Dural Closure in Confined Spaces of the Skull Base with Nonpenetrating Titanium Clips

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BACKGROUND: Dural repair in areas with limited operative maneuverability has long been a challenge in skull base surgery. Without adequate dural closure, postoperative complications, including cerebrospinal fluid (CSF) leak and infection, can occur.

OBJECTIVE: To show a novel method by which nonpenetrating, nonmagnetic titanium microclips can be used to repair dural defects in areas with limited operative access along the skull base.

METHODS: We reviewed 53 consecutive surgical patients in whom a dural repair technique utilizing titanium microclips was performed from 2013 to 2016 at our institution. The repairs primarily involved difficult-to-reach dural defects in which primary suturing was difficult or impractical. A detailed surgical technique is described in 3 selected cases involving the anterior, middle, and posterior fossae, respectively. An additional 5 cases are provided in more limited detail to demonstrate clip artifact on postoperative imaging. Rates of postoperative CSF leak and other complications are reported.

RESULTS: The microclip technique was performed successfully in 53 patients. The most common pathology in this cohort was skull base meningioma (32/53). Additional surgical indications included traumatic dural lacerations (9/53), nonmeningioma tumors (8/53), and other pathologies (4/53). The clip artifact present on postoperative imaging was minor and did not interfere with imaging interpretation. CSF leak occurred postoperatively in 3 (6%) patients. No obvious complications attributable to microclip usage were encountered.

CONCLUSION: In our experience, intracranial dural closure with nonpenetrating, nonmagnetic titanium microclips is a feasible adjunct to traditional methods of dural repair.

KEYWORDS: Anastomotic clips, Dural closure, Durotomy, Nonpenetrating Titanium clips, Skull base

Dural repair in deep or narrow intracranial spaces has long been a challenge in cerebral surgery. This is especially true in complex dural defects of the anterior, middle, and posterior fossae. When possible, primary repair or direct suturing of graft material to the dura mater is the preferred initial step. Modern techniques to repair complex dural defects employ several autologous and synthetic materials with a common theme centered on a multilayered closure.1,2 It is well understood that inadequate dural closure can lead to postoperative leakage of cerebrospinal fluid (CSF) with resultant neurological sequelae.3

In the case of skull base meningiomas and other dural-based pathologies, aggressive dural resection is often limited by the inability to repair dural defects in narrow cranial spaces (eg, planum sphenoidale or foramen magnum). This may reduce the extent of resection, which, in the context of meningiomas, may lead to higher recurrence rates.4,5

In the setting of skull base dural defects resulting from trauma, primary dural repair can be challenging, especially along the posterior and lateral margins of the anterior fossa. Without question, harvesting pericranial flaps is a valuable technique in anterior skull base repair. Depending on the severity of dural injury, suturing of pericranium or graft material may be quite tedious, if not impossible.
AnastoClips® are nonpenetrating titanium microclips originally designed for vascular anastomoses (LeMaitre Vascular Inc, Burlington, Massachusetts). More recently, these clips have been utilized in multiple surgical specialties, including neurosurgery. Authors have reported promising results for dural repair in minimally invasive lumbar spine surgery as well as pediatric spinal surgery.6-8 These studies have shown multiple benefits to dural closure with microclips, including reduced repair time, ease of clip deployment, sufficient clip closure strength, and greater closure maneuverability along narrow corridors of the spine.7,9 Despite the potential advantages that dural clip closure may afford, to our knowledge, the present series represents the first description of clip utilization for repair of dural defects along skull base.

In this study, we describe a novel technique for repair of complex dural defects using nonpenetrating, nonmagnetic titanium clips in a cohort of 53 patients. In our opinion, utilization of this technique allows for greater versatility in primary dural repair, as the working room required is less than with traditional suturing. Patient outcomes and illustrative cases are presented.

METHODS

Patient Selection

We conducted a retrospective review of 53 consecutive patients who underwent cranial surgery with subsequent dural repair using microclips between 2013 and 2016 at our institution. The dural repairs primarily involved difficult-to-access skull base locations in which primary suturing is difficult or impractical. Clinical records, hospital charts, operative notes, and imaging studies were reviewed through a minimum follow-up time of 2 mo. This study was performed with approval from our institutional review board.

