Reconstruction of Skull and Skull Base Defects Using Titanium, Collagen, Polyesterurethane and Other Alloplastic, Allogeneic, Xenogeneic and Autogenic Materials

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We present our experience in the reconstruction of 12 defects of the skull and lateral skull base following the resection of advanced stage malignant tumors. The reconstruction was performed using three pectoralis major flaps and six temporalis muscle flaps, local skin flaps in two cases and one skin graft. For three dural defects, the plasty was performed using synthetic substitutes. In two cases titanium mesh was utilized for protection of the soft tissues. In one patient a gold plate was used to counteract the effects of facial nerve paralysis on eyelid closure. The advantages and disadvantages of the reconstructive methods are discussed, together with a literature review listing frequently used methods of skull base defect restoration, including autogenous tissues in the form of local, regional or distant flaps, as well as allogeneic, xenogeneic and alloplastic materials.

Keywords: skull base, reconstruction, muscle flap, titanium, collagen

In surgery of craniofacial malignancies the prognosis and the survival of the patient is very often directly related to the extent of the resection. Such surgery leads to impressive cosmetic and functional deficits with high psychological impact as well as severe impact on the patient's quality of life. In most of the cases the ablative surgery has as result the removal of large amounts of tissues and a reconstruction will be necessary. There are many types of reconstructive methods from the various types of skin grafts to local flaps and regional flaps, as well as the use of various other autogenic materials, but also alloplastic, allogeneic and xenogeneic materials. We present our experience emphasizing the importance and the reliability of the muscle flaps and various other synthetic materials in cranial base reconstructive surgery. The temporal muscle flap is a very well axial vascularized tissue, located in the proximity of the reconstruction site, easy to tailor and manipulate with satisfactory results [1]. Pectoralis major myocutaneous flap is another quite versatile type of regional flaps, it can be used in the reconstruction of the tissue defects of the pharynx, larynx, oral cavity, neck but also, as in our cases, craniofacial regions [2]. The purpose of this paper is to review our 5 years' experience in using various reconstructive methods, tissues and materials for craniofacial, skull and skull base defects after tumors resection surgery.

Experimental part

Materials and methods

We reviewed 12 cases of skull and skull base defects following the removal of advanced stage malignancies: 5 basal-cell carcinomas (one in the auricular region, 3 in the temporal region and one frontal region carcinoma), 2 adenocarcinoma metastasis with skull base invasion, 2 squamous cell carcinomas of the frontal sinuses extended to the orbit and skull base, one case of thyroid papillary carcinoma metastasis with mandible and skull base invasion, one previously operated synovial sarcoma of the right TMJ (temporo-mandibular joint) with recurrence in the skull base and orbit, and one sphenoid meningioma extended to the pterygomaxillary space. Among the included patients there was only one woman. The age of the patients was between 46 and 83 years old.

Defect closure was achieved by the help of a great pectoralis muscle flap in 3 patients and a temporalis muscle flap in 6 cases. The rotation of the surrounding skin into the defect was used for closure in 2 patients and skin graft coverage was used in one case. For 3 dural defects, the plasty of dura mater was performed using synthetic substitutes (Neuro-Patch in two patients and Duragen in one patient). In 2 cases titanium mesh was utilized for soft tissue protection. In one patient with postoperative facial paralysis, lagophthalmos was addressed by inserting a gold plate at the level of the superior eyelid.

Results and discussions

For all the included cases good results were achieved regarding defect closure, with satisfactory outcomes regarding facial appearance, but most importantly with good isolation of the intracranial space, without postoperative occurrences of cerebrospinal fluid fistulas or intracranial space infections. The substitutes used for dura mater reconstruction allowed a good layered closure of the defect (fig. 1-5). Both the temporalis muscle flap and the pectoralis major flap were equally efficient for the isolation of the neurocranium, with the specification that pectoralis major offered initially more mass for better dead space obliteration in more extended defects. Minor postoperative complications developed in some cases involving hematoma formation, marginal necrosis of the skin paddle of the greater pectoralis muscle flap and wound dehiscence, without exposure of the intracranial space. Lagophthalmos treatment by gold plate insertion in the superior eyelid had good results regarding eyelid closure.

Craniofacial tumors with bone and skull base involvement are challenging lesions. Once you decide to

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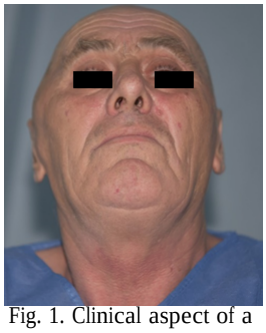

Fig. 1. Clinical aspect of a patient diagnosed with a colon adenocarcinoma metastasis extended to the skull and skull base, showing deformation in the right parotid region and temporo-zygomatic region.

