Intraoperative ultrasonography used to determine the extent of surgery necessary during posterior fossa decompression in children with Chiari malformation Type I

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Object. In this retrospective analysis, the authors report a prospective study in which intraoperative ultrasonography was used to determine the extent of surgery necessary during posterior fossa decompression surgery for Chiari malformation Type I (CM-I) in children.

Methods. Between 1995 and 2003, posterior fossa decompression was performed in 149 patients (mean 5.9 years of age, range 9 months–18 years of age) with CM-I. Of these, 130 underwent intraoperative ultrasonographic evaluation of the craniocervical junction (CCJ) and 15 did not. Four patients with craniosynostosis were excluded from the study. Duraplasty and tonsillar shrinkage were performed when ultrasonographic evidence showed significant decreases in cerebrospinal fluid (CSF) or abnormal tonsillar piston action. Surgical success was determined on the basis of clinical outcome and need for reoperation.

One hundred and twenty-four (95.5%) of the children had successful outcomes following surgery and six (4.5%) experienced continued or worsening symptoms requiring reoperation. Forty patients did not undergo duraplasty because the ultrasonography evidence showed adequate decompression with bone removal alone. Of 90 patients with significant compression, decreased CSF dynamics, and/or abnormal tonsillar piston-like action at the CCJ, 85 underwent duraplasty and tonsillar shrinkage and five did not for various reasons. One patient in whom the dura mater was violated accidentally during bone decompression subsequently underwent duraplasty. Hospital stays lasted 6.4 ± 3.9 days (mean ± standard deviation) when duraplasty was performed compared with 4.3 ± 1.1 days when it was not (p < 0.0003). After bone decompression alone, no patient experienced complications. After duraplasty, 12 patients experienced complications and had headaches, nausea, and pain more often than patients who underwent bone decompression alone. Mean tonsillar descent was 11 ± 4 mm after bone decompression only and 13.9 ± 4.9 mm after duraplasty, with tonsillar shrinkage (p < 0.0003) seen on magnetic resonance imaging.

Conclusions. In patients who undergo decompressive surgery for CM-I, intraoperative ultrasonography may be a useful tool to aid the surgeon in deciding whether to opt for bone removal alone or bone removal plus duraplasty and tonsillar shrinkage.

KEY WORDS • Chiari malformation Type I • duraplasty • posterior fossa decompression • intraoperative ultrasonography • pediatric neurosurgery

The optimal surgical treatment for symptomatic CM-I continues to be controversial. In addition to bone decompression of the posterior fossa, surgeons have advocated the removal of the cervical lamina, duraplasty, ablation of the cerebellar tonsils, removal of the outer dural layer, and placement of third and/or fourth ventricular or syringosubarachnoid shunts.1,8,9,14 The success of these procedures ranges from 47 to 93%. The risk of complications—including CSF leakage, pseudomeningocele formation, infection, headache, prolonged recovery, neurological injury, and death—tends to increase the more invasive the procedure.2,5,9,18

Abbreviations used in this paper: CCJ = craniocervical junction; CM-I = Chiari malformation Type I; CSF = cerebrospinal fluid; MR = magnetic resonance.

Some authors argue that only bone decompression is needed to relieve the pressure at the CCJ. Others support maximal decompression by duraplasty, tonsillar shrinkage, and shunt insertion. Ultimately, the goal of surgery is to restore “normal” CSF dynamics at the CCJ. In this retrospective review, we evaluate a prospective study in which intraoperative ultrasonography was used to determine the need for duraplasty and tonsillar shrinkage in children undergoing posterior fossa decompression for CM-I.