Surgical Technique

The clip applier consists of an 8-cm or 15-cm shafted hand piece with a gently curved tip. The applier contains a varying number of titanium clips, depending on the desired clip size (small, medium, large, extra large). There is an internal rotatory mechanism allowing for rotation of the applier tip to achieve the desired angle(s). We prefer the extra-large clips for the majority of intracranial applications, as the internal diameter (maximum combined thickness of the 2 tissue edges to be apposed) is 3 mm. The extra-large clip applier contains 25 clips, which may be applied in succession.10

Though not required in all circumstances, we prefer to perform the closure under microscopic visualization. Nonlocking forceps are used to appose the edges of the dural graft and native dura mater at the desired orientation while the clip applier hand piece is used to place each clip at the desired location. An illustration of this technique is shown in Video. Supplemental Digital Content. With a technique akin to applying skin staples, the clips are rapidly applied in an interrupted fashion by squeezing together a lever resting under the surgeon’s thumb and forefinger. Upon depressing the lever, the current clip is released and a new one is shifted in its place for deployment. As the repair is made, the forceps are used to advance in a circumferential fashion until completion.

Outcome Assessment

Postoperative imaging was obtained in all patients as part of a routine protocol. All postoperative films were interpreted by a neuroradiologist. An analysis of microclip artifact on postoperative imaging was performed in all patients. Radiographic reports were examined for statements indicating difficulty in film interpretation related to microclip artifact.

Patients underwent a full neurological examination by the attending neurosurgeon immediately after surgery and at routine outpatient follow-up. New or worsened neurological deficits were documented as complications. Inpatient and outpatient records were used to report postoperative CSF leakage, surgical site infection, and other complications that were surgically related.

CASE ILLUSTRATIONS

Case 1

A 65-yr-old male presented with right neck and shoulder pain 2 yr after undergoing resection of a large right cerebellar convexity hemangiopericytoma. The patient was found to have tumor recurrence extending along the dura into the paracerebellar space and involving the V3 and V4 segments of the right vertebral artery (Figures 1A and 1B). Prior to surgery, the patient underwent angioembolization of the corresponding segments of the right vertebral artery. A right far lateral transcondylar craniotomy was performed for resection of the tumor, including the involved dura mater. Along with a dural graft, microclips were used to perform a primary repair of the dura along the cerebellar convexity extending inferiorly along the lateral aspect of the spinal dura to the level of C2 (Figures 1C and 1D).

Pathology confirmed recurrence of hemangiopericytoma. Postoperatively, the patient developed hydrocephalus, requiring ventriculoperitoneal shunt placement; however, he did not develop a pseudomeningoecele or leak into this previously radiated surgical site. The patient was discharged to a skilled nursing facility.

Case 2

A 64-yr-old female with a history of a torcular meningioma resected at an outside institution presented after a syncopal episode. She was found to have a right anterior clinoidal meningioma (Figure 2A). Physical examination demonstrated a right-sided superior visual field deficit and otherwise intact cranial nerves.

The patient underwent a right-sided minipterional craniotomy for resection (Figure 2B). An extradural clinoidectomy was performed, decompressing the optic nerve. Involved dura, extending anteriorly over the optic canal and orbital roof and inferiorly along the medial aspect of the sphenoid/superior orbital fissure, was resected. Resection of the tumor component involving the cavernous sinus was not pursued. Intraoperative dural graft placement with microclips is shown in Figures 2C-2G. Clips were used in this case because closing of the dura near the orbital
FIGURE 1. Case 1: A and B, preoperative contrast-enhanced axial and coronal CT of the brain revealing a homogenously enhancing right cerebellar hypodensity extending inferiorly to the level of the V3-V4 segment of the vertebral artery. Evidence of previous craniotomy is demonstrated by the presence of embolic material present in the occipital artery feeders. C, Postoperative contrast-enhanced axial CT of the brain revealing the outline of the clips around the dural patch attached to the native dura (green arrows). Gross total resection was achieved. Artifact is visible from the embolization materials; this is illustrated with the blue arrow labeled V3, referring to the third segment of the vertebral artery. Images windowed for viewing both the brain and the bone reveal no clip artifact. D, Intraoperative picture demonstrated successful primary dural repair with clips. The embolized vertebral artery (V3) and the first cervical vertebra (C1) are labeled for reference.
apex would involve suturing over the optic nerve in a confined space.

