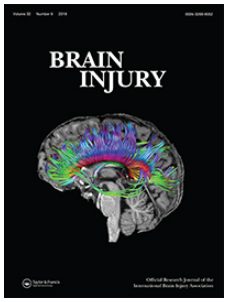

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"Five-layer gasket seal" watertight closure for reconstruction of the skull base in complex bilateral traumatic intraorbital meningoencephaloceles: a case report and literature review

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ABSTRACT

Purpose: Traumatic meningoencephalocele primarily occurs as a rare but complex complication of cranial base and orbital roof fractures. Traumatic intraorbital meningoencephalocele, which is rare and easily overlooked, can be life-threatening since cephalomeningitis occurs due to cerebrospinal fluid (CSF) leakage. It is obscure for the operative indications or standard surgical methods of traumatic meningoencephaloceles since the combined intricate craniofacial and basal fractures, brain injury, and CSF leak may exist. This case report proposes a new operative method for the repair of complex skull base fractures following traumatic intraorbital meningoencephalocele.

Methods: A 30-year-old male with a history of complex trauma presented with symptoms of exophthalmos and traumatic CSF rhinorrhea was evaluated via 3D CT of the skull base and brain MRI and was diagnosed with bilateral intraorbital meningoencephaloceles and multiple craniofacial bone, skull base, and orbit fractures.

Results: Successful resection of the meningoencephaloceles and reconstruction of the skull base defects were performed via craniotomy using a "five-layer gasket seal" technique that involved, from extracranial to intracranial, a gelatin sponge, muscular paste, vascularized periosteum, RapidSorb Orbital Floor Plate (OrbFloor), and Neuro-Patch layers.

Conclusions: The diagnosis and treatment of complex intraorbital meningoencephalocele require careful attention. Resection of herniated tissue is suggested due to potential contamination. The "five-layer gasket seal" watertight closure technique is recommended for successful repair of the skull base in cases involving traumatic meningoencephalocele with complex skull base fractures.

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Meningoencephalocele; exophthalmos; CSF leak; skull base reconstruction

Introduction

Traumatic meningoencephaloceles following traffic accidents that present with the symptoms of exophthalmos, traumatic CSF rhinorrhea, and dysosmia or dysopia are rare and can be easily neglected (1). This condition is typically accompanied by cerebral contusion or hematoma and can be life-threatening since cephalomeningitis occurs due to CSF leakage (2). The most common causes of meningoencephaloceles are trauma, tumors, and congenital skull malformations (3). Although congenital meningoencephaloceles have been clearly classified and well managed (4), it is obscure for the surgical standardization of traumatic meningoencephaloceles since this entity is more complicated than congenital meningoencephaloceles and usually combined with intricate craniofacial and basal fractures, brain injury, and CSF leak (5).

Here, we describe a patient diagnosed with bilateral traumatic intraorbital meningoencephaloceles who presented with exophthalmos and complex basal, cranio-maxillo-facial, and orbital fractures and was successfully treated via skull base and orbit reconstruction with a "five-layer gasket seal" watertight closure technique that was newly proposed to address this condition.

Case presentation and methods

A 30-year-old male was injured in a fatal traffic accident on a highway. He was not belted in the passenger seat, and his face was impacted by an airbag when his car impacted the tailgate of a truck. After the accident, he lost consciousness for 30 minutes. Brain CT and skull base 3D-CT showed bifrontal contusions, traumatic subarachnoid hemorrhage (tSAH), bilateral traumatic meningoencephaloceles, cranio-maxillo-facial fractures, and basal and orbital fractures (Figure 1A, B and C). After receiving conservative treatment for 10 days, he was transferred to our hospital due to aggravated exophthalmos.

Neural and mental examinations indicated hyperpathia at the forehead, CSF rhinorrhea, dysosmia, and delusions of persecution. An examination by ophthalmologists revealed bilateral eyelid edema with both inner and left outer canthus polyps, conjunctival congestion and edema with profuse secretion, and asymmetric exophthalmos of 8 mm and 4 mm for the left and right eyes, respectively. The pupils were equal in diameter and responded normally to light. Abducent movement of the left eye was limited, but the right eye moved freely in each direction (Figure 1E and F).

