How I Do It: Endoscopic-Microscopic Anterior Skull Base Reconstruction

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ABSTRACT

Reconstruction of the anterior skull base must be secure and watertight. Failure to achieve this places the patient at risk of the development of cerebral sepsis. We have developed the technique of endonasal duraplasty and have achieved a 90% long-term success rate. In this article we described the key elements of our technique starting with radiographic and fluorescein localization of a skull base defect. The main steps in reconstruction and materials used are detailed, together with modifications of our technique for certain difficult situations and tips for success. Attention is drawn to potential pitfalls that have been identified over 25 years of clinical practice.

KEYWORDS: CSF fistula, cranial base repair, duraplasty, fess

The indications for endonasal micro-endoscopic anterior skull base reconstruction are malformations, traumatic cerebrospinal fluid fistulas, and dural defects acquired during surgical procedures that require resection of the anterior skull base. In these patients, a watertight and secure dural repair is essential to avoid complications such as meningitis or brain abscess. Although a scar might suffice in the short term, it should be remembered that scars are often an inadequate barrier against infection. The patient will remain at risk of developing potentially fatal intra-cranial complications years or even decades afterward. This risk can only be

reduced by achieving a solid and watertight repair of the dura at the outset.¹

Success rates of more than 90% with low morbidity have established endonasal duraplasty as the method of choice when dealing with most anterior skull base defects.²⁻⁴ We began to repair circumscribed anterior cerebrospinal fluid (CSF)-fistulas transnasally more than 25 years ago. Our experience with successful closure of large anterior skull base defects taught us that the size of the lesion is not the most critical indicator of success in endonasal duraplasty. Even a defect of the entire ethmoid roof, cribriform plate, and planum sphenoidale can

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be reconstructed using the transnasal approach. Bony reconstruction has never been necessary in our personal experience. The principles and personal techniques of transnasal dural repair are the subject of this article, as micro-endoscopic reconstruction of the anterior skull base via the transnasal approach has become a highly attractive procedure that is being used more and more commonly.

LOCALIZATION OF THE DURAL LESION

The first prerequisite for the secure closure of frontobasal dural defects is recognizing that there is a dural lesion and determining precisely where it is. Without this, site-directed repair is impossible and the patient remains at risk of developing fatal intra-cranial complications. One should always be aware of the fact that a CSF fistula or an inadequate thin dural scar may not be immediately obvious to a physician and may require sophisticated diagnostic testing to locate. Treatment of patients with pneumococcal meningitis or recurrent meningitis taught us that an undetected dural defect must always be excluded. At the outset we were surprised how many previously unnoticed dural lesions were found. Late complications of these defects and malformations are not uncommon.^{5,6} A very important lesson was the realization that some patients have more than one site of damage. Detection and successful closure of one skull base defect might not be enough for these patients and meningitis may recur because of another dural lesion.⁷ We recommend an evaluation of the whole skull base in every case, even in patients in which there is an obvious dural defect. Never be blinkered to the possibility that there is more than one defect.

Close cooperation with the neuroradiologist is of the greatest importance. A constant awareness of the complexity of the skull base is essential, especially in malformations. In addition to high-resolution computed tomography (CT), magnetic resonance imaging (MRI), and MRI or CT

cisternography,^{8,9} the use of sodium fluorescein has proven to be of great diagnostic benefit. Fluorescein dye can be seen easily with the endoscope, even when very dilute (1:10,000,000). This technique enables the detection of CSF fistulas that might be missed by other diagnostic tests.¹⁰ With this technique a thin dural scar that is impregnated by the fluorescein dye can be seen easily. Lesions like this cannot be detected by any other investigative technique. More benefits accrue with its use during surgical repair as it helps to localize the leak, confirms integrity of the repair and alerts the surgeon to the possibility of another defect.

PRINCIPLES AND CRUCIAL ASPECTS

Several autologous and allogenic materials have been suggested and used for duraplasty. The main principle of endonasal duraplasty is the insertion of a scaffold at the site of the dural lesion. This is subsequently replaced by granulation tissue and ultimately by a thick scar. It is important to select a degradable graft material. Cross-linked collagen grafts are not degraded by either enzymatic or cellular processes during the wound healing process and should not be used. In experimental studies we found evidence of cellular migration from the edge of the dura when a suitable graft had been used. Collagen grafts are extremely effective in this context, whereas no cellular migration was found onto cartilage surfaces or poly-P-dioxanon sheets.¹¹ As a result of this, we recommend the use of collagen grafts.² For some time we employed allogenic collagen grafts but now rely solely on autologous collagen grafts, for example, fascia lata. We believe that infection rates are also lower as a result.