Clinical Material and Methods
The 149 patients who were the focus of this retrospective review (age range 9 months–18 years) underwent posterior fossa decompression surgery for symptomatic CM-I by a single surgeon (K.R.C.) at the Cincinnati Children’s Hos-
Ultrasonography during posterior fossa decompression

pital Medical Center between 1995 and 2003. Of these patients, 130 underwent diagnostic ultrasonography to assess the CCJ intraoperatively; 15 patients did not undergo ultrasonography because of equipment malfunction or nonavailability early in the series; and four patients who also had craniostenosis were excluded from the study. We defined CM-I as at least 3 mm of tonsillar herniation and abnormal CSF dynamics at the CCJ observed on sagittal and cine MR imaging. We evaluated the effectiveness of intraoperative ultrasonography retrospectively to determine the extent of decompression needed to treat CM-I.

Operative Technique

With the patient positioned prone, the head is placed in a horseshoe or Mayfield headrest with the neck flexed. The skin is incised linearly from the inion to about the C-2 spinous process at midline. After reflection of the muscular attachments, an occipital craniectomy (~ 3 × 3 cm) is created to expand the posterior fossa. A single laminectomy or multiple cervical laminectomies can also be performed to increase the area of decompression around the CCJ, typically from C-1 down to the lowest level of tonsillar descent. In our series, the laminectomies encompassed one level in 91 patients, two levels in 36, three levels in one, and five levels in one. (One patient did not undergo the procedure.) After removal of the bone, any cranio cervical epidural adhesion band or scar tissue is then removed. After the surgical field has been filled with sterile saline, an intraoperative ultrasound device (such as the Acuson Sequoia Echo; Siemens Inc., Mountain View, CA) is positioned so that the neuroradiologist can examine the CCJ. Using real-time imaging, decompression is considered adequate when a CSF space is present anterior to the brainstem and dorsal to the cerebellar tonsils (that is, between the neural elements and the dura mater) and when there is no evidence of abnormal tonsillar piston activity.

When bone decompression is inadequate, a more invasive type of surgery is performed. After the dura has been opened with a Y- or lazy S-shaped incision, the cerebellar tonsils are identified. Sharp dissection of arachnoid adhesions is performed to free the tonsils and identify the major vessels and their branches (that is, the posterior inferior cerebellar arteries). A small cottonoid is then placed between the brainstem and/or spinal cord and tonsils. As irrigation cools the surrounding tissues, bipolar cautery (10–15 W) is used to shrink the tonsils slowly until they reach the level of the foramen magnum. The region of the obex and fourth ventricle is examined for CSF outflow; if necessary, a shunt can be placed to increase this outflow. Most shunts are placed through the fourth ventricle; however, if CSF outflow through the fourth ventricle is insufficient, we occasionally cannulate the third ventricle by gently passing a small-diameter ventricular catheter through the cerebral aqueduct. Finally, a duraplasty created with a bovine pericardial patch expands the area of the CCJ. Intraoperative ultrasonography is repeated if adequate decompression remains a concern. When decompression is deemed adequate, no additional decompressive surgery is performed. The muscles are loosely approximated and the fascia is tightly closed before closure of the skin incision (Fig. 1).

Statistical Analysis

The determination of surgical outcome was based on our review of hospital records, clinical charts, analyses from referring physicians, and medical examinations. Surgical treatment was considered successful when the preoperative conditions notably improved and the patient required no additional surgery (for example, shunt insertion or repeated exploration). We reviewed all information regarding complications, hospital stay, and postoperative MR imaging studies. Finally, we determined if any preoperative factors (such as age, sex, clinical presentation, or tonsillar descent measurements on preoperative MR images) were predictive of the type of surgery needed for adequate decompression. Statistical significance was determined using the Student t-test.

