Non-watertight dural reconstruction in meningioma surgery: results in 439 consecutive patients and a review of the literature

Clinical article

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Object. There are various schools of thought when it comes to dural reconstruction following meningioma surgery, which are largely based on the personal experience of the individual surgeons. The authors' aim in this study was to review different dural reconstruction techniques, with an emphasis on their experience with the synthetic onlay dural graft technique.

Methods. The medical records of 439 consecutive patients who were surgically treated for an intracranial meningioma over a period of 7 years, and for whom dural reconstruction was performed using the onlay dural graft DuraGen (Integra Neurosciences) were reviewed retrospectively. The most common tumor location was the convexity (27.6%), and 12% of the patients had undergone previous surgery. Complications related to the closure technique and/or closure material, such as CSF leakage from the incision, rhinorrhea, or infectious or chemical meningitis were reviewed.

Results. A CSF leak was encountered in 2 patients (0.4%), and 10 patients (2.3%) experienced graft-related complications in the form of chemical meningitis, cerebritis, and accumulation of extraaxial fluid. Infectious complications were seen in 4 patients (0.9%; bacterial meningitis, osteomyelitis, epidural abscess). None of the patients had pseudomeningocele that required a second intervention.

Conclusions. In the authors' experience, the incidence of CSF leakage following non-watertight reconstruction of the dura mater in meningioma surgery performed using dural onlay graft was 0.4%. Graft-related complications occurred in 2.3%. These figures compare favorably to the majority of the series in which watertight dural closure is described and emphasized. (DOI: 10.3171/2010.7.JNS10460)

KEY WORDS • dural reconstruction • meningioma • watertight closure

The practice of dural closure, like many surgical techniques and applications, is largely based on the personal experiences of individual surgeons, shaped by training passed down from mentors, and repeated generation after generation. The traditional teaching in neurosurgery has been that the dural reconstruction has to be “watertight.” This is of particular importance in meningioma surgery, where achieving this goal may be a real challenge, especially when working at the skull base, or following an extensive resection of a large convexity meningioma.

Over the last few years, we have been using onlay collagen matrix graft for dural reconstruction in surgery for intracranial meningiomas. This material has been gaining more popularity in the neurosurgical community; however, the published reports consist of heterogeneous groups of pathological conditions and a relatively small number of patients. In this study, we present our experience with dural reconstruction performed using collagen matrix following surgery for intracranial meningiomas in a relatively larger number of patients.

Methods

The medical records of 439 consecutive patients who
were surgically treated for an intracranial meningioma by a single surgeon over a period of 7 years, and for whom dural reconstruction was performed using the onlay dural graft DuraGen (Integra Neurosciences) were reviewed retrospectively. Of note, petrous/petroclival meningiomas were excluded from this list because the onlay collagen matrix graft was not used in this group of patients, due to the relatively small size of the craniotomy and dural opening that we use for tumors in this location. The dural reconstruction technique used in these cases has been described previously.\(^\text{21}\)

Complications related to closure technique and/or closure material, such as CSF leakage from the incision, rhinorrhea, and pseudomeningocele formation requiring a second surgery as well as infectious or inflammatory reactions were reviewed.

**Results**

The most common location of the tumor was the convexity, in 121 patients (27.6%). The patient distribution according to tumor location is shown on Table 1. The most common location for the craniotomy was frontotemporal/pterional, with or without an associated skull base approach in 152 patients (34.6%). The distribution according to the craniotomy location is detailed in Table 2. Of the 439 patients, 53 (12.1%) had previous surgery, and 15 (3.4%) had radiation treatment. In 10 patients (2.3%), the closure was additionally reinforced by a pericranial flap, and in 6 patients (1.4%) with anterior fossa meningiomas, abdominal fat graft was used. In 14 patients (3.2%), acrylic cranioplasty was performed, and in 6 patients (1.4%), titanium mesh was used as a substitute for the bone flap.