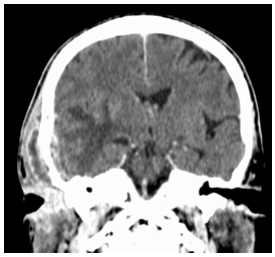

Fig. 2. CT section showing tumor invasion in the temporal skull, lateral skull base and the right ear canal.

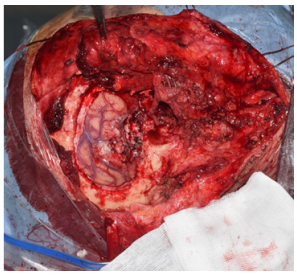

Fig. 3. Intraoperative aspect of the composite defect following tumor removal showing extended dural defect.

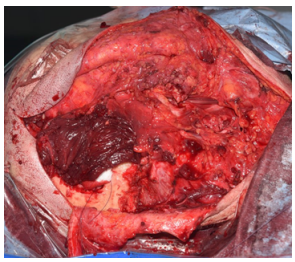

Fig. 4. Intraoperative view of the temporalis muscle flap closing the intracranial space.

Fig. 5. Final postoperative result following tumor removal, plasty using a pedicled temporalis muscle flap and direct skin closure.

treat the lesion, the goal is complete resection and even this is not always easy, after your resection you are facing another, often more difficult, problem – the reconstruction. There are many accepted methods, and the choice will depend on the amount and the specificity of the obtained defect after the resection, on the preference and personal experience of the surgeon and, of course, on the availability of service facilities. In our patients the suitable method of defect closure was decided according to the amount of missing soft tissues and bone, considering in the first place to firmly isolate the intracranial space and minimizing complications. The aesthetic outcome was less of a concern, while oncologic safety and function preservation were the primary focus of the surgery.

One of the main problem in the resection of large, aggressive, locally invasive carcinomas is the integrity of the dura. It is quite common to notice during your surgery the infiltration of the meningeal layers and the radical resection is made with the assumed price of a dural defect. When this occurs, in conditions of septic spaces communications – nasopharyngeal, paranasal, mastoid – there is a high risk of ascending infections and postoperative severe meningitis. This is why it is mandatory to achieve the closure of dural defects whenever it's possible and to isolate cranial and facial compartments by proper, large, healthy, well vascularized barrier – myocutaneous flap. We managed to repair our dural defects using dural substitutes.

Another problem in face of a surgery that involves the nasal spaces, frontal, sphenoid and ethmoid sinuses is the risk of infection especially when the dura and subarachnoid space is open. The type of surgery in these cases can be considered as clean-contaminated [3]. In our patients we use a prophylactic antibiotic coverage for at least 48 hours after surgery, but, in specific cases, in which we opened nasal or sinus spaces and intracranial compartment, we preferred at least 7 days of antibiotic treatment and we didn't notice any major infectious complication.

Voluminous skin and bone defects imposed the use of large soft tissue flaps for obtaining closure. The pectoralis muscle pedicled flap is reliable in covering a wide surface, while also providing volume due to the muscle mass. It can also be rotated to reach defects as far as the parotid, auricular and temporal regions. Although a reliable flap for various types of defects, the pectoralis muscle flap is not without downfalls [4]. One disadvantage is that the initial aspect is not preserved over time, due to the gradual decrease in volume because of muscle atrophy [5]. Another important issue is the marginal flap necrosis that sometimes happens during the normal healing period. It is essential to adequately place these flaps so that a potential flap necrosis does not compromise the sealing of the neurocranium. In such an occurrence, the plasty can be easily performed using skin grafts or local skin flaps. In one of the cases included in our review, even in the presence of a large surface defect, a skin graft was preferred for coverage due to the patient's advanced age and the need for a short surgery time. This was possible because part of the temporalis muscle was preserved, as well as the periosteum.

Another issue is adequately positioning the muscle flap for closing or filling postoperative defects that open cavities of the facial skeleton [6]. In two of our patients, orbital extension dictated the need for performing orbital exenteration. In addition to skull or skull base defect closure, the muscle flap was also used for filling of the orbital socket. The temporalis muscle flap is particularly useful in this regard, considering the proximity to the defect site.

Autologous materials including connective tissue grafts can be used for closing dura mater defects, but this is depended on the size of the defect and the availability of regional tissue for harvest, as well as consideration for the morbidity of a second harvesting site. Another option is the use of allogeneic graft materials, such as *lyophilized* dura mater, but the incidence of transmitted viral infections proved to be high in several studies using this technique. Xenogeneic materials, such as collagen membranes of porcine or bovine origin, coated or not with fibrin polymerization enhancing agents, are maybe the most used for achieving dura mater closure, with good results related to obliteration and biocompatibility, explained by the structure of the dura which is mainly composed of Type 1 collagen. Alloplastic materials in the form of degradable (Polyglactin 910, poly-P-dioxanon, polyester-urethane) and non-degradable (nylon, Dacron, silastic) sheets can also be considered for dura mater defect obliteration [7].

