Autologous cervical fascia duraplasty in 123 children and adults with Chiari malformation type I: surgical technique and complications

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OBJECT Techniques for combined extradural and intradural decompression with expansile duraplasty for Chiari malformation type I (CM-I) have been well described, with various allogenic and autologous materials used for duraplasty. However, the approach and surgical technique used for duraplasty in our treatment of CM-I and developed by the senior author in the 1990s has not been described.

METHODS A prospective database was initiated in March 2003 to denote the use of cervical fascia for duraplasty and incorporate an ongoing detailed record of complications during the surgical treatment of children and adults with CM-I with and without syringomyelia. A total of 389 surgeries for CM-I were performed on 379 patients from March 2003 to June 2016. A total of 123 posterior procedures were performed on 123 patients in which both a posterior fossa extradural and intradural decompression with duraplasty (extra-intradural) was performed. In this paper the authors describe the surgical technique for harvesting and using cervical fascia for duraplasty in the surgical treatment of CM-I and analyze and discuss complications from a prospective database spanning 2003–2016.

RESULTS The authors found that cervical fascia can be harvested in patients of all ages (2–61 years old) without difficulty, and it provides a good substitute for dura in creating an expansile duraplasty in patients with CM-I. Cervical fascia is an elastic-like material with a consistency that allows for a strong watertight closure. Harvesting the cervical fascia graft does not require any further extension of the incision superiorly or inferiorly to obtain the graft. Complications were uncommon in this study of 123 children and adults. The risk of any type of complication (aseptic meningitis, CSF leak, pseudomeningocele, infection, development of hydrocephalus, and need for ventriculoperitoneal shunt) for the 78 patients in the pediatric age group was 0%. The risk of complication in the adult group was 6.7% (1 patient with aseptic meningitis and 2 patients with CSF leak).

CONCLUSIONS Autologous cervical fascia is easy to obtain in patients of all ages and provides an effective material for duraplasty in the treatment of CM-I. Complications from the combination of both an extradural and intradural decompression with autologous cervical fascia duraplasty are uncommon.

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KEYWORDS Chiari I malformation; tonsillar herniation; tonsillar ectopia; duraplasty; intradural; extradural; syringomyelia; pericranium; allograft; surgical technique
the heterogeneity in the pathophysiology of CM-I. Some patients only require a posterior fossa extradural decompression to achieve adequate decompression. Other patients, however, will continue to be symptomatic and/or will have persistent syringomyelia despite an extradural decompression. These patients require a combination of both a posterior fossa extradural and intradural decompression with expansile duraplasty to achieve adequate decompression. The intradural decompression may or may not include any of the following depending on the degree of the tonsillar herniation and impaction: lysis of adhesions, opening of foramen of Magendie, and tonsillar reduction. The combination of extradural and intradural decompression with expansile duraplasty aims to treat all aspects of the pathophysiology of CM-I with or without syringomyelia. Although opening the dura potentially provides a more complete decompression compared with an extradural decompression alone, the risk for CSF complication is increased. In fact, authors of some studies have expressed concerns about opening the dura given the sizeable rates of CSF complications and have utilized a posterior fossa extradural decompression as a first-line treatment in all symptomatic CM-I patients with or without syringomyelia.

Techniques for the combined extradural and intradural decompression with expansile duraplasty for CM-I have been well described with various allogenic and autologous materials used for duraplasty. However, the approach and technique developed in the 1990s by the senior author (A.H.M.) has not been described. In this paper we describe our posterior fossa extradural and intradural decompression with cervical fascia duraplasty in the surgical treatment of CM-I in children and adults, with and without syringomyelia. We describe in detail harvesting cervical fascia for duraplasty in patients of all ages. We analyze and discuss complications using this technique from a prospective database spanning 2003–2016.

**Methods**

Much of the following methods first appeared in our previously published study.