A CSF leak from the incision occurred in 2 patients (0.4%): 1 patient with a foramen magnum and 1 with olfactory groove meningiomas. Graft-related complications such as chemical meningitis, cerebral inflammation, and extraaxial reactive fluid collection were encountered in 10 patients (2.3%). Of these, 2 had posterior fossa meningiomas and in the remaining 8, the tumor location was supratentorial. Bacterial meningitis, osteomyelitis/epidural abscess were seen in 4 patients (0.9%). No patient had persistent subcutaneous CSF collection or a pseudomeningocele that required a second intervention.

**TABLE 1: Incidences of meningiomas according to location in 439 patients**

<table>
<thead>
<tr>
<th>Location</th>
<th>No. (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>convexity</td>
<td>121 (27.6)</td>
</tr>
<tr>
<td>falcoregister</td>
<td>40 (9.1)</td>
</tr>
<tr>
<td>parasagittal</td>
<td>37 (8.4)</td>
</tr>
<tr>
<td>anterior fossa</td>
<td>36 (8.2)</td>
</tr>
<tr>
<td>tuberculum sellae</td>
<td>34 (7.7)</td>
</tr>
<tr>
<td>clinoidal</td>
<td>33 (7.5)</td>
</tr>
<tr>
<td>tentorial/torcular</td>
<td>30 (6.8)</td>
</tr>
<tr>
<td>middle/lateral sphenoid</td>
<td>27 (6.2)</td>
</tr>
<tr>
<td>orbitosphenoid</td>
<td>25 (5.7)</td>
</tr>
<tr>
<td>other</td>
<td>56 (12.7)</td>
</tr>
</tbody>
</table>

**TABLE 2: Incidence of the craniotomy location in 439 patients**

<table>
<thead>
<tr>
<th>Craniotomy Location</th>
<th>No. (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>frontotemporal/pterional(*)</td>
<td>152 (34.6)</td>
</tr>
<tr>
<td>frontal</td>
<td>92 (21)</td>
</tr>
<tr>
<td>bifrontal</td>
<td>43 (9.8)</td>
</tr>
<tr>
<td>parietal</td>
<td>39 (8.9)</td>
</tr>
<tr>
<td>suboccipital(*)</td>
<td>38 (8.7)</td>
</tr>
<tr>
<td>occipital</td>
<td>25 (5.7)</td>
</tr>
<tr>
<td>other</td>
<td>50 (11.4)</td>
</tr>
</tbody>
</table>

\(*\) With or without an associated skull base approach.

**Discussion**

**Watertight Closure: Do we Really Achieve it?**

As stated earlier, the traditional teaching in neurosurgery advocates that we perform a watertight closure. However, do we really achieve it? In a recent study by Boogaarts and colleagues,\(^\text{1}\) in which they looked intraoperatively at 49 cases following primary dural closure with a minimum linear dural incision of 2 cm (autologous duraplasty materials were used as needed to provide secured closure), 69% of the patients had spontaneous CSF leakage through the repair, and 25% developed leaks following a Valsalva maneuver of 20 cm H\(_2\)O. Only 6% of the patients did not demonstrate CSF leakage despite Valsalva maneuvers.

A fundamental element of the watertight closure is the use of suturing. However, the attempted tight closure may result in a so-called one-way valve along the suture line, causing the leaked fluid (that is, from postoperative coughing) to accumulate outside of the dura mater.\(^\text{7}\) Megyesi and colleagues\(^\text{10}\) tested different suturing in an in vitro model, comparing the efficacy of various sutures (interrupted simple, running simple, running locked, and interrupted vertical mattress sutures) on primary closure of linear incisions and closure of defects performed using grafts. Their results showed that although sutured linear incisions were more resistant to leakage than dural patches, once the leak has been established, the pressure needed for it to continue was less than the opening pressure in both groups. This is probably due to the initial pressure stretching the suture holes and line. 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 an extradural CSF collection. This may be even more of a concern when implanting synthetic graft materials, because dural tearing may be caused by the sutures themselves, as a result of the elastic properties of these grafts, which exert traction on the sutures.\(^\text{12}\)

