Dural Reconstruction in Meningioma Surgery

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Introduction

When it comes to dural reconstruction following meningioma surgery (or following any neurosurgical procedure), there are two schools of thought and practice. One is the “watertight” closure, and the other, which is less popular in practice, the nonwatertight closure. The practice of dural closure, like many surgical techniques and applications, is largely based on personal experiences of the individual surgeons, shaped by training passed down from senior residents and mentors, and repeated generations after generations. In this chapter we present a brief review of different dural reconstruction techniques, in addition to our personal experience with synthetic on-lay dural graft technique.

Watertight Closure

Often, we simply do something just because that is how we were taught, and, as in the case of watertight dural closure, it became a universal dogma without significant scientific basis.

A fundamental element of the watertight dural reconstruction is the use of suturing. Megyesi and colleagues developed an in vitro model, where they tested different suturing techniques in providing watertight closure of the dura (13). They compared the efficacy of the interrupted simple, running simple, running locked, and interrupted vertical mattress sutures on primary closure of linear incisions and closure of dural defects using rectangular grafts. Their results showed superiority of interrupted simple suture on primary closure of linear incisions over other techniques listed above. In the cases where dural grafts were used, no single suturing technique proved to be superior over others tested. Overall, sutured linear incisions were more resistant to leak than dural patches. In the literature, the emphasis on watertight closure has been strong to the point that special techniques have been developed and proposed to reach difficult areas in order to achieve optimal dural reconstruction (26).

However, one potential risk of using primary suture closure would be to create pinholes from the suture needle (18). In an attempt to achieve watertight closure, holes created on either side of the dura or the dural substitute may commonly lead to cerebrospinal fluid (CSF) leakage. The attempted “tight” closure results in somewhat of a “one-way valve” along the suture line, causing the leaked fluid (from postoperative coughing, for example) to accumulate outside of the dura. On the other hand, when the dura is not closed in a watertight fashion, in the absence of underlying hydrocephalus, the leaked CSF has a chance to flow back into the intradural space, preventing accumulation of extradural CSF collection. It has also been described that once leak has established either through the needle hole, or through the incision line in between sutures, the pressure needed for it to continue is less than the opening pressure. Because the initial pressure stretches the suture holes and line (13). In addition, while implanting synthetic graft materials, dural tearing may be caused by the sutures themselves because of the elastic properties of these grafts which exert traction on the sutures (14). It is probably because of these factors that studies have shown up to sevenfold more favorable rates of effective dural closure when suture repair is augmented by tissue adhesives (3,14,16).

Dural Grafts

Use of dural grafts has been a common neurosurgical practice, especially when primary closure is not possible. This is of significance particularly in meningioma surgery (i.e., convexity meningiomas), where the removal of a large piece of dura along with the tumor to achieve a Simpson grade I or II resection results in a sizable defect that requires grafting.

There has been a consensus in the literature with regard to the qualities of an ideal dural graft material. An ideal graft would provoke no inflammation in the host body and show no neurotoxicity and adhesion to the underlying brain. At the same time it would be easily available and inexpensive; durable, yet flexible, and easily prepared
and shaped. Ideally, at the same time it would be rapidly resorbed, allowing the endogenous connective tissue to build up. Additionally, while providing adequate protection for the underlying brain, it should ensure watertight closure.

Since the late nineteenth century, when rubber (1) and gold leaf (2) were described as dural substitutes, various materials have been introduced during different time periods, such as amniotic membrane in the 1940s (21) and lyophilized human cadaveric dura in the 1950s (23). It may be practical to classify the contemporary dural substitutes as autografts (i.e., fascia latae, temporalis fascia), allografts (i.e., amniotic and placental membranes, pericardium, fascia, lyophilized dura), xenografts (i.e., bovine or porcine pericardium, peritoneum, dermis), and synthetic materials (i.e., polytetrafluoroethylene [PTFE], polyester urethane) (28). However, each material poses certain disadvantages that limit their usage. For instance, the fascia latae, which is widely used, and which may in most aspects appear as an ideal dural graft (24), requires a second incision, thereby introducing another source for potential morbidity. Availability becomes a concern for other autografts that are accessible through the same incision such as the pericranium and temporalis fascia, especially when a large extent of graft is required. The most common limitations have been immunogenic reactions and risk of transmitting prion-related diseases for allografts; increased immunogenic reactions for xenografts; and difficult handling and poor sealing qualities of synthetic materials (10,25,28). However, one has to note that all of these materials are developed to ensure a watertight closure and require suturing to the endogenous dura.