**Patients**

The senior author (A.H.M.) initiated a prospective database of all CVJ abnormalities, including CM-I, in 1978. In March 2003, we modified the database to denote the use of cervical fascia for duraplasty and incorporate an ongoing detailed record of complications. A total of 389 surgeries for CM-I were performed on 379 patients from March 2003 to June 2016 (Fig. 1). A total of 123 posterior procedures were performed on 123 patients in which both a posterior fossa extradural and intradural decompression with duraplasty (extra-intradural) was performed. One hundred nine of these surgeries were first-time intradural procedures, 6 were repeat intradural decompressions (first surgery was performed at another institution), and 10 had associated osseoligamentous abnormalities requiring occipitocervical fusion at the time of duraplasty. A 1-year follow-up was required for inclusion. No patients presented with signs/symptoms of hydrocephalus. All surgeries were performed by the senior author (A.H.M.) from March 2003 to June 2016 and by the first author (B.J.D.) and senior author (A.H.M.) from July 2015 to June 2016. The University of Iowa IRB approved this study.

**FIG. 1.** Flow diagram illustrating the total number of CM-I surgeries and patients and breakdown per type of surgery from March 2003 to June 2016 in our prospective database. A total of 123 posterior procedures using autologous cervical fascia for duraplasty were performed on 123 patients in which both an extradural and intradural decompression (extra-intradural) was performed. OC = occipitocervical. Figure is available in color online only.
CM-I Treatment Algorithm and Indications for Intradural Decompression and Duraplasty

Important to this study is the selection criteria for performing an intradural decompression and duraplasty following the standard extradural decompression for CM-I. The authors utilized a tailored treatment strategy for each patient with CM-I with and without syringomyelia. All patients underwent preoperative evaluation and if deemed symptomatic, a posterior decompression was offered. Symptomatic patients included patients who presented with Valsalva-induced occipital headaches, bulbar signs/symptoms, cerebellar signs/symptoms, cranial nerve deficits, or spinal cord signs/symptoms. Intraoperative ultrasonography was utilized through the different stages of the extradural decompression to assess for effective decompression and sufficient subarachnoid space and CSF flow around the tonsils. The presence of CSF behind the tonsils or tonsillar ascent was each a criterion for effective extradural decompression. Although intraoperative ultrasonography is used on all patients, in most patients with CM-I and syringomyelia the authors performed a posterior extra-intradural decompression due to data suggesting that patients with syringomyelia have a significantly greater prevalence of arachnoid veils obstructing the foramen of Magendie.15,29,43

Surgical Technique

Step 1: Posterior Extradural Decompression and Intraoperative Ultrasound Assessment

All posterior extra-intradural decompressions for CM-I with or without syringomyelia are performed similarly. Prior to intraoperative assessment by ultrasound, a posterior extradural decompression is performed. A posterior occipitocervical incision is made and a subperiosteal dissection performed to expose the occiput, foramen magnum, and C1 lamina. A high-speed electric drill and rongeurs are used to remove approximately 25–30 mm of the posterior foramen magnum. The occiput is removed superiorly by approximately 30 mm to the inferior nuchal line. The posterior 25–30 mm of the superior two-thirds of the C1 lamina is removed and the occipitocervical epidural compressive ligament is excised. Ultrasound is performed to assess the adequacy of the extradural decompression and to determine whether to proceed with intradural decompression and duraplasty (see indications above).

Step 2: Harvesting Cervical Fascia Autograft for Duraplasty

The edge of the cervical fascia in the midline is isolated with Allis clamps (Figs. 2 and 3, Video 1).

VIDEO 1. Clip showing harvest of autologous cervical fascia for duraplasty. This video is an operative illustration of the step-by-step technique for obtaining autologous cervical fascia for duraplasty in the treatment of CM-I. Copyright Brian J. Dlouhy. Published with permission. Click here to view.