**Dural Grafts**

The use of dural grafts has been a common practice when primary closure is not possible. This is of particular significance in convexity meningiomas and in skull base meningiomas to an extent, in which the removal of a large piece of dura mater along with the tumor to achieve a
Dural reconstruction in meningioma surgery

Simpson Grade 1 or 2 resection results in a sizeable defect. A number of materials have been proposed in the literature for this purpose. Ideally, a graft would provoke no inflammation in the host body, have no neurotoxicity, and would not adhere to the underlying brain. At the same time it would be easily available, inexpensive, durable yet flexible, and easily prepared and shaped. And last but not least, while providing adequate protection for the underlying brain, it should ensure watertight closure. It may be practical to classify the contemporary dural substitutes as autografts (fascia latae, temporalis fascia); allografts (amniotic and placental membranes, pericardium, fascia, lyophilized dura); xenografts (bovine or porcine pericardium, peritoneum, dermis); and synthetic materials (PTFE, polyester urethane).20 Understandably, each material poses certain disadvantages that limit its usage: for example, the fascia latae requires a second incision and thereby introduces another source for potential morbidity. For other autografts that are accessible through the same incision, such as the pericranium and temporalis fascia, availability becomes a concern, especially when a large graft is required. For allografts and xenografts, the most common limitations have been immunogenic reactions and risk of transmitting prion-related diseases, and for synthetic materials, the difficulty in handling and the poor sealing qualities.5,18,20 One common characteristic of all of these materials is that all of them were developed to ensure a watertight closure, and they require suturing to the endogenous dura mater.

Non-Watertight Dural Reconstruction With Collagen Matrix: Rationale and Application

Recently there has been interest in the use of collagen matrix for dural reconstruction. This collagen matrix provides a low-pressure absorptive surface to diffuse CSF and attaches to the dural surface via surface tension.16 It also helps clot formation by the platelets that deposit themselves on the collagen; these then disintegrate and release clotting factors, ultimately facilitating fibrin formation.6 This fibrin has an important role in holding the graft in place until fibroblasts, associated with blood vessels, proliferate into the graft.16 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 mater. On the other hand, materials such as the allogenic cadaveric dura or synthetic materials may become encapsulated in a connective tissue layer.6 The compact structure of the xenogenic materials may limit the fibroblast migration to the edges or to the suture holes.15 These processes do not constitute an ideal situation with regard to the sealing quality of the material.

When applying it over the dural defect, the collagen matrix is easily shaped and does not require any suturing. The procedure simply consists of onlay application of the material over the dura (Fig. 1). Danish and colleagues3 reported a significantly lower (36-minute) operating time with the use of the collagen matrix as compared with sutureable acellular human dermis. The rates of pseudomeningocele formation, wound infection, and CSF leakage were similar in both groups. One can possibly argue that significant shortening of the surgical procedure may potentially decrease the risk of anesthesia-related complications, and may even help reduce the medical costs related to operating room usage.

Dural Substitutes: Comparative Outcome

Incidence of CSF Leakage. The incidence of CSF leakage reported in the literature varies, even when practitioners are using similar materials, probably indicating user-dependent variations. For instance, the incidence of CSF leakage following cranial procedures was reported as 2%–2.2% for acellular human dermis,3,20 15% for allogenic cadaveric dura,18 3% with allogenic and xenogenic pericardium and dura,17 7% for vicryl mesh, and 10% for autologous fascia.19 Malliti and colleagues9 reported an 8-fold higher CSF leakage rate in patients who had dural reconstruction with synthetic dural graft as compared with patients in whom reconstruction was performed using a pericranial graft. Nagata and colleagues12 reported an incidence of 3% when PTFE was used along with a tissue adhesive, as compared with 20.3% when PTFE was used alone. In a more recent study, consisting of 79 patients with various cranial and spinal pathological conditions, no patient developed postoperative CSF leakage.15