There were no complications postoperatively. Pathology confirmed a WHO grade I meningothelial meningioma. The patient was discharged to a rehabilitation facility. The patient’s visual field deficit improved on follow-up. The tumor remnant located in the cavernous sinus was treated with stereotactic radiosurgery.

Case 3

An 18-yr-old female presented after being involved in an all-terrain vehicle accident in which she suffered extensive anterior skull base fractures involving the frontal sinus, cribiform plate, ethmoid bone, sphenoid bone, and clivus (Figures 3A-3D). Physical examination demonstrated persistent CSF leakage.

An extended bifrontal transbasal craniotomy was performed to repair the CSF leak, cranialize the frontal sinus, and repair the
calvarial and facial fractures. A large pericranial flap was harvested on initial dissection. The depressed calvarial fragments and their associated dural lacerations were identified. Under microscopic vision, a subfrontal extradural dissection was performed to identify the posterior and lateral margins of the involved dura.

The remaining intact dura surrounding the cribiform plate was released in order to facilitate dural laceration repair over the planum sphenoidale (Figure 3E). Using the microclip closure technique, a synthetic dural graft was clipped to the posterior-most aspect of the dural defect, and the remaining dural repair

**FIGURE 3.** Case 3. A-D, preoperative imaging of axial, coronal, sagittal, and reconstructed CT of the face and sinuses. A complex fracture involving the anterior and posterior tables of the frontal sinus, the cribiform plate bilaterally, the ethmoid and sphenoid sinuses, and the clivus is visualized along with associated pneumocephalus. Multiple displaced boney fragments are noted. E-H, Immediate postoperative axial, coronal, sagittal, and reconstructed CT of the face and sinuses demonstrating fracture repair. The margins of the primary dural repair are outlined by the hyperdense microclips visualized in all views (green arrows).
was performed in a circumferential fashion (Figures 3E-3H). The remainder of the closure was performed using our standard technique, including pericranial graft placement. Microclips were also used to affix the pericranium to the native dura at the desired location beyond the primary dural graft repair.

There were no complications postoperatively, and the patient’s CSF leak was resolved. The patient was discharged to a rehabilitation facility. The patient has not developed a CSF leak at 1 yr from repair.

**Postoperative Imaging of Microclips**

To illustrate the limited amount of clip artifact on postoperative MRI, we have included pre- and postoperative imaging of an additional 5 cases in Figure 4. The microclip artifact is outlined in each postoperative image as indicated. In general, microclips may be identified on postoperative T1- and T2-weighted MRI as small, rectangular-shaped hypointensities. On CT, the shape of the microclip is readily identifiable and appears as a small hyperdensity. Brief descriptions of each case are provided below. Selected preoperative images are also provided for reference.

Figures 4A and 4B illustrate the case of a 54-yr-old male who underwent an extended bifrontal transbasal craniotomy for resection of an esthesioneuroblastoma with significant intracranial extension. The tumor-associated dura was resected surrounding the margins of tumor extension into the cranium. A dural graft was clipped into place in a circumferential fashion to repair the defect in conjunction with a pericranial flap. Clip artifact is appreciated in Figure 4A on T1-weighted images as a U-shaped ring of small hypointensities outlining the repair margin.

In Figures 4C and 4D, pre- and postoperative MRI of a 64-yr-old female who underwent resection of a carcinoma with neuroendocrine features is provided. A left minipterional craniotomy, left orbital exenteration, and an endoscopic endonasal exploration were performed. The tumor-involved dura overlying the greater and lesser wings of the sphenoid as well as the orbital roof was resected. An orbital exenteration was performed, as tumor invasion of the periorbita was present. A dural graft was clipped into place in a circumferential fashion along the dural resection margins. Clip artifact present along the posterior and lateral margins of the dural defect is highlighted in Figure 4C as a linear row of hypointensities on T1-weighted MRI.