Church scissors are used to conduct a suprafascial dissection and expose 3 cm of cervical fascia laterally and 4 cm superiorly and inferiorly. A rake or combination of skin hooks can be used to hold the skin and subcutaneous fat outward. Saline is injected into the subfascial plane to assist with dissection from the underlying muscle. A no. 15 blade is used to dissect the fascia from the underlying cervical musculature. Church scissors are used to remove the cervical fascia graft. A 3 × 2–cm graft is typically obtained. Hemostasis of the underlying musculature is
FIG. 3. Intraoperative photographs of the step-by-step approach for harvesting autologous cervical fascia for duraplasty in a 29-year-old man with CM-I and syringomyelia (top of each panel is superior and bottom of each panel is inferior; asterisk indicates cervical fascia). A: Allis clamps attached to the edge of the cervical fascia on the right. B: Church scissors are used to conduct a suprafascial dissection (arrow) and expose 3 cm of cervical fascia laterally. C: Complete exposure of cervical fascia. Skin hooks can be used to hold the skin and subcutaneous fat in place. D and E: A no. 15 blade is used to dissect the fascia from the underlying cervical musculature. F and G: Church scissors are used to remove the cervical fascia. A 3 × 2–cm graft is typically obtained. H and I: Hemostasis of the underlying musculature is obtained and interrupted closure is performed with polyglycolic acid sutures, thereby allowing a tight fascial approximation with the left-sided fascia when closing. Figure is available in color online only.
obtained and interrupted closure is performed with poly-
glycolic acid (Vicryl) sutures, thereby allowing a tight fas-
cial approximation with the opposite-sided fascia during
closure. The cervical fascia graft can be trimmed to the
appropriate size and any extraneous fat or muscle can be
removed if present.

Step 3: Posterior Intradural Decompression With Cervical
Fascia Duraplasty

Using a surgical microscope under high-power magni-
fication, the posterior fossa dura is opened starting at the
superolateral quadrant on the right and proceeding down
to the midline at the foramen magnum and then along the
dorsal axis of the cervical canal toward the lamina of C1
in a curvilinear-like fashion (Fig. 4). Care is taken to leave
the arachnoid intact during dural incision. Stay sutures
hold apart the exposure. Hemostasis in the venous sinuses
is secured with titanium clips.

Upon completion of the dural opening, the arachnoid is
inspected and divided in the midline and held apart
temporarily and attached to the dural edges with titanium
clips. Arachnoid adhesions are lysed and the foramen of
Magendie (opening of fourth ventricle) is explored and any
adhesions and arachnoid veil are cauterized and lysed.

Cerebellar tonsillar reduction is performed through
low-power bipolar pia-arachnoid electric coagulation of
the cerebellar tonsils such that the tonsils ascend upward
and outward. This opens the roof of the fourth ventricle
and exposes the egress of the fourth ventricle. The in-
tegrity of the pia mater is maintained to avoid potential
adhesion, scarring, and recurrence. Modified cisterna
magna reconstruction is performed with placement of a
patulous elliptical cervical fascia dural graft previously
harvested from the patient. Typically, the side of the fas-
cia not adjacent to the cervical musculature should face
the intradural contents when suturing the graft. Cervical
fascia is elastic and pliable and when sutured, the fascia
fills in the suture holes, allowing a watertight closure. Ad-
ditionally, the fascia will billow in and out with the CSF
pulsations, allowing for even more expansion without
requiring a large duraplasty. Tisseel is layered over the
duraplasty incision and a piece of Gelfoam is placed over
the exposed dura to prevent muscular adherence to the
dura. The wound is closed meticulously in a multilayered
muscular and fascial closure to ensure musculoligamen-
tous stability.

Results

Demographics

A total of 123 patients underwent posterior fossa extra-
intradural decompression with cervical fascia duraplasty
(Fig. 1). The mean age of patients was 17.6 years (range
2–61 years; Table 1). Seventy-eight patients (63.4%) were
pediatric (< 18 years old) and 45 patients (36.6%) were
adults (≥ 18 years old). A total of 81 females and 42 males
underwent surgery. The mean tonsillar herniation was
15.2 mm (range 4.5–26.4 mm). Cervicomedullary com-
pression with cervicomedullary buckle was observed in
90 patients (73.2%). Syringomyelia occurred in 89 patients
(72.4%). No hydrocephalus was observed in any of the pa-
tients preoperatively. Associated CVJ abnormalities were
observed in 10 patients (8.1%). Six surgeries (4.8%) were
repeat intradural procedures in which the first surgery was
performed at another institution. Follow-up was at least 1
year from surgery (mean 4.8 years).