Nonwatertight Dural Reconstruction with Collagen Matrix

Recently, there has been an interest in processing tissues with high connective tissue components such as pericardium and dermis to yield an acellular, antigen-free scaffold for growing endogenous tissue (10).

In our practice, we use collagen matrix (DuraGen, Integra Neurosciences, Plainsboro, NJ) for dural reconstruction in the majority of meningioma cases where dural augmentation is required. This material is made up of type I collagen and is processed from bovine Achilles tendon. The collagen matrix provides a low-pressure absorptive surface to diffuse CSF and attaches to the dural surface via surface tension (18). It also helps clot formation by the platelets depositing themselves on the collagen, which then disintegrate and release clotting factors, ultimately facilitating fibrin formation (10). This fibrin has an important role in holding the graft in place until fibroblasts, associated with blood vessels, proliferate into the graft (17). This fibroblast infiltration starts by day 3–4 and becomes established in 10–14 days. The fibroblasts use the pores on the matrix to lay down endogenous collagen. By 6–8 weeks, the collagen matrix is resorbed and is integrated to the endogenous dura (18).

The nonwatertight reconstruction of the dura using the collagen matrix simply consists of the onlay application of the material over the dura. It is easily shaped and has the main advantage of not requiring any suturing. In the study of Danish and colleagues, in which suturable acellular human dermis use was compared to collagen matrix, the operative time was significantly lower (36 min) with the use of the collagen matrix, and similar rates of pseudomeningocele formation, wound infection, and CSF leak were reported (6). This technique has proven to be at least as effective as other techniques described in the literature in the management of dural reconstruction in spinal surgery as well (18).

As described above, the collagen matrix is incorporated in the endogenous tissue in a relatively short period of time and in 24 weeks becomes barely distinguishable from the endogenous dura, unlike the allogenic cadaveric dura, which shows inadequate fusion with the endogenous dura and in addition becomes encapsulated in a connective tissue layer (10). This encapsulation has also been described for synthetic materials (22), which appear not to be an ideal situation with regard to the sealing quality of the material. It has also been shown that the compact structure of the xenogenic materials may limit the fibroblast migration to the edges or to the suture holes (20).

In addition, the collagen, in the form of sponge, can absorb fluid without increasing its volume, and can act as a moistening agent for the brain, allowing penetration of CSF into the graft (11). It also forms an effective separation layer and minimizes adhesions between the brain and the overlying tissue.

Nonwatertight Dural Reconstruction in Meningioma Surgery

In our series, since the material was available to us in February 2000, dural reconstruction was performed using the collagen matrix in 237 patients with meningioma until December 2005. The most common location of the tumor was the convexity (29.1%). The patient distribution according to tumor location is shown in Table 64-1. Of the 237 patients, 26 (11%) had previous surgery and 6 (2.5%) had radiation treatment. In 5 patients (2.1%) the closure was additionally reinforced by a pericranial flap, and in 4 patients (1.7%) with anterior fossa meningiomas, abdominal fat graft was used. In 7 patients (3%), acrylic cranioplasty was performed, and in 4 patients (1.7%), titanium mesh was used as a substitute for the bone flap.

CSF leak occurred in 1 patient (0.4%), and 2 patients (0.8%) experienced graft-related complications: namely, chemical meningitis, cerebritis, and accumulation of reactive extra-axial fluid. No patient had persistent subcutaneous CSF collection or pseudomeningocele that required a second intervention.