Figures 4E and 4F demonstrate a case of a 44-yr-old female who underwent a right minipterional craniotomy for resection of a middle fossa meningioma. The tumor-involved dura was resected up to the posterior aspect of the cavernous sinus near the petrous apex. The clip artifact present on T2-weighted MRI is highlighted in Figure 4E as a C-shaped ring of hypointensities.

Figures 4G and 4H demonstrate the case of a 67-yr-old female who underwent an extended bifrontal transbasal craniotomy for resection of a hyperostosing olfactory groove meningioma. A preoperative MRI was not available for this patient. The preoperative CT illustrating significant hyperostosis present within the tumor is provided in Figure 4H. Tumor-involved dura was resected following mass removal and skull base drilling. The resulting oval-shaped dural defect was repaired using a dural graft and microclips in conjunction with a pericranial flap. A postoperative T2-weighted MRI demonstrating clip artifact along the posterior margin of the planum sphenoidale is provided in Figure 4G.

Figures 4I and 4J demonstrate minimal clip artifact after a right minipterional cranietomy was performed for resection of a sphenoid wing meningioma in a 34-yr-old female. Figure 4I illustrates postoperative clip artifact present on T2-weighted MRI along the margins of the resected dura overlying the greater and lesser sphenoid wings.

**RESULTS**

**Patient Data**

A total of 53 patients underwent a cranial operation in which the microclip repair technique was successfully performed. Of these, 39 (74%) were women and 14 (26%) were men. The median age at operation was 53 yr. These data are given in Table 1. The patient cohort consisted of a wide range of surgical pathologies. The most common pathology treated was skull base meningioma. In Table 2, we provide a detailed breakdown of the surgical pathologies present in this cohort. In short, 32/53 (60%) patients underwent resection of skull base meningioma, 9/53 (17%) underwent an operation after trauma to the anterior skull base, 8/53 (15%) patients underwent resection for nonmeningioma skull base tumors, and 4/53 underwent an operation for other reasons.

**Surgical Outcomes**

As the present cohort is quite heterogeneous with respect to the pathologies treated, we have stratified the postoperative neurological complications as presented in Table 3. Patients who underwent meningioma resection (32 patients) experienced the following complications: surgical site infection in 4/32 patients, trigeminal distribution pain in 4/32 patients, third nerve palsy in 3/32 patients, dysphagia in 2/32 patients, diplopia in 2/32 patients, ptosis in 1/32 patients, intracerebral hematoma in 1/32 patients, hydrocephalus in 1/32 patients, and seizure in 1/32 patients. Among those who underwent resection of nonmeningioma skull base tumors, surgical site infection occurred in 2/8 patients, dysphagia in 1/8 patients, hemiparesis in 1/8 patients, and hydrocephalus in 1/8 patients. In the other pathologies group, 1/8 patients experienced a seizure and pneumocephalus. The trauma group did not develop a postoperative CSF leak, surgical site infection, or new neurological deficits as a result of surgery.

Of the 53 patients who underwent dural closure using the microclip repair technique, postoperative CSF leak occurred in 3 (6%) patients. Among those who developed a CSF leak, there was 1 patient with a large frontal bone and anterior skull base...
FIGURE 4. Microclip artifact on magnetic resonance imaging (MRI). Panels A and B illustrate the postoperative clip artifact on T1-weighted axial MRI after resection of an esthesioneuroblastoma with significant intracranial extension. Panels C and D illustrate clip artifact on T2-weighted axial MRI after resection of a carcinoma with neuroendocrine features that extended into the orbit, middle fossa, and infratemporal fossa. Panels E and F illustrate the clip artifact on T2-weighted axial MRI after resection of a middle fossa meningioma. Panels G and H illustrate the clip artifact on T2-weighted axial MRI after resection of an olfactory groove meningioma. Panels I and J represent the clip artifact on T1-weighted axial MRI after resection of a sphenoid wing meningioma.
TABLE 1. Patient Characteristics