It is very important to realize that the choice of transplant material determines the size of the graft to be used for dural repair. While a moistened allogenic collagen transplant retains its shape, an autologous collagen graft can be expected to shrink

by a factor of up to 30%. An autologous collagen graft must cover the dural defect generously with plenty to spare. If it does not, subsequent shrinkage will result in an incomplete dural closure with early recurrence of a CSF fistula.

Lessons can also be learned from our mistakes. Never use rigid grafts like cartilage. While collagen grafts can be modeled precisely to the shape of the skull base defect, a rigid graft cannot. It may become displaced in the early postoperative period, resulting in a CSF fistula. The intention of the surgeon to achieve a stable reconstruction of the anterior skull base does not mean cartilage, bone or synthetic materials have to be used. Multiple layers of collagen grafts are all that is necessary to produce a firm and reliable reconstruction and induce a stable scar. If a cartilage or bone graft is employed, we recommend leaving additional perichondrium or periosteum attached to it that can be overlapped

onto the adjacent tissues. This collagen surface will support the graft and cover the defect; it also presents a more suitable surface over which cellular migration can take place.

SURGICAL TECHNIQUES

Our preferred surgical methods for reconstruction include both onlay and underlay techniques. Our underlay graft placement employs both intradural and extradural underlay elements. The intradural underlay technique implies the insertion of a graft from below through the bony and dural defect onto the top of the dural lesion (Fig. 1A). In many cases, transnasal positioning of an intradural graft is limited and is not sufficient for a tight dural repair. This type of underlay is used when high CSF

Figure 1 (A) Placement of a graft between the arachnoid and the dura (intradural underlay technique), (B) between the elevated dura margins and bony skull base (extradural underlay technique), or (C) onto the skull base from below (onlay technique) should be distinguished in endonasal duraplasty.

pressure is expected to exert a force on the duraplasty. The intradural underlay supports subsequent layers of the duraplasty by reducing the CSF pressure on these additional layers. In the past, this technique was used as a preliminary step when dealing with high-flow CSF fistulas between the sphenoid sinus and basal cisterns.

We place an extradural underlay graft with extended ear instruments such as a Rosen knife and delicate dissectors. The dura is detached from the bone along the borders of the defect in order to create a pocket between the bone and the dura. If a suction tube is needed, only devices with an opening on the side and not the end of the tip are used to avoid accidental suction of brain vessels and tissue. The graft is then trimmed to the appropriate size and placed between the dura and the bone (Fig. 1B). Fibrin glue is used to ensure stable graft fixation between the elevated dura and bone. With an elongated application device, the fibrin glue is applied directly into the pocket after placement of the underlay graft. If elevation of the dura from the bone might risk injury to vessels or nerves, for example, in the area of the cavernous sinus, the graft is placed from the sinus onto the bony borders (Fig. 1C). By contrast to a graft placed using the underlay technique, an onlay graft is even more at risk of being displaced. Like the underlay graft, the onlay graft is fixed to the bone using fibrin glue. When an extradural underlay graft and an onlay graft are used in combination, this technique is termed the "sandwich technique." In all cases, the site of dural repair is finally covered by a mucosal flap to accelerate epithelization.

When starting to expose a frontobasal skull base defect, a decision must be made whether to use a pedicled or free mucosal flap as the final layer. This in turn is covered with layers of oxidized cellulose sponge to cover and stabilize the mucosal flap. A nasal pack is then placed and left for periods ranging from 3 to 14 days, depending on the size of the skull base defect that has been reconstructed. Prophylactic antibiotics are required while the pack is in place.

SENSE OF SMELL

Transnasal duraplasty offers the chance of preserving the sense of smell, an important factor for a large number of patients. But how should a patient be handled who presents with a CSF fistula close to the olfactory groove or within the confines of the cribriform plate and who still has an intact sense of smell? On rare occasions the leak comes from a missing or ruptured olfactory fiber. In these cases, primary closure of the small opening is achieved by bipolar coagulation. The dural opening is then covered by an onlay graft and a mucosal flap. If the CSF fistula is placed at the junction of the ethmoid roof to the olfactory groove, the graft should be placed using an onlay technique or a combination underlay and onlay technique. After exposure of the skull base defect the dura is elevated from the skull base only to the most lateral part of the defect, in this way avoiding the risk of injury to olfactory fibers. The graft is then inserted between the elevated dura and the bone (underlay) while a second graft is placed directly onto the bone medially (onlay). If one decides to close a defect in one olfactory groove on one side while preserving olfactory function on the other side, a pocket is created between the mucosa/periosteum and the septal bone. The onlay graft is then placed into this pocket, which gives additional support to the graft. If there are better options to preserve olfaction than the transnasal approach, these should be considered. In cases of preserved olfactory function and the presence of a dural defect in the olfactory groove, an intradural approach with placement of the grafts between the olfactory fibers might be superior to a transnasal dura repair.