Complications

Complications were assessed in the immediate post-
operative period; at 3, 6, and 12 months postoperatively;
and for the entirety of the follow-up period for each of
the 123 patients (Table 1). No intraoperative complica-
tions occurred with graft harvest or graft placement in
any of the patients. No postoperative complications oc-
curred in the 78 patients in the pediatric age group (< 18
years old). Only 3 CSF complications were observed in
the 123 patients, all of which occurred in the adult group.
Aseptic meningitis, defined as severe nonbacterial menin-
gitis that resulted in postoperative headache, fevers, pro-
longed vomiting, and/or readmission for these symptoms,
occurred in 1 adult patient. CSF leak occurred in 2 adult
patients, both of which occurred in 2005. One patient re-
quired reexploration and a small leak was noted at the
edge and the end of the autologous cervical fascial graft
and the native dura. A single stitch was placed here and
the patient did well postoperatively. The other leak was
treated with a lumbar drain for 5 days, which was effec-
tive in eliminating the CSF leak, and the patient tolerated
this without worsening symptoms or recurrent symptoms
in the future.

The only radiographic pseudomeningocele or symp-
toms of a pseudomeningocele were the 2 patients described
above who presented with a CSF leak. No superficial or
deep infections occurred. No patients developed hydro-
cephalus on imaging or with signs/symptoms. Therefore,
no patients required ventriculoperitoneal shunting for hy-
drocephalus. Additionally, no patients required ventricu-
loperitoneal shunting for any reason, including persistent
syringomyelia, CSF leak, or pseudomeningocele.

Four adults and no pediatric patients required read-
mission within the 3-month postoperative period. These
included the 2 patients who developed a pseudomenin-
gocele and CSF leak requiring treatment as described
above, the adult patient who developed aseptic meningi-
tis, and a fourth patient who was admitted for migraine
headache management. One adult patient and 1 pediatric
patient required a future repeat intradural reoperation for
increase in syrinx size, resulting in increased symptoms.
On reexploration, no complications were observed from
the graft—it was intact without scarring—and more ag-
gressive intradural lysis of adhesions was performed. This
procedure resulted in improvement in symptoms and de-
crease in the syrinx size on follow-up.

Discussion

Key Results and Interpretation

This is the first study to describe the surgical tech-
nique and use of an autologous cervical fascia duraplasty
in the treatment of CM-I in patients of all ages (children
and adults) with and without syringomyelia. We found
that cervical fascia can be harvested in patients of all ages

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FIG. 4. A 13-year-old girl with CM-I and syringomyelia who underwent extradural and intradural decompression with cervical fascia duraplasty. A: Suboccipital craniectomy from the inferior nuchal line to the foramen magnum, superior two-thirds C1 laminectomy, and excision of occipitocervical epidural compressive band. Dashed line illustrates proposed dural opening. Ultrasound is used at this point to assess for adequate decompression. If not adequate, the autologous cervical fascia is harvested and the dura opened. B: Dura opened along proposed dashed line (panel A) and held back with stay sutures. Adhesions were lysed, the foramen of Magendie opened, and the tonsils reduced with pia-arachnoid coagulation. C–F: The cervical fascia graft (CfG) is sutured to the native dura in a patulous but watertight fashion. G: Preoperative sagittal T2-weighted MR image demonstrating the tonsillar herniation, cervicomedullary kink, and large cervical syrinx. H: Three-year postoperative sagittal T2-weighted MR image revealing good decompression of the cervicomedullary junction with CSF surrounding the tonsils, brainstem, and upper cervical spinal cord. Ascent of the cervicomedullary junction and complete resolution of the cervical syrinx is demonstrated. Oc = occipital bone. Figure is available in color online only.
TABLE 1. Demographics and complications associated with cervical fascia duraplasty after extradural and intradural decompression for CM-I in 123 children and adults