<table>
<thead>
<tr>
<th>TABLE 1. Patient Characteristics</th>
<th>n (%)</th>
<th>Median age (range)</th>
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<tbody>
<tr>
<td><strong>Patients</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td>53</td>
<td>53 (16-85)</td>
</tr>
<tr>
<td>Men</td>
<td>14/53 (26)</td>
<td>57 (18-69)</td>
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<tr>
<td>Women</td>
<td>39/53 (74)</td>
<td>37 (16-85)</td>
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<td><strong>Reason for operation</strong></td>
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<tr>
<td>Meningioma</td>
<td>32/53 (60)</td>
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<tr>
<td>Trauma</td>
<td>9/53 (17)</td>
<td></td>
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<tr>
<td>Nonmeningioma tumor</td>
<td>8/53 (15)</td>
<td></td>
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<tr>
<td>Other</td>
<td>4/53 (8)</td>
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TABLE 2. Surgical Pathologies

<table>
<thead>
<tr>
<th>TABLE 2. Surgical Pathologies</th>
<th>n</th>
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<tbody>
<tr>
<td>Meningioma (n = 32)</td>
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<tr>
<td>Sphenoid wing</td>
<td>18/32</td>
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<tr>
<td>Clinoide</td>
<td>5/32</td>
</tr>
<tr>
<td>Spheno-cavernous</td>
<td>3/32</td>
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<tr>
<td>Olfactory groove</td>
<td>3/32</td>
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<tr>
<td>Petroclival</td>
<td>1/32</td>
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<tr>
<td>Sphenopetroclival</td>
<td>1/32</td>
</tr>
<tr>
<td>Planum</td>
<td>1/32</td>
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<tr>
<td><strong>Trauma location (n = 9)</strong></td>
<td></td>
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<tr>
<td>Cribriform plate</td>
<td>3/9</td>
</tr>
<tr>
<td>Planum sphenoidale</td>
<td>5/9</td>
</tr>
<tr>
<td>Tuberculum sellae</td>
<td>1/9</td>
</tr>
<tr>
<td>Nonmeningioma tumors (n = 8)</td>
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<tr>
<td>Papilloma</td>
<td>2/8</td>
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<tr>
<td>Osteoma</td>
<td>2/8</td>
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<tr>
<td>Esthesioneuroblastoma</td>
<td>1/8</td>
</tr>
<tr>
<td>Sinonasal undifferentiated carcinoma</td>
<td>1/8</td>
</tr>
<tr>
<td>Hemangiopericytoma</td>
<td>1/8</td>
</tr>
<tr>
<td>Carcinoma with neuroendocrine features</td>
<td>1/8</td>
</tr>
<tr>
<td>Other (n = 4)</td>
<td></td>
</tr>
<tr>
<td>Frontal sinus mucocele</td>
<td>2/4</td>
</tr>
<tr>
<td>Repair of CSF leak post tumor resection</td>
<td>1/4</td>
</tr>
<tr>
<td>Fibrous dysplasia</td>
<td>1/4</td>
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osteoma that required an extensive reconstruction during the initial surgery, and 2 patients with a sphenoid wing meningioma. These data are given in Table 4. In each case, the CSF leak was noted after initial discharge when the patient presented with wound breakdown and surgical site infection. In each case, the patient was taken for intraoperative wound exploration and revision. The patients were then treated with several weeks of antibiotics. None have required permanent CSF diversion at a minimum of 2-mo follow-up.

Radiographic Outcome

On review of postoperative imaging reports performed by neuroradiologists, microclip artifact is readily identifiable, though it has yet to significantly limit diagnostic interpretation in our cohort.

**DISCUSSION**

CSF leaks are a well-known potential complication following spinal and cerebral surgery. Prevention of these leaks is important in minimizing postoperative complications. CSF leakage due to inadequate dural closure may lead to multiple neurological sequelae including infection and pseudomeningocele.\(^3\) The strategy for closure of most complex dural defects centers around a multilayered approach with synthetic and autologous material.\(^1,2,11\) Although this assists in preventing CSF leaks, primary dural repair or direct attachment of graft material to the dura mater is preferred.\(^12\)
Previous studies have investigated the most effective methods for intracranial dural repair. For instance, studies have shown that interrupted simple suturing affords the most watertight closure for linear incisions. While suturing may be the most cost-effective and straightforward method for dural repair, it is not always feasible. Narrow working angles, deep cranial locations, and thin or torn dura present unique challenges for suture placement. The most obvious limitation is the size of the suture needle and its proximity to critical neurovascular structures. Complex defects requiring extensive suturing are also tedious and time consuming.