Traditionally, the incidence of CSF leaks or symptomatic pseudomeningoceles have been reported to be relatively higher after procedures involving the posterior

![Fig. 1. Intraoperative photographs. Left: Extensive resection of a right-sided orbit-sphenoid meningioma resulting in a large dural defect. Right: Onlay application of the collagen matrix graft.](image)
fossa. In a series of 128 patients who underwent posterior fossa surgery for various vascular, neoplastic, and other types of diseases, and in whom various dural reconstruction techniques and materials were used, the incidence of CSF leakage was 25% for sutured bovine collagen, 12% for reformulated bovine collagen, 8% for acellular dermis, and none for bovine collagen. In another study consisting of 52 patients undergoing posterior fossa surgery for various pathological entities, dural reconstruction performed using collagen matrix resulted in no leakage. Litvack and colleagues reported a CSF leakage rate of 11% following infratentorial procedures, and this was significantly lower when bilayered collagen matrix grafts were used. In our series, although the incidence of CSF leakage was higher in the posterior fossa (2.6% vs 0.2% in the supratentorial location), due to the small number of patients who had leakage overall, this did not reach statistical significance.

The major difference in our series that distinguishes it from the other reports is that it consists of a relatively large number of patients treated by a single surgeon for the same pathological entity. This not only makes the patient population relatively more homogeneous, but it also removes the surgeon-dependent variables that may confound interpretation of the data in the other reported series. The 0.4% incidence of postoperative CSF leakage in our experience compares favorably with that in the literature in which watertight techniques are used. In this context, we believe that meticulous closure of the subsequent layers may actually play a more critical role in the prevention of postoperative CSF leakage from the wound, regardless of the dural reconstruction technique used.

Inflammatory Reactions. Inflammatory reactions caused by dural graft materials have been reported in the literature, and can present in a time frame of 1–6 months following surgery. In their series of almost 3000 patients with various neurosurgically treated pathological conditions, in whom allogenic and xenogenic dense connective tissue grafts such as fascia lata, pericardium, and dura mater were used, Paržízek and colleagues reported the incidence of chemical meningitis as 2.3%. Chemical meningitis in general has a propensity to occur in posterior fossa craniotomies, but this may not be applicable when it comes to chemical meningitis caused by a dural substitute. In our experience, the incidence of inflammatory reactions was relatively higher after posterior fossa surgery (5.2%) compared with supratentorial locations (2%); however, this has not reached statistical significance. Although chemical meningitis due to bovine collagen matrix has been reported previously, to the best of our knowledge, this study constitutes the largest series reporting on non-watertight dural closure performed using collagen matrix in patients undergoing surgery for intracranial meningiomas who were treated by the same surgeon. In our experience, postoperative CSF leakage was seen in only 0.4% of the patients. Graft-related complications were seen in 10 patients (2.3%). These figures compare favorably to the majority of the reported series in which various techniques of watertight closure are used. Also, the absence of a major concern regarding watertightness in closure would allow for aggressive dural removal when necessary.

Conclusions

To the best of our knowledge, this study constitutes the largest series reporting on non-watertight dural closure performed using collagen matrix in patients undergoing surgery for intracranial meningiomas who were treated by the same surgeon. In our experience, postoperative CSF leakage was seen in only 0.4% of the patients. Graft-related complications were seen in 10 patients (2.3%). These figures compare favorably to the majority of the reported series in which various techniques of watertight closure are used. Also, the absence of a major concern regarding watertightness in closure would allow for aggressive dural removal when necessary.

Disclosure

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Author contributions to the study and manuscript preparation include the following. Conception and design: Lee, Sade. Acquisition of data: Sade, Oya. Analysis and interpretation of data: all authors. Drafting the article: Sade, Oya. Critically revising the article: Lee, Sade. Reviewed final version of the manuscript and approved it for submission: all authors. Study supervision: Lee.

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