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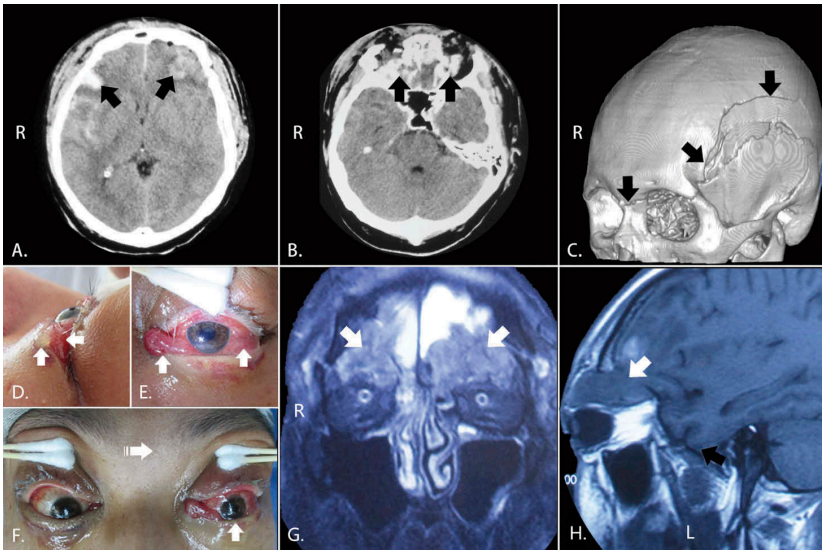

Figure 1. A and B: Axial CT (soft tissue window) shows bifrontal contusions, tSAH, and anterior skull base fractures. C: 3D-CT demonstrates multiple cranio-maxillo-facial, basal, and orbital fractures. D, E and F: Images of the eyes indicate bilateral eyelid edema with both inner and left outer canthus polyps, conjunctival congestion, and edema with profuse secretion as well as limited leftward (abducent) movement of the left eye. G and H: MRI reveals intraorbital meningoencephaloceles on both sides, with greater severity on the left side; on that side, meningoencephalocele was detected within the frontal sinus and the ethmoidal sinus.

MRI demonstrated intraorbital meningoencephaloceles on both sides, with greater severity on the left side; on that side, meningoencephalocele was detected within the frontal sinus and the ethmoidal sinus (Figure 1G and H). The patient was diagnosed with compound injury, moderate traumatic brain injury, bifrontal contusions, tSAH, cranio-maxillo-facial fractures, anterior skull base fracture, orbital fracture, bilateral traumatic meningoencephaloceles, CSF rhinorrhea, dysosmia, post-traumatic stress disorder (PTSD), and exophthalmos of both eyes.

Oral and written consent were obtained from the patient and his family for the publication of all relevant information, including images presented in this study.

Results

Under general anesthesia, craniotomy was performed via an ultralow bilateral subfrontal approach, with free double frontal bone flaps used to reconstruct the skull base. During craniotomy, both frontal sinuses were opened. After the frontobasal tissues were lifted from the basicranial side of frontal bone, the fractures and the crevasse of the endocranium were exposed. Brain tissues were found to have herniated into the left orbital cavity via the front side of the paries superior orbitae and into the ethmoidal sinus, with a fracture at the region of the sinus frontalis. The paries superior orbitae was reconstructed using a "five-layer gasket seal" watertight closure technique (involving gelatin sponge, muscular pad, vascularized periosteum, RapidSorb Orbital Floor Plate (SYNTHES, Oberdorf, Switzerland) and Neuro-Patch (Guanhao Biotech Co., Guangzhou, China) layers, as shown in Figure 2L). First, a lamina gelfoam base was placed at the bottom of the cavity to provide basal support (Figure 2E). OrbFloor was then introduced instead of bone to provide sufficient support (Figure 2F). Muscular pads were used to fill the space below the OrbFloor to seal the outer rim of the crevasse (Figure 2G). Next, vascularized periosteum was used to fill the area between the muscular pads and the OrbFloor to seal the inner rim of the skull base crevasse (Figure 2H). The periosteal pedicle was fixed locally and sealed with human fibrin sealant (Figure 2I and J). Finally, Neuro-Patch was sutured and turned over to fill the skull base between the OrbFloor and the sutured dura breakage (Figure 2K). The vent of the ethmoidal sinus was then occluded with the comminuted muscle, and the sinus frontales were repaired using gelfoam, muscle, and medical adhesive. The same process was performed on the right side. Brain tissues were found to have herniated into the right orbital cavity via the front side of the paries superior orbitae. During the operation, herniated tissues were removed, and the skull base was reconstructed.