Results

Of the 130 patients who underwent intraoperative ultrasonography such that the CSF dynamics at the CCJ could be analyzed, 40 (31%) patients had adequate decompression with bone removal alone and 90 (69%) had abnormal ultrasonographic findings after bone decompression (Fig. 1; Table 1).
Type of Surgery

In 40 patients with normal ultrasonographic findings, 39 required no further decompressive surgery and one patient, who had an accidental dural opening during bone removal, subsequently underwent a duraplasty without tonsillar shrinkage. Of 90 patients with ultrasonographic evidence of significant abnormalities at the CCJ, 85 (94%) underwent duraplasty and tonsillar shrinkage procedures; abnormalities included abnormal piston action of the cerebellar tonsils in 72 (80%) and significant constriction of the CCJ in 13 (14%). The other five patients with evidence of abnormalities did not undergo duraplasty or tonsillar shrinkage for various reasons; two had hydrocephalus, one had abnormal vascular anatomy at the CCJ, and two had preoperative medical morbidities (one patient with Smith-Lemli-Opitz syndrome required a preoperative fresh-frozen plasma transfusion for coagulopathy and another, a 1.5-year-old child, had significant preoperative apnea and pulmonary hypertension).

In patients with hydrocephalus (even those who have shunts), opening the dura increases the likelihood that CSF leakage will develop because fluid tends to flow through the path of least resistance. Therefore, a posterior fossa dural defect, if not properly closed, can pose less resistance to CSF flow than a shunt and lead to a CSF leak. In our patients with CM-I and hydrocephalus, the latter was treated first. During CM-I surgery, we were conservative in our decision to perform duraplasty. Nine patients had hydrocephalus that required shunts, all of which, on the basis of clinical and CT findings, were presumed to be working before CM-I decompression. All nine patients had abnormal ultrasonographic findings after bone decompression; seven underwent duraplasty and two did not. When compared with the seven patients with hydrocephalus, these two patients had mild tonsillar pistoning and a smaller degree of tonsillar herniation (8 compared with 13.7 mm, respectively) and therefore did not require further decompressive surgery. After surgery, hydrocephalus resolved in one patient, thus allowing removal of the shunt.

Hospital Stay and Complications

Mean hospital stays of patients who underwent duraplasty averaged 6.4 ± 3.9 days (range 3–32 days) compared with 4.3 ± 1.1 days for those who did not (range 2–7 days; p < 0.0003). In 40 patients who underwent bone decompression only, no surgical complication occurred. In 85 patients who underwent duraplasty and tonsillar shrinkage, complications occurred in 12 (13.3%; Table 2). Complications included wound infections that required intravenous antibiotic therapy (two patients), pseudomeningocele formation that required no surgical treatment (four patients), CSF leaks that needed surgical repair (five patients; two with superimposed meningitis), and prolonged intubation (> 2 weeks) because of bronchiopulmonary dysplasia (one patient). Reoperation rates as a result of complications were 5.9% in the duraplasty and tonsillar shrinkage group. All patients had postoperative pain, which was prolonged and required steroid therapy in those who underwent duraplasty. Prolonged pain may be a consequence of dura opening, graft reaction, or chemical meningitis from blood in the CSF.

Surgical Results

At follow-up examination (mean 20 months) in outpatient settings, the surgery was found to have been successful in 124 (95%) patients (surgical success is defined as a notable improvement in preoperative symptoms and no need of further treatment; Table 3). Improved preoperative symptoms related to CM-I included headache, neck pain, dysphagia, speech difficulties, sleep apnea, clumsiness, hypotonia, spasticity, scoliosis, motor impairments, paresthesia, and lower cranial nerve deficits.

There were four surgical failures in the bone decompression group and two in the duraplasty group. After bone decompression, four patients underwent a second operation when symptoms recurred or worsened (26.7 ± 17.6 months). After duraplasty and tonsillar shrinkage, two patients experienced worsening symptoms caused by adhesion formation. Despite ultrasonographic evidence of tonsillar piston activity, duraplasty and tonsillar shrinkage were not performed in a 1.5-year-old girl because she had significant preoperative apnea and pulmonary hypertension. After an