The microclips discussed in this note are from the AnastoClip® Vessel Closure System (LeMaitre Vascular, Inc., Burlington, Massachusetts). The clips were originally designed for vascular anastomoses, but their use has expanded to include roles in neurosurgery, urology, and pediatric surgery. The microclip applier is a single-shafted instrument with an angled tip allowing for unobstructed visualization of the tines of the clip during deployment. The price of the applier varies based on hospital contract, but at our institution the cost is roughly $400 for a disposable device that contains a 25-clip cartridge. While more expensive than sutures, we note that microclips are used in areas that would be difficult if not impossible to suture. In our experience, a significant advantage of the microclips is that the tip of each tine on a given clip is unable to violate the dura mater or graft material. Rather than penetrating the protective dural covering, the clips compress the tissue edges together. This is in contrast to suturing in difficult-to-reach areas where repetitive suturing may lead to inadvertent injury from needle trauma to the cerebral cortex or other neurovascular structures located immediately deep to the dural covering.

Despite the nonpenetrating nature of the microclips, at increased hydrostatic pressures, authors have reported microclip use to be associated with a lower rate of fluid leakage than traditional suturing. At physiological hydrostatic pressures, authors have also found no difference in CSF leakage rate when comparisons between monofilament sutures, braided sutures, and microclips were made. Passing the suture needle through dura creates a hole through which the suture passes. When traction is applied to the suture in an effort to appose the edges, the needle holes may be inadvertently enlarged or the dura may be torn. Not only does this create potential pathways for CSF leak, but the dura mater is also a vascularized tissue that can hemorrhage when injured (eg, near the cerebral venous sinuses where the dura is thin). We hypothesize that because the microclips do not penetrate the dura mater, they offer little risk of injury to underlying structures.

Studies on dural repair in non-skull base locations have shown favorable outcomes with clip utilization. In the pediatric population, the clips have been used for spinal dural closure. A study of 27 pediatric patients found that in tight spaces, spinal dural closure was accomplished more rapidly with the use of clips. In accordance with the present series, the authors reported no significant complications or postoperative CSF leaks, and that the clips did not interfere with postoperative imaging.

Published studies in vascular literature have demonstrated a reduction in anastomose repair times with clips when compared to traditional suturing methods. These results are similar to cardiovascular studies, which have shown nonpenetrating clip closure of large arteries to have a significantly reduced repair time when compared to interrupted suturing. These results coincide with our own anecdotal experience that clip usage allows for a more rapid repair in areas where suturing is challenging.

From an oncological perspective, it is well known that meningioma recurrence rate is dependent on the extent of resection, including the involved dura matter and hyperostotic bone. In an effort to maximize the extent of resection of the dural attachment while maintaining the ability to achieve adequate dural closure, the senior author began employing the microclip repair technique to augment existing methods of dural repair. Here, we do not assert that microclips are associated with lower meningioma recurrence rates. Given the generally slow growth rate of skull base meningiomas, we do not yet have the long-term follow-up necessary to determine the potential impact, if any, on recurrence rates. In addition, although the impetus for this technique was to extend tumor-involved dural resection, further quantitative analysis will be necessary to determine if a greater extent of dural resection is achieved using this technique. Regardless, it is reasonable to assert that microclips offer an adjunct to standard techniques of dural repair after meningioma resection.

