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Outcomes and complications for individual neurosurgeons for the treatment of Chiari I malformation at a children's hospital

Tasha-Kay Walker-Palmer[1,2] · D. Douglas Cochrane[1] · Ashutosh Singhal[1] · Paul Steinbok[1]

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Abstract

Purpose The aim of this study was to evaluate the outcomes and complications for individual surgeons at British Columbia Children's Hospital for the treatment of Chiari I Malformation (CMI) in children.

Methods This was a retrospective review of patients with CMI who had surgery from 1986 to 2015. We assessed the Chicago Chiari Outcome Scores (CCOS) and complication rates by surgeon.

Results Seventy patients, 38 males and 32 females, underwent posterior fossa decompression including 14 extradural and 56 intradural approaches. Syringomyelia was present in 74.3%. Most syringomyelia improved with no difference between intradural and extradural surgeries.

After initial surgery, 13 patients (18.6%) had complications including 2/14 (14.3%) of extradural and 11/56 (19.6%) of intradural surgeries. Two patients required surgical intervention for complications whereas 11 had transient complications. The complication rate by surgeon ranged from 11 to 20% for extradural (2 surgeons only) and 10.5 to 40% for intradural surgeries (4 surgeons). The CCOS ranged from 12 to 15 for extradural and 6 to 16 for intradural. The CCOS ranges for surgeons 1 and 2 were 12–15 and 13–15 respectively for extradural. The CCOS ranges for surgeons 1, 2, 3, and 4 were 12–16, 6–15, 12–16, and 12–16 respectively for intradural.

Thirteen patients had a second surgery for CMI.

The final CCOS was good in 86% and moderate in 14%.

Conclusion There was variability in surgeries performed at BCCH by different surgeons, with variations in CCOS and complication rates. This information is important during decision making, consent process, and for quality improvement.

Keywords Chiari I malformation · Syringomyelia · Posterior fossa decompression · Outcomes · Pediatric · Complications

Introduction

Chiari malformation type I (CMI) is characterized by the downward displacement of the cerebellar tonsils more than 5 mm below the level of the foramen magnum [1]. CMI may be congenital or acquired and may be idiopathic (primary) or secondary to several conditions, including craniosynostosis, hydrocephalus, and lumboperitoneal shunting. The excessive cerebellar tonsillar tissue at the craniocervical junction in CMI may result in blockage of CSF flow across the foramen magnum and may secondarily result in syringomyelia [2, 3].

The clinical presentations of CMI are wide-ranging, which complicates attempts to guide patient management and review the response to treatment [4]. Children diagnosed with CMI may be asymptomatic, in which case no surgery is needed [5–7]. However, when CMI is symptomatic or when it is associated with a large syrinx, surgical treatment is usually undertaken to decompress the craniocervical junction and allow free flow of CSF across the foramen magnum [6]. There are many variations in technique and controversies about the best surgical option for treating CMI in children. Surgical decompression techniques include bony removal only or in combination with one or more of the following: dural thinning/splitting, durotomy with dura left open, duraplasty, and shrinking

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✉ Tasha-Kay Walker-Palmer
tkkwalker@gmail.com

[1] Division of Neurosurgery, British Columbia Children's Hospital, 4480 Oak Street, Rm K3-159, Vancouver, BC V6H 3V4, Canada

[2] The University of the West Indies, Mona, Kingston, Jamaica

or removal of the herniated cerebellar tonsils [8–54]. Some surgeons perform the same procedure in all patients while others tailor their approach to each patient based on symptoms and MRI findings of syrinx or level of tonsillar descent or medullary or cord compression. An ultrasound may be used intraoperatively for assessment of adequacy after bony decompression and then decide if dural opening is needed [54–58]. In an international survey in 2003, 76% of surgeons always open the dura [6]. In 2011, 90% of surgeons in North America reported that they routinely open the dura [59]. However, an international survey in 2016 conducted by Singhal et al. suggests there has been a trend towards more extradural surgeries [7].

In a meta-analysis by Durham et al. of 582 patients who had surgery for CMI malformation, there was an increase in the reoperation rate with extradural surgery, but an increased CSF complication rate with opening the dura [10]. The CSF complication rate was 18.5% after dural opening in this report [10].

At British Columbia Children's Hospital (BCCH), multiple techniques have been used over the years to address CMI. The decision as to the approach was primarily surgeon dependent. To counsel parents and patients adequately about the pros and cons of the surgical options, it is not appropriate to just quote the success and complication rates from the literature, since those rates have been very variable depending on the technique, the surgeon, and the center. It is important to quote the individual surgeon's success and complication rates. Furthermore, knowledge of the results of the individual surgeon may assist in planning improvement strategies. Knowing one's individual outcomes should help with personal review and attempts at improvements in technique and patient management which will ultimately lead to improvement in outcomes.