### TABLE 1

<table>
<thead>
<tr>
<th>Ultrasound Finding &amp; Procedure(s)</th>
<th>No. of Patients (%)</th>
</tr>
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<tbody>
<tr>
<td>normal</td>
<td>40 (31)</td>
</tr>
<tr>
<td>bone decompression</td>
<td>39</td>
</tr>
<tr>
<td>duraplasty</td>
<td>1*</td>
</tr>
<tr>
<td>tonsillar piston effect or decreased CSF at the CCJ</td>
<td>90 (69)</td>
</tr>
<tr>
<td>no duraplasty</td>
<td>5</td>
</tr>
<tr>
<td>duraplasty &amp; tonsillar shrinkage</td>
<td>85</td>
</tr>
</tbody>
</table>

* After this patient had an accidental dural opening during bone decompression, he underwent a duraplasty without tonsillar ablation.

### TABLE 2

<table>
<thead>
<tr>
<th>Type of Complication</th>
<th>No. of Patients</th>
</tr>
</thead>
<tbody>
<tr>
<td>infection</td>
<td>2</td>
</tr>
<tr>
<td>pseudomeningocele</td>
<td>4</td>
</tr>
<tr>
<td>CSF leak</td>
<td>5</td>
</tr>
<tr>
<td>brainstem swelling/extended ventilation</td>
<td>1</td>
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</table>

* No complications occurred with bone decompression alone. The repeat operation rate due to complication was 5.9%.

### TABLE 3

<table>
<thead>
<tr>
<th>Result by Group</th>
<th>No. of Patients</th>
</tr>
</thead>
<tbody>
<tr>
<td>bone decompression*</td>
<td>40</td>
</tr>
<tr>
<td>successful procedures†</td>
<td>36</td>
</tr>
<tr>
<td>w/ complications</td>
<td>0</td>
</tr>
<tr>
<td>duraplasty &amp; tonsillar ablation‡</td>
<td>85</td>
</tr>
<tr>
<td>successful procedures‡</td>
<td>83</td>
</tr>
<tr>
<td>w/ complications</td>
<td>12</td>
</tr>
</tbody>
</table>

* Average hospital stay was 4.3 ± 1.1 days (mean ± standard deviation).
† Surgical success was defined as documented clinical improvement without the need for repeated operation.
‡ Average hospital stay was 6.4 ± 3.9 days (mean ± standard deviation).
initial improvement, her symptoms returned 5 years later
and necessitated a second surgery consisting of invasive de-
compression with duraplasty and tonsillar shrinkage. An-
other patient, who initially did not undergo duraplasty
and tonsillar shrinkage because of ultrasonographic evi-
dence of adequate decompression, experienced worsening
symptoms 15 months later. During a second surgery, ultra-
sonography recordings revealed severe constriction of the
CCJ, and the patient underwent duraplasty and tonsillar
shrinkage. Four patients improved after second surgeries;
despite radiographic evidence of adequate decompression,
two patients showed no clinical improvement after dura-
plasty.

Although the extent of improvement was not assessed,
cases of documented scoliosis or syringomyelia and/or hy-
dromyelia were analyzed. Of 10 patients with scoliosis
(average 24.5° based on Cobb angle measurements) who
underwent decompression, the degree of scoliosis remained
stable in six patients and improved (average 12.5°) in four.
Of 27 patients with syringomyelia and/or hydromyelia, ra-
diological studies after decompression revealed improve-
ment in 13 patients, resolution in eight, and no change (that
is, stability) in the syrinx in five. One patient was lost to fol-
low up. None of the patients had evidence of worsening
scoliosis or syrinx growth (Fig. 2, Table 4).

Other Factors Affecting the Surgical Decision

We identified no preoperative factors (that is, age, sex,
clinical presentation, or tonsillar descent) on preoperative
MR images that influenced the decision regarding the extent
of surgery required based on intraoperative ultrasound find-
ings. All five patients younger than 1 year of age showed
adequate decompression following bone removal alone and
required no further procedure.