Because our cohort was composed of a variety of pathologies, it is difficult to compare our results to the existing literature. However, we have attempted to compare our cohort, well aware that the rate of CSF leakage is of primary interest in those wanting to implement this technique. In this series, 3 patients developed a CSF leak postoperatively. One patient harbored a large osteoma involving the anterior skull base and the other 2 patients had sphenoid wing meningiomas. In comparison to other studies examining anterior skull base tumors, previous authors have reported CSF leaks in 11% (6/55) and 5% (1/21) of patients after resection of benign and malignant anterior skull base tumors. Two cases of postoperative CSF leak developed after resection of a medial sphenoid wing meningioma. Our CSF leak rate among all patients with sphenoid wing meningiomas was 11% (2/18). Both of these patients presented with wound breakdown and surgical site infection postoperatively. Nevertheless, this rate is higher than that previously reported. Authors have reported postoperative CSF leak in 6.5% (7/108) of patients after resection of medial sphenoid wing meningiomas. In each case of postoperative CSF leak in this series, there was an associated surgical site infection. After wound revision and medical treatment, these patients have not developed a subsequent CSF leak in outpatient follow-up. Also, as none of the patients required permanent CSF drainage, we feel this is likely related to poor wound healing from infection rather than a leak resulting from poor closure technique. Future analysis in our sphenoid wing meningioma cohort will be valuable in determining refinements in our approach with regard to the margins of dural resection.
Interestingly, our study had zero postoperative CSF leaks in the trauma cohort (0/9). This rate is lower than trauma studies that have reported postoperative leaks in 12% (5/43) and 13% (3/23) of patients after anterior skull base dural repair.\textsuperscript{19,20} In addition, these studies included patients with only isolated frontal bone or frontal sinus defects, excluding patients with fractures located more posteriorly along the anterior skull base. In our series, we included patients not only with frontal sinus involvement but also patients with defects along the cribiform plate, planum sphenoidale, and tuberculum sellae. Although our cohort is relatively small in comparison, we feel these results are promising. Despite the heterogeneity of this cohort, we believe a combined overall CSF leak rate of 6% (3/53) suggests that this technique is at least no worse than traditional methods used for dural closure, and may offer an advantage in the trauma population with anterior skull base defects. Further analysis with a larger trauma cohort will be necessary to confirm these findings. Though we have not performed a controlled comparison between traditional suturing and the microclip repair technique, we feel clip placement to be a reasonable alternative to dural suturing in difficult-to-reach cranial locations. We do acknowledge that it is impossible to get a watertight closure in all cases and do not suggest omitting standard multilayered closure techniques. Lastly, we feel it is important to note that microclips may also be used to act as a tacking stitch to tether a pericranial flap or other graft material in locations we have previously been unable to place a suture.

**CONCLUSION**

In our experience, intracranial dural closure with nonpenetrating titanium microclips is an easily performed technique for dural repair in spaces with limited operative maneuverability. The technique described offers an additional method of augmenting primary dural repair when direct suturing is difficult or impossible.

**Disclosure**

The authors have no personal, financial, or institutional interest in any of the drugs, materials, or devices described in this article.

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**Supplemental digital content** is available for this article at [operativeneurosurgery-online.com](http://operativeneurosurgery-online.com).

**COMMENTS**

The authors present a case-based description of a technique that they use as an option for dural closure in difficult to access regions of the skull base. CSF leaks can be a difficult to manage surgical complication in skull base surgery. This is most certainly a condition that is better prevented in the first place. To that end, multiple techniques for dural closure, repair, and reconstruction have been described and utilized with varying degrees of success. The authors describe their early experience with non-penetrating titanium clips as a modality for closing/reapproximating the dura in difficult to access regions of the skull base. The technique, though not novel, is yet another tool that skull base surgeons can keep in their armamentarium for CSF leak prevention. We commend the authors for their addition to the skull base repair literature and eagerly anticipate longer term results for this dural closure technique.

Jaideep ThakurBharat Guthikonda
Shreveport, Louisiana
The authors present their preliminary experience using vascular clips to achieve primary dural closure in a series of 53 skull base surgical cases. This technique has been reported previously for closure of spinal dura and other surgical procedures. When presented with a difficult dural closure there are many options to consider such as various dural onlay grafts, autologous non-vascularized tissues such as fascia and or adipose, local rotational flap such as temporalis muscle, etc. In the majority of the cases the authors were able to achieve a suitable closure including a number of a cases that appeared to involve complex reconstructions. Like so many closure options, this technique is not perfect nor fool-proof for all situations, as the series does include some cerebrospinal fluid leaks, but nonetheless it does appear to be another option for surgeons to consider. Many cases such as those presented in the authors’ series have unique features and one must therefore consider a number of variables as to which would be the most suitable closure strategy. The authors present another technique that is worth considering in some circumstances. The authors demonstrate that there was relatively limited artifact on postoperative CT and MRI. Nonetheless the follow-up is short and it is possible this artifact could have some impact on the future ability to detect small areas of tumor recurrence, for example. More cases with longer follow-up will broaden our understanding of the potential utility of this technique.

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