In our study, synthetic materials were useful in certain cases of neurocranial defects for providing protection. There is a wide variety of alloplastic materials available for reconstruction. We consider their implementation useful for the plasty of dura mater defects– Neuro-Patch (2 patients), Duragen (1 patient), but also for the reconstruction of bone surfaces, such as skull defects, where titanium mesh provides defense from traumatisms. Neuro-Patch is a fine fibred structure made by a highly purified polyesterurethane and Duragen is a type I collagen based structure from bovine Achilles tendon in which the precise porosity of the material allows that fibroblasts to

integrate the patch to the endogenous dura mater. Both of these dural substitutes have high liquid tightness, good tissue tolerance, high tensile strength for good suturability, very good elasticity to make them adaptable to the anatomic conditions. Duragen will be fully resorbed and replaced by native tissue and even the sutures are not always required, in our case we used tensionless stay sutures for a better placement of the patch.

Bone defects involving the frontal or temporal skull can impose additional reconstruction methods for providing shape and mechanical resistance and protection of the intracranial structures. Alloplastic materials can be especially useful in providing form and strength while eliminating the need for bone graft reconstruction that would be limited, considering the shape and extent of the defect, as well as additional donor site morbidity. The alloplastic materials available for hard tissue reconstruction include bioactive glass ceramics, cements (Polymethyl-methacryl-PMMA bone cement, hydroxyapatite cement), composite materials (carbon-fiber polymers and an epoxy resin matrix), plastics (porous polyethylene, polyetheretherketone) and most importantly- metals (Titanium mesh) [7, 8]. We prefer using titanium mesh for its chemical properties and resulting mechanical characteristics.

The industrial extraction of titanium from iron involves complex methods. Since pure titanium (under one percent additives) production is a complex procedure, other elements are found in association with titanium, producing alloys that are generally available in commercial osteosynthesis titanium meshes or plates, with the chemical structure of Ti-6Al-4V (6% aluminium and 4% vanadium) or Ti-6Al-7Nb (6% aluminium and 7% niobium) [9]. A titanium oxide layer forms at the surface of the material, contributing to both corrosion resistance and biocompatibility due to glycoprotein adhesion. It's corrosion resistance, biocompatibility, the elasticity modulus above the one of human bone (105 kN/mm2), the light mass and high stability, are the main properties that make titanium a very appropriate material for hard tissue reconstruction [9]. Titanium mesh, by the supplemental characteristics offered by the pattern and structure of the panel, is especially useful for skull base reconstruction, since it offers the possibility of simple shaping while also providing the increased strength necessary for the protection of intracranial structures. Another advantage is the possibility of intraoperative modelling of the mesh as well as the possibility of using computer aided shaping [10].

In 2 of our cases we used cranioplasty techniques and we consider that titanium mesh is really helpful in situations that require a mechanical reinforcement for better brain protection and for satisfying cosmetic results. Titan mesh provide good structural support, is easy to shape and contour, assures a good soft tissue coverage, is biological inert, has a good resistance and durability, low infection rate [11] and is safe for MRI further survey. In addition, cranioplasty has a favorable effect on cerebral metabolism and facilitate rehabilitation [12]. In the same time, it prevents the moving of the soft tissues used for lining of the cutaneous defect. This brain moving are not only an unpleasant aspect of the patient but also will impede the good healing of the tissue.

Gold plates inserted in the superior eyelid can also be used for treating the functional aspects of lagopthalmos following facial nerve paralysis, since this is a frequent condition in cases of malignancies with different origins invading the lateral skull base.

Although a variety of materials are available for neurocranial defects, the implication of several tissues, involving the dura mater, bone, soft tissues and skin, impose careful evaluation of the choice of material and reconstructive technique. The main purpose of reconstruction is achieving a tight closure of the intracranial space. We consider that this desiderate is achievable in composite craniofacial defects by performing a layered closure using collagen or polyesterurethane membranes for dura closure, together with regional muscle flaps for dead space obliteration, ensuring tissue volume, but also skin defect closure where needed. In our experience, titanium mesh reconstruction of fronto-temporal bone defects provides excellent protection of the intracranial structures. Additional sequelae of the extensive cranio-facial resection procedures, such as facial nerve paralysis sequelae, can be addressed in subsequent surgeries.

Conclusions

This study presents our experience in the resection of difficult craniofacial malignancies in which the gross total resection was our goal and, as a consequence, the reconstruction of the large tissue defects was challenging. Synthetic materials are really helpful in this type of surgery providing adequate closure of dural defects and proper reconstruction in cases with large bone resections. Using these materials we are now able to avoid serious complications such as CSF fistulas and to achieve good mechanical, functional and esthetical results reflected in a good quality of life for our patients.

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Manuscript received: 15.11.2017