Does the dominant presenting symptom affect the type of
surgery needed for adequate decompression? We divided
patients into five categories—general, spinal, brainstem, ce-
rebellar, and combination—on the basis of their predomi-
nant clinical symptoms. The general group included patients
with headache, nausea/vomiting, and irritability. The spinal
group included patients with extremity paresthesias, weak-
ness, or scoliosis. The brainstem group included patients
with apnea, bradycardia, dysphagia, hypotonia, or spasticity.
The cerebellar group included patients with ataxia or clum-
siness, and the combination group included patients with
multiple symptoms from different categories (Table 5). Of
note, 20 (87%) of 23 patients in the spinal group underwent
duraplasty and tonsillar shrinkage surgery. When compared
with the overall trend and the spinal group, the other four
groups showed no difference or trend toward the type of
surgery needed for adequate decompression.

Among the 130 study patients, 124 had available preop-
erative MR images which were analyzed for degree of ton-
sillar descent. Mean tonsillar descent measured 10.8 ± 3
mm in the 36 patients who underwent bone decompression
only and 13.9 ± 6 mm in the 88 patients who underwent
duraplasty with tonsillar shrinkage (p < 0.0014).

Discussion

Significant Findings

In our study, intraoperative ultrasonography was effec-
tive and helped us make the decision whether to perform bone removal only or bone removal plus duraplasty and tonsillar shrinkage for the treatment of CM-I in children. On the basis of several theories regarding the pathophysiology of CM-I that focus on abnormal CSF dynamics at the CCJ, we identified our goal in CM-I surgery as the restoration of normal fluid dynamics at this junction.

Bone decompression alone can sometimes be sufficient to restore normal CSF dynamics at the CCJ. This result was observed in our 40 patients who required no further surgery when intraoperative ultrasonography showed adequate CSF space at the anterior and dorsal spinal-medullary regions and absence of abnormal tonsillar piston effect. After bone decompression only, hospital stays lasted a mean of 4 days and no complications occurred.

When ultrasound evidence showed that bone decompression was inadequate, further surgery was needed. In our series, 85 (94%) patients required additional surgery and five (6%) did not because of hydrocephalus or other medical reasons. Ultrasound studies demonstrated abnormal tonsillar piston activity in 85% of these patients and severe crowding at the CCJ in 15%. In these 85 patients, hospital stays averaged 6 days; complications occurred in 12 patients. Although many subjective factors (such as hospital policy, surgeon preference, and family dynamics) can influence the number of days patients remain in the hospital, we found that the children who underwent duraplasty stayed longer than those who had bone decompression only.

Our success rate (95%) was defined by notable clinical improvement without the need for additional surgery. After surgery, the radiographs of 10 patients with scoliosis and 26 with syrinx (excluding the patient lost to follow up) showed evidence of stability, improvement, or resolution of the scoliosis/syrinx. Repeated operation was needed for two (2%) of 85 patients after duraplasty and tonsillar shrinkage because of adhesion formation and two (4%) of 45 patients after bone decompression alone.

Regarding preoperative factors that influence surgical decision-making, we found that patients younger than 1 year of age uniformly had adequate decompression after bone removal and did not require duraplasty and tonsilectomy (the data were not statistically significant). This observation correlated with the findings of Yundt, et al. As a whole, roughly two thirds of our patients required duraplasty and tonsilectomy. Based on preoperative symptoms, the 87% of patients who presented with spinal symptoms (that is, sensory, motor, or scoliotic abnormalities) required duraplasty and tonsillar shrinkage more often than did the other 13% of patients (the data were not statistically significant).

Finally, preoperative tonsillar descent was 3.1 mm greater in patients undergoing duraplasty and tonsillar shrinkage than in patients who underwent bone decompression alone.

