Neurosurgery, this technology was used in 445 patients with extensive defects in the bones of the arch and base of the skull, as well as the facial skeleton of a complex configuration (mainly fronto-orbital localization). Planning of reconstructive operations includes several stages: direct data collection based on the developed CT scanning protocols; data processing with modeling of three-dimensional models and detailed study of bone fragments of the skull to be restored. The complex geometry of bone defects in the skull and their large size require the use of CT scans with a slice thickness of 1 mm or less. The results of CT data stored in DICOM medical image files and / or standard BMP graphic format are sent to IPLIT via an electronic network. Received tomograms Using the 3DView software package developed at IPLIT, they are converted into a three-dimensional computer model in STL format, which is the basis for the software operation стереолитографииof the LS-250/E laser stereolithography unit (Fig. 2). For unilateral bone defects, modeling and construction of implants is carried out using the "mirror symmetry"method. When locating defects along the midline, the "virtual donor" method is used. This method is based on the created database of 3D reconstructions of skulls of various configurations. From the database, a 3D model of the skull is selected that is close to the parameters of the patient's skull, and on its basis all the stages of prototyping are carried out with the creation of an implant model. An important advantage of the domestic technology in contrast to foreign analogues is not only the modeling of the implant, but also the development of a model of the implant mold and full-scale prototyping of skull models from photopolymerizing solutions on a stereolithograph. The duration of" growing " models is from 4 to 12 hours. Plastic models are delivered to the Institute of Neurosurgery, where they are subjected to gas sterilization (ethyleneoxide). Implants are made from biocompatible modern polymethylmethacrylates (R. Polacos, acetone G-40 Heraeus Kulzer, Germany). The presence of a mold allows you to make an implant both intraoperatively in sterile conditions, and before the operation with subsequent sterilization. In the latter case, the operation time is shortened and, most importantly, the polymerization of the implant with an exothermic reaction occurs outside the wound, thereby eliminating the possibility of thermal damage to the brain, its membranes and bone structures. Manufacturing an implant using a mold requires some experience due to the rapidly changing fluidity and plasticity of the material. During the manufacturing process, it is possible to pre-modify the implant on a plastic model of the skull and finally fit it using high-speed cutters. An exact plastic copy of the patient's skull also allows you to make an implant from a titanium mesh before surgery, which reduces the operation time and improves its quality. In our series of observations, when using all stages of the technological process, 95.3% of patients received good functional and cosmetic results. Unsatisfactory results (3.9% of patients) were due to a combination of consequences of combined craniofacial trauma and atrophic changes in the scalp, and purulent-inflammatory complications were noted in 3 (0.8%) cases. To further improve the quality of reconstructive operations, it is necessary to take into account changes in the soft tissues of the head, primarily due to scar-atrophic changes in the temporal muscle, the possibility of contact of the implant with the air-bearing sinuses, the presence of inflammatory processes in the area of damage and risk factors for their occurrence, and an adequate choice of plastic material [2, 3, 8]. The use of computer modeling technology and laser stereolithography has brought new opportunities to reconstructive neurosurgery and significantly improved the quality of operations in complex configuration and localization of craniocerebral and craniofacial diseases. damage.