SPECIAL SURGICAL TECHNIQUES

Dural defects of the skull base that involve the sphenoid sinus may be more challenging. It is difficult to inspect the lateral recess completely and almost impossible to ensure that all the mucosa

Figure 2 (A) A large piece of fascia lata formed into a pouch is placed in the sphenoid sinus and pressed against the sphenoid sinus walls by moistened gelatin sponge pieces ("tobacco pouch" technique). In sphenoid sinus obliteration a graft can be wedged into the defect before filling the sinus completely with abdominal fat grafts. (B) To avoid displacement of the fat grafts, the sinus opening is closed by an additional fascial graft covered by a mucosal flap.

has been removed. Furthermore, the surgeon could be confronted with profuse escape of CSF from the large basal cisterns. It is also important to consider the relationship of the major vascular and neural structures, especially in the sphenoid sinus. Removal of bony fragments and the elevation of dura close to these might not be wise, so the surgeon must decide whether to insert an onlay graft or whether to use one of the special techniques advocated for this situation, namely the "tobacco pouch" technique as described by Kley¹² and/or sinus obliteration.

In both techniques the mucosa is removed as thoroughly from the sphenoid sinus as is possible. A piece of tissue can be wedged into a fracture line to reduce CSF flow and limit the pressure that will eventually be transmitted to the duraplasty. The tobacco pouch technique¹² is particularly suitable in those situations where there are multiple fractures involving the sphenoid sinus. The aim of this technique is to introduce a large graft that can cover multiple CSF fistulas. An appropriate piece of fascia lata is formed into a pouch by inverting stitches and filling it with pieces of gelatin sponge. The pouch is then placed in the sphenoid sinus and the purse-string suture pulled tight. The gelatin sponge is then moistened and this causes the pouch to expand, pressing the fascia lata firmly against the walls of the sphenoid sinus (Fig. 2A).

Huge bony defects within the sphenoid sinus where there is a meningocele are an indication for sinus obliteration. If one intends to obliterate the sphenoid sinus, only a limited opening into it should be made. After removal of as much mucosa as possible, it is filled with abdominal fat and covered with a fascial graft that engages the anterior bony rim. In this way the sinus is closed. A second graft is placed from the front onto the bony borders of the anterior sphenoid sinus wall to act as a second seal (Fig. 2B).

POSSIBLE PITFALLS

It is important to leave an appropriate amount of time between instillation of the fluorescein dye and any surgical intervention. At the outset, we injected fluorescein solution 4 to 6 hours before surgery, but now we usually do this the evening before surgery. Be aware, however, that in patients with high-flow CSF fistulas, all fluorescein dye might have leaked out by the following day. On the other hand, one should note that the distribution of fluorescein dye may need a longer time than usual in patients who have had several episodes of meningitis. In one of our patients the fluorescein dye did not become apparent for 24 hours after injection.

It is also important to use the correct concentration of fluorescein, as too high a concentration or too large an amount is dangerous.^{10,13} Using the protocol detailed by the Graz group, we have had excellent results using lumbar injections of 0.05 to 0.1 ml of a 5% fluorescein solution/10 kg body weight, but never more than 1 ml of a 5% fluorescein solution without any additives. We tend to use fluorescein solution that has been freshly prepared by our hospital pharmacy but commercial preparations are available (Alcon Pharma GmbH, Freiburg, Germany).

For successful closure of a dural defect it is mandatory to expose the defect completely. If the transnasal exposure does not allow an adequate view of the skull base it might be impossible to know if the graft covers the defect completely. In this situation the risk of a recurrent CSF fistula is high. The endonasal route for dural repair should only be used if the skull base defect can be clearly visualized by this approach. Dural defects of the ethmoid roof, cribriform plate, and the walls of the sphenoid sinus are usually easily accessible. The chance of closing a skull base lesion in the inferior part of the posterior frontal sinus wall medial to a virtual plane through the lamina papyracea is dependent on favorable anatomy, which may not be present in every patient.

If graft placement is difficult in a small CSF fistula, it may be advisable to enlarge the bony skull base defect. In this way, elevation of the dura from the bone with creation of the intended pocket is facilitated, resulting in a more stable graft placement.

Another important factor in producing a successful endonasal reconstruction of the anterior skull base is to ensure that the graft is stable after placement. Experimental studies show that the graft becomes incorporated with the dura after 1 week.¹⁴ Consequently, it is essential that any surgical technique ensure that the graft remains stable for those first 7 days. Displacement of the graft is one of the main reasons for failure. When oxidized cellulose has been used to stabilize the duraplasty, it is important that this is clearly written in the notes

and everyone in the surgical team is aware. Cellulose dressings can be mistaken for blood clot very easily and this might result in unintentional suctioning and graft displacement.

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