Goal of Surgery for CM-I

Theories of surgical treatment of symptomatic CM-I stress the importance of CSF dynamics near the CCJ. Several authors suggest that CM-I results from a mesodermal defect after the closure of the neural folds that leads to the underdevelopment of the basichondrocranium, which results in a small posterior fossa, overcrowding of neural elements, and abnormal CSF dynamics at the CCJ. In their hydrodynamic theory, Gardner, et al., postulated that an incomplete embryonic opening of the outlet of the fourth ventricle leads to communication between it and the central canal. This partial obstruction of the fourth ventricle contributes to a “water hammer” effect into the central canal that is seen with each arterial pulse. Continued pressure causes the development of a syrinx, cord cavitation, and/or further neurological symptoms. Williams demonstrated a differential pressure gradient between the intraventricular and lumbar subarachnoid spaces by using simultaneous measurements. He then proposed the “cranial-spinal pressure dissociation theory” that CSF flow is obstructed in patients with CM-I at the CCJ due to the herniated cerebellar tonsils, resulting in a differential pressure gradient between the cranial and spinal cavities. Significant pressure differentials between these two areas can occur during the systolic cardiac cycle or during routine activities such as sneezing and coughing. This effect increases the impact of tonsils at the CCJ, creating a piston effect that drives CSF into the Virchow–Robin and interstitial spaces, thus leading to the formation of a syrinx and subsequent neurological symptoms. Using intraoperative ultrasonography, Oldfield, et al., demonstrated partial occlusion of the subarachnoid space and abnormal CSF flow at the CCJ in patients with CM-I and syringomyelia. Intraoperative ultrasonography observations of the CCJ in patients with CM-I demonstrates that expansion of the brain during systole imparts a downward force through the junction that manifests by an abnormal piston motion of the cerebellar tonsils. This abrupt motion compresses the spinal cord and medulla, forcing CSF into the cord via the lymphatic vessels and resulting in

<table>
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<th>TABLE 4</th>
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<tr>
<td>Results for patients with scoliosis or syrinx by procedure</td>
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<table>
<thead>
<tr>
<th>Subgroup</th>
<th>No. of Patients</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Bone Removal Only</td>
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<tr>
<td>scoliosis improvement</td>
<td>0</td>
</tr>
<tr>
<td>no change</td>
<td>1</td>
</tr>
<tr>
<td>syrinx resolution</td>
<td>1</td>
</tr>
<tr>
<td>improvement</td>
<td>3</td>
</tr>
<tr>
<td>no change</td>
<td>2</td>
</tr>
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* Most patients who presented with spinal symptoms underwent duraplasty and tonsillar ablation based on intraoperative ultrasonography criteria.

<table>
<thead>
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<th>TABLE 5</th>
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<tr>
<td>Summary of patient groups by clinical presentation and surgical treatment</td>
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<table>
<thead>
<tr>
<th>Group (no. of patients)</th>
<th>Symptoms</th>
</tr>
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<tbody>
<tr>
<td></td>
<td>Bone Removal Only</td>
</tr>
<tr>
<td>general (27)</td>
<td>headache, nausea/vomiting, irritability, ataxia, clumsiness</td>
</tr>
<tr>
<td>spinal (23)*</td>
<td>paresthesia, weakness, scoliosis, hypotonia, spasticity</td>
</tr>
<tr>
<td>brainstem (37)</td>
<td>apnea, bradycardia, dysphagia, ataxia, clumsiness</td>
</tr>
<tr>
<td>cerebellar (13)</td>
<td>combination (30)</td>
</tr>
<tr>
<td>No. of Patients</td>
<td>12</td>
</tr>
<tr>
<td>6</td>
<td>7</td>
</tr>
<tr>
<td>11</td>
<td>26</td>
</tr>
<tr>
<td>3</td>
<td>20</td>
</tr>
<tr>
<td>12</td>
<td>22</td>
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the progression of syringomyelia and neurological symptoms.