After the operation, exophthalmos was immediately alleviated, and CSF rhinorrhea disappeared. MRI and 3D-CT demonstrated that the intraorbital meningoencephaloceles on both sides had disappeared and that both eyeballs had been repositioned. The patient was followed for one year, and abducent movement of the left eye recovered.

Discussion

Traumatic meningoencephalocele primarily occurs as a rare but complex complication of cranial base and orbital roof fractures (6). It has been reported that 7.1% of patients with head injuries have orbital roof fractures, and 13% of these patients develop intraorbital meningoencephalocele (7). Common ocular signs of this condition include exophthalmos, enophthalmos, globe

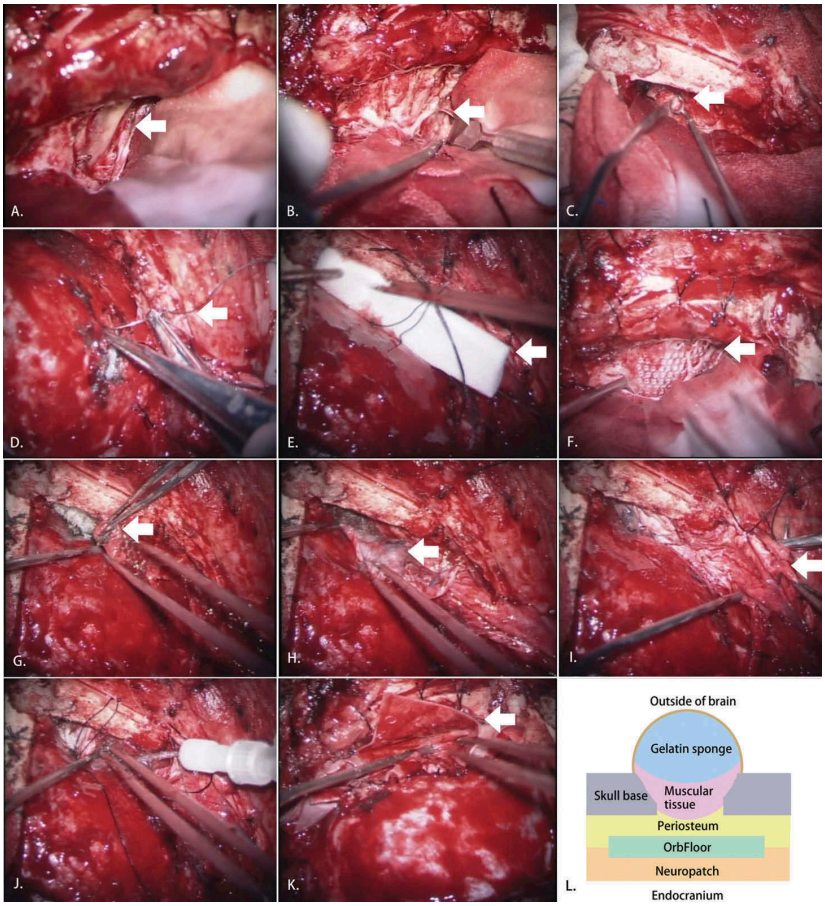

Figure 2. A and B: Operational images show fractures of the paries superior orbitae and the dura crevasse. C: Brain tissues had herniated into the orbital cavity and are removed. D: The crushed orbital bone is lifted, the dural breakage is sutured, and the paries superior orbitae is reconstructed layer by layer using the detailed procedure described below. E: First, a lamina gelfoam base is placed at the bottom of the cavity to provide basal support. F: Then, RapidSorb Orbital Floor Plate (OrbFloor) is introduced instead of orbital bone to ensure that support is sufficiently strong. G: Muscular pads are used to fill the region below the OrbFloor to seal the outer rim of the skull crevasse. H: Next, a vascularized periosteal flap is used to fill the area between the muscular pads and the OrbFloor to seal the inner rim of the skull base crevasse. I and J: The periosteal pedicle is fixed locally and sealed with human fibrin sealant. K: Finally, Neuro-Patch is sutured, turned over, and attached to the skull base under the sutured dural breakage. L: A schematic diagram showing the construction of a "five-layer gasket seal" watertight closure from the region outside the brain to the endocranium.