<table>
<thead>
<tr>
<th>Variable</th>
<th>All Patients (n = 123)</th>
<th>Pediatric (&lt;18 yrs; n = 78)</th>
<th>Adult (≥18 yrs; n = 45)</th>
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<tbody>
<tr>
<td>Demographics</td>
<td></td>
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<tr>
<td>Mean age, yrs (range)</td>
<td>17.6 (2–61)</td>
<td>10.4 (2–17)</td>
<td>30.1 (18–61)</td>
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<td>Male gender, n (%)</td>
<td>42 (34.1)</td>
<td>30 (38.5)</td>
<td>12 (26.7)</td>
</tr>
<tr>
<td>Mean tonsillar herniation, mm (range)</td>
<td>15.2 (4.5–26.4)</td>
<td>15.9 (4.5–26.0)</td>
<td>14.0 (5.0–26.4)</td>
</tr>
<tr>
<td>Cervicomedullary kink/buckle, n (%)</td>
<td>90 (73.2)</td>
<td>60 (76.9)</td>
<td>30 (66.7)</td>
</tr>
<tr>
<td>Syringomyelia, n (%)</td>
<td>89 (72.4)</td>
<td>59 (75.6)</td>
<td>30 (66.7)</td>
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<tr>
<td>Hydrocephalus, n (%)</td>
<td>0 (0)</td>
<td>0 (0)</td>
<td>0 (0)</td>
</tr>
<tr>
<td>Associated CVJ osseoligamentous abnormality, n (%)</td>
<td>10 (8.1)</td>
<td>6 (7.7)</td>
<td>4 (8.9)</td>
</tr>
<tr>
<td>Repeat CM-I decompression w/ duraplasty, n (%)</td>
<td>6 (4.9)</td>
<td>6 (7.7)</td>
<td>0 (0)</td>
</tr>
<tr>
<td>Mean total follow-up, yrs (range)</td>
<td>4.8 (1–13.1)</td>
<td>4.8 (1–12.9)</td>
<td>4.8 (1–13.1)</td>
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<tr>
<td>Postop complications, n (%)</td>
<td></td>
<td></td>
<td></td>
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<tr>
<td>Aseptic meningitis</td>
<td>1 (0.8)</td>
<td>0 (0)</td>
<td>1 (2.2)</td>
</tr>
<tr>
<td>CSF leak*</td>
<td>2 (1.6)</td>
<td>0 (0)</td>
<td>2 (4.4)</td>
</tr>
<tr>
<td>Pseudomeningocele*</td>
<td>2 (1.6)</td>
<td>0 (0)</td>
<td>2 (4.4)</td>
</tr>
<tr>
<td>Infection</td>
<td>0 (0)</td>
<td>0 (0)</td>
<td>0 (0)</td>
</tr>
<tr>
<td>Development of hydrocephalus</td>
<td>0 (0)</td>
<td>0 (0)</td>
<td>0 (0)</td>
</tr>
<tr>
<td>Need for ventriculoperitoneal shunt</td>
<td>0 (0)</td>
<td>0 (0)</td>
<td>0 (0)</td>
</tr>
<tr>
<td>Need for reoperation due to other complication†</td>
<td>1 (0.8)</td>
<td>0 (0)</td>
<td>1 (2.2)</td>
</tr>
<tr>
<td>Need for readmission</td>
<td>4 (3.25)</td>
<td>0 (0)</td>
<td>4 (8.9)</td>
</tr>
<tr>
<td>Need for reoperation for CM-II/syrinx in future unrelated to complications</td>
<td>2 (1.6)</td>
<td>1 (1.3)</td>
<td>2 (2.2)</td>
</tr>
</tbody>
</table>

* The only radiographic pseudomeningocele or symptoms of a pseudomeningocele were the 2 patients who presented with a CSF leak.
† One adult patient required readmission and reoperation for a subcutaneous fluid collection associated with the use of bone morphogenetic protein; this complication was described and reported in Lindley TE, Dahdaleh NS, Menezes AH, et al: Complications associated with recombinant human bone morphogenetic protein use in pediatric craniocervical arthrodesis. J Neurosurg Pediatr 7:468–474, 2011.