Recent advances in imaging technology support the role of abnormal CSF dynamics in the pathophysiology of CM-I. Puig et al.,19 state that normal CSF dynamics around the CCJ are related to the area of the subarachnoid space at this junction and to the extent of tonsillar motion. Magnetic resonance imaging and phase-contrast studies show that the subarachnoid space in the dorsal spinal-medullary region and the posterior fossa volume are often compromised in patients with CM-I.13 Cine phase-contrast MR imaging demonstrates an abnormal tonsillar piston effect in patients with CM-I.17,19,21,23 We have found these ultrasonographic and MR observations to apply to our patients and have made our surgical goal the restoration of normal CSF dynamics.

Use of Intraoperative Ultrasonography

Isu, et al.,8 used intraoperative ultrasonography in seven patients with CM-I to determine whether removal of the outer dural layer was sufficient to decompress the posterior fossa. Six of seven patients whose intraoperative ultrasonography studies showed evidence of adequate decompression improved clinically. Hida and coworkers8 used ultrasonography to confirm decompression and pulsatile flow of CSF around the CCJ in 33 adults with CM-I and syringomyelia who underwent osseous decompression plus removal of the outer dural layer or duraplasty. Navarro and associates20 recently used this study to determine if bone removal with dural scoring was sufficient to achieve decompression in 72 children. On the basis of ultrasonographic findings in their series, 15 patients required further surgical decompression, including duraplasty with or without tonsillar manipulation, and success rates of 72 and 68%, respectively, were achieved; complications were higher in the duraplasty group.

Although dural scoring can increase the area of the CCJ, this technique was not performed in our patients. We believe that when decompression is inadequate following bone removal, better decompression can be achieved with duraplasty and tonsillar shrinkage than with dural scoring alone. Navarro et al.,20 performed duraplasty and tonsillar manipulation in 26 patients with evidence of hydromyelia; they also recommend that ultrasonography be used to assess the necessary extent of surgical decompression.

Similar to these three groups of authors, we used ultrasonography after bone removal to determine if decompression was adequate. We found that removal of the outer dural layer was unnecessary to achieve adequate decompression of the CCJ in one third of our patients. Oldfield, et al.,17 used intraoperative ultrasonography to study the pathophysiology of CM-I and syringomyelia. In six of seven patients, this imaging method demonstrated a piston-like action of the tonsils and abnormal CSF dynamics near this junction. Immediately after dural opening, the piston-like activity diminished or ceased. We witnessed this phenomenon as well as an abnormal tonsillar piston activity in some of our patients after opening the dura. All patients who underwent a duraplasty procedure underwent tonsillar shrinkage because it significantly increased the subarachnoid space.13 In a report of the use of intraoperative ultrasonography in determining treatment for CM-I, Yundt and coauthors24 found that none of the three children with CM-I in their study required duraplasty and all improved clinically after bone removal alone; these authors used the presence of retrocerebellar space and decreased pulsatility of the tonsils as an index of adequate decompression. We deem decompression to be successful when the piston-like activity of the cerebellar tonsils is alleviated and CSF spaces are present, not only in the retrocerebellar area, but around all neural elements at the CCJ. In a recent surgical series of 345 adult patients with CM-I (82 undergoing an initial operation and 163 a repeated operation), Milhorat and Bolognese12 used ultrasonography to determine if bone decompression plus duraplasty is required for adequate decompression compared with more invasive surgery.

Conclusions

The optimal surgical treatment for symptomatic patients with CM-I remains controversial. We found that, in general, the restoration of normal CSF dynamics at the level of the CCJ can be achieved with bone decompression alone in particular patients with CM-I. Less invasive surgery (that is, bone decompression alone) was associated with fewer complications and shorter hospital stays than more invasive surgery (that is, bone decompression plus duraplasty and tonsillar shrinkage). The use of intraoperative ultrasonography proved to be effective for surgical decision making in CM-I surgery.

References


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