proptosis, ocular mobility disturbances, ocular edema, hemorrhage, and ultimately loss of vision (8). In certain cases, exophthalmos manifests as pulsatile exophthalmos (9). Pulsatile exophthalmos has many causes, including traumatic and non-traumatic carotid-cavernous fistulae (CCF) (10,11), aortic regurgitation (12), intracranial (13) and intraosseous (14) arteriovenous malformations, and sphenoid wing dysplasia with temporal lobe herniation in neurofibromatosis (15). A CT angiogram or digital subtraction angiography (DSA) can be used to exclude CCF (9). In this case, the CT angiogram was negative. Possible intracranial symptoms include rhinorrhea, pneumocephalus, meningitis, frontal lobe contusions, and meningoencephalocele (16). The first case of orbital meningoencephalocele was reported in 1952 (17). When orbital roof fractures associated with frontal contusions are observed, orbital meningoencephalocele should be suspected. Antonelli suggested that MRI is the optimal examination tool for such patients because MRI allows for the direct visualization of meningoencephaloceles (18,19).

In general, basal and orbital meningoencephaloceles that have herniated into the paranasal sinuses, nasal cavity, or orbital cavity and are accompanied by CSF rhinorrhea should be corrected surgically because of the risk of subsequent meningitis, whereas simple asymptomatic meningoencephaloceles can be monitored without surgical intervention (2). When meningoencephalocele of the orbit is confirmed, a surgical approach via the subfrontal route is indicated to resect herniated, contused brain tissues; close dural breakages; and reconstruct the orbital roof (18). Most specialists suggest resecting herniated tissues because they may be contaminated and are likely to be non-functional (3). Craniotomy is the most common approach used to resect herniated tissues and repair the skull base, with a success rate of 60–80% (3). Leng et al. proposed a "gasket-seal" technique for the closure of skull base defects with or without a vascularized mucosal flap. In their case, due to considerations related to stable bony support, the fascia and porous polyethylene were placed between the skull and the dura (16). Although Leng et al.

reported achieving successful reconstruction using a three-layer "gasket-seal" technique, in our case, it would have been difficult to perfectly and firmly reconstruct the skull base without CSF leakage using Leng's technique because our patient had complex base and orbit fractures and defects as well as severe basal dura damage. Therefore, we developed a "five-layer gasket seal" watertight closure technique. From the outside to the endocranium, gelatin sponge, muscular pads, vascularized periosteum, OrbFloor, and Neuro-Patch layers were distributed (Figure 2L). The first layer is lamina gelfoam, which is used to form a base at the bottom of the cavity for support. The next layer is muscular pads, which are used to fill the cavity to seal the outer rim of the skull base crevasse. Subsequently, a vascularized periosteum flap is used to seal the inner rim of the skull base crevasse, and another layer of OrbFloor is installed to provide sufficient bony support. The final layer is Neuro-Patch, which is sutured and turned over for attachment to the skull base. The concept of layered closure is key to reconstructive success; a vascularized mucosal flap can be added as needed for large defects. Complete mucosal resection surrounding a bony defect is essential, and the entire bony defect must be clearly exposed to allow for good adherence of the reconstruction and avoid post-operative mucocele formation (3).

Traumatic meningoencephaloceles following a traffic accident that present with the symptoms of exophthalmos, CSF leakage, and dysosmia or dysopia are rare and can be easily neglected. The diagnosis and treatment of this condition merit careful attention. Intraorbital meningoencephalocele with severe exophthalmos should be corrected because this condition impairs vision and eye movements. Basal meningoencephalocele with brain tissues herniating into the paranasal sinuses, nasal cavity, or orbital cavity accompanied by CSF leakage should also be corrected surgically because of the risk of subsequent meningitis. Since the herniated tissue is rarely functional and may be contaminated, most experts advocate resection. The "five-layer gasket seal" watertight closure technique is recommended for skull base repair in cases involving traumatic meningoencephalocele with complex skull base fractures.

Conflicts of interest

The authors report no conflicts of interest

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