Complications

Postoperative complications associated with intradural exploration and duraplasty for the surgical treatment of CM-I vary significantly in the literature. Studies have found the risk of complications to be between 3% and 40% and consist of aseptic meningitis, pseudomeningoele, CSF leak, postoperative hydrocephalus, wound infection, and meningitis.13,16,21,33 CSF complications specifically have been reported to occur in 3%–19% of reported series.16,21,25,26 In this study we found the complication risk profile was very small using a cervical fascia duraplasty. The risk of any type of complication for the 78 patients in the pediatric age group was 0%, and the risk of complication in the adult group was 6.7% (1 patient with aseptic meningitis and 2 patients with CSF leak). Similarly, others have also demonstrated small rates of complications with the combination of extradural and intradural CM-I decompression with duraplasty.21

Autologous and Allogenic Materials Used in Duraplasty

The types of autologous, allogenic, and synthetic materials used for duraplasty in CM-I are extensive.1,13 These materials include autologous and allogenic pericranium, autologous and allogenic fascia lata, autologous ligamentum nuchae, lyophilized cadaveric dura, acellular human dermis allograft (AlloDerm; Allergan, Inc.), porcine small intestinal submucosa (Durasis; Cook Medical), fetal bovine tissue (Durepair; Medtronic, Inc.), processed bovine collagen matrix (DuraGen; Integra, Inc., and DuraMatrix; Stryker, Inc.), synthetic Gore-Tex, expanded polytetrafluoroethylene, autologous posterior atlantooccipital membrane, autologous splenius capitis muscle flap, and porcine small intestinal submucosa (Durasis; Cook Medical). A survey of pediatric neurosurgeons in July 1998 by the AANS revealed wide variation in preferred material for duraplasty.19

Others have proposed criteria for an optimal dura mater graft. Theoretically, the ideal graft would provide watertight dural closure without inflammatory reaction against the leptomeninges or cortex; induce no adhesions to the brain tissue or arachnoid; provide protection against external bacteria; be readily and easily available, durable, flexible, elastic, easily prepared, inexpensive, easily sterilized and handled, and easily shaped; and be known to be chemically inert and nontoxic. Only a few studies have compared one graft or multiple grafts against each other. However, these studies are hindered by many limitations.
Therefore, no study has shown superiority of either autologous or allogenic grafts for duraplasty in CM-I. Autologous cervical fascia meets many of the criteria for an optimal dura mater graft and harvesting autologous cervical fascia does not require extension of the incision or a separate incision. The most common autologous material used for duraplasty reported in the literature is the pericranium. However, most techniques for harvesting pericranium require extension of the incision superiorly beyond the need for adequate exposure for the CM-I posterior fossa decompression. Although theoretical, an additional advantage of autologous cervical fascia is that it is unlikely to induce bone development (a risk more associated with younger children with CM-I), unlike other materials, such as pericranium, which could potentially induce bone growth and result in future compression and symptom recurrence.

Limitations
Although this study was prospective in nature, it was not a randomized study. Therefore, there is a selection bias of patients with CM-I who underwent intradural exploration and duraplasty. For most patients with syringomyelia, an extra-intradural decompression is performed to ensure egress from the foramen of Magendie. As discussed, we individualize the treatment strategy using intraoperative ultrasonography to determine the need for greater decompression through intradural exploration, tonsillar resection, and duraplasty. Therefore, not all patients undergo intradural exploration and duraplasty. However, with this individualized strategy, it appears the risk of complication with an intradural procedure and autologous cervical fascia graft is quite minimal.

Conclusions
Autologous cervical fascia is easy to obtain in patients of all ages and provides an effective material for duraplasty in the treatment of CM-I. Complications from the combination of both an extradural and intradural decompression with cervical fascia duraplasty are uncommon.

References