Reconstructive surgery of cranioorbital injuries

One of the urgent problems of modern neurotraumatology is the diagnosis and treatment of craniofacial trauma and its most common variant — cranioorbital injuries, which are characterized by a violation of the differentiation of the cranial cavities, orbit, paranasal sinuses; displacement of the eyeball, visual and oculomotor disorders that determine functional and cosmetic deficiencies [1, 22-24]. Planning and evaluation of the effect of operations were carried out on the basis of the results of clinical examination and spiral computed tomography data. In patients with the most complex defects and deformities, preoperative planning was performed using computer modeling and stereolithographic models [1]. Depending on the location and extent of the injury, reconstructive interventions have different goals: restoring the shape of the face, contours and volume of the orbit, eliminating herniated protrusion of the medulla into the orbit and disconnecting the contents of the orbit from the cranial cavity and/or paranasal sinuses, sealing the dura mater, reconstructing the anterior cranial fossa, eliminating displacement of the eyeballs, restoring their position in the mobility, elimination of diplopia, as well as preparation of the orbit for subsequent ophthalmoplastic interventions [1, 22]. In our clinic, first of all, intracranial interventions are performed, after which reconstructive operations are performed on the skull and facial skeleton (craniofacial osteosynthesis; Fig. 3) using the basic principles of craniofacial surgery, including: a) wide subcostal exposure of the fracture zone to accurately assess the extent of damage and the nature of displacement of bone fragments; b) open reposition of bone fragments in an anatomically correct position and their stable internal fixation using titanium micro -and mini-plates; c) primary bone autoplasty for irreversible bone loss with the formation of defects. Out of 374 patients with cranioorbital trauma hospitalized at the N. N. Burdenko Research Institute of Neurosurgery from 1998 to 2010, 288 (77%) underwent reconstructive surgery on the skull and facial skeleton. In 254 (88%) patients out of 288, interventions were performed on the anterior base of the skull, upper and/or middle zones of the facial skeleton with the restoration of various parts of the orbit, in 48 (16.7%) — with the reconstruction of the base and plasty of cerebrospinal fluid fistulas. In 167 (65.7%) out of 254 patients, the cranioorbital region reconstruction was performed to correct displacement of the eyeballs (enophthalmos, hypophthalmos, or a combination of them, less often exophthalmos). With fractures of the thin walls of the orbit (mainly lower and medial), it is almost impossible to compare fragments due to the high degree of fragmentation. That is why bone autotransplants, less often titanium implants, were used to restore their integrity. After restoration of the contours and volume of the bone orbit, a thorough reposition of soft tissues, including the medial and lateral canthal ligaments, was performed (if necessary). Reconstruction of the cranioorbital This procedure resulted not only in cosmetic improvement and repositioning of the eyeball, but also in regression or significant reduction of oculomotor disorders and diplopia.

Reconstructive endovascular surgery of intracranial vascular injuries in craniobasal trauma

In craniocerebral trauma, the main extra-and intracranial vessels are often damaged, for the treatment of which the endovascular method is the most adequate. Initially, it was developed by F. A. Serbinenko in the late 60s-early 70s of the XX century for reconstructive operations using balloon catheters in traumatic carotid-cavernous fistulas (CCS) [28]. Currently, the scope of minimally invasive endovascular interventions has expanded dramatically, and the methods have changed significantly (the use of spirals, stents, and modern adhesive compositions should be highlighted) [6]. The N. N. Burdenko Research Institute of Neurosurgery has accumulated extensive experience (1314 patients with CCS) in the treatment of vascular consequences of craniocerebral trauma, and in 99% of cases the fistula was completely occluded by the endovascular method, and in 80% of cases blood flow through the internal carotid artery was preserved [2]. Endovascular treatment has also been used successfully for traumatic hard артерио -shell arteriovenous fistulas in the sinus region, arteriovenous fistulas in the cerebral vessels and extracranial sections of the main vessels. In case of false aneurysms of the internal carotid artery in the sphenoid sinus and profuse nosebleeds (64 cases), it is necessary to resort to balloon occlusion of the internal carotid artery at the level of its rupture. катамнезаNo recurrence of nosebleeds was observed during the period of catamnesis from 1 year to 10 years. Thanks to the developments of the Research Institute of Neurosurgery, highly effective, mainly reconstructive endovascular treatment of surgically significant vascular consequences of craniocerebral trauma has been introduced into practice [2, 6, 28]. Among other vascular consequences of trauma, a special place is occupied by chronic subdural hematomas, in the treatment of which in recent years the clinical effectiveness of sparing, minimally invasive methods has been proven [2, 3, 9, 29].

Conclusion

The developed and tested modern methods of reconstructive interventions using computer planning, stereolithographic models, as well as reconstructive endovascular operations were included in the approved list of standards for providing high-tech medical care to victims with craniofacial and combined craniocerebral injuries.

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