The purpose of this study was to describe the degree of variability of successful clinical outcome and operative complications associated with individual surgeons' operative approaches.

Methods

After approval by the Clinical Research Ethics Board, a retrospective study was performed by reviewing the charts of all patients who underwent CMI decompression at BCCH from January 1982 to December 2015. Patients were included if they were younger than 18 years and had primary CMI. Patients were excluded if they had secondary CMI and if there were no follow up data.

Data collected included demographic information (age, sex), symptoms and signs, MRI findings of syringomyelia and/or syringobulbia, surgical procedure type, length of stay, complications, syringomyelia outcome, scoliosis outcome, functional outcome, and length of follow up.

For clinical outcome assessment, we used an externally validated outcome score [13, 60, 61], the Chicago Chiari Outcome Score (CCOS) (see Appendix) as the primary outcome. This CCOS was applied retrospectively. The data was summarized and group differences analyzed using Statistical Package for the Social Sciences (SPSS) 23.0.

Results

Patients

From 1982 to 2015, 84 patients who had undergone posterior fossa decompression for CMI were identified. Fourteen patients were excluded: craniosynostosis (5), treated hydrocephalus (4), arachnoid cyst (2), lipomyelomeningocele (1), lost to follow up (1), and surgery done at an external hospital (1). Thus, there were 70 patients in the valid study group. The age at surgery ranged from 2.5 to 17.2 years (median 11 years). The length of stay in hospital ranged from 3 to 11 days (mean 4.89 days). The follow up period ranged from 4.6 to 239.7 months (mean 63.9 months).

Clinical presentation

The most common presenting symptom for which decompression was performed was headache (50%). Other symptoms and signs included ataxia, cranial nerve palsies, decreased or altered sensation, motor deficits, and scoliosis (Table 1).

Of the 35 patients with headache, 13 had documentation of suboccipital headache, 5 patients had frontal headaches, 2 had temporal headaches, and 15 patients were noted to have headache but the location was not specified.

Scoliosis was present in 31 patients (44.3%). In three of these patients, the angle of scoliosis could not be ascertained. Of the 28 patients with information on scoliosis angle, 19 patients had an angle of 40 or less while 9 had an angle of over 40 degrees (overall range 10–82 degrees).

Syringomyelia was present in 52 patients (74.3%). Three of these patients also had syringobulbia. Thirty patients (97%) with scoliosis had an associated syrinx. The one patient without syrinx had mild scoliosis clinically but the angle was not measured.

Five patients had symptoms starting only after minor trauma and were found to have CMI on imaging; one patient who initially had an incidental CMI then later developed classic occipital headache, poor hand coordination, and decreased abdominal and limb reflexes. Other diagnoses included developmental delay (5), autism (1), hereditary spastic paraparesis (1), and seizures (3).

Table 1 Presenting symptoms/signs noted in 70 patients with Chiari I malformation who underwent surgical intervention at BCCH

Symptoms/signs	Number	Percentage % ($N = 70$)
Headache	35	50.00%
Scoliosis	31	44.29%
Absent or decreased abdominal reflexes	24	34.29%
Decreased sensation	17	24.29%
Increased limb reflexes	15	21.43%
Weakness	11	15.71%
Unsteady gait	11	15.71%
Neck pain	11	15.71%
Back pain	10	14.29%
Cranial nerve deficit	9	12.86%
Paraesthesia	9	12.86%
Absent or decreased limb reflexes	7	10.00%
Abnormal coordination	6	8.57%
Dizziness	5	7.14%
Limb pain	5	7.14%
Difficulty swallowing	5	7.14%
Nystagmus	4	5.71%
Snoring	4	5.71%
Sleep disturbance	3	4.29%
Double vision	3	4.29%
Hoarseness/voice changes	2	2.86%
Torticollis	2	2.86%
Nausea and vomiting	2	2.86%
Urinary symptoms	2	2.86%
Difficulties breathing	1	1.43%
Blurry vision	1	1.43%
Photophobia	1	1.43%
Syrinx developed on subsequent imaging	1	1.43%

Initial surgeries performed

Intradural surgeries were performed in 56 (80%) and extradural in 14 (20%) patients. Extradural surgeries included bone only decompression (5), adding dural thinning (8), and dural tenting (1). All five patients who underwent bone only decompression involved suboccipital craniectomy. Four of these five patients also had C1 laminectomy with use of ultrasound to confirm adequacy of decompression whereas the other patient had suboccipital craniectomy and occiput to C3 fusion due to associated ventral compression by the odontoid with basilar settling.

For intradural surgeries, duraplasty with tonsillar resection or shrinking was done in 37/56 patients (66%). Other intradural surgeries performed included opening the dura only in 2 (3.6%), duraplasty only in 8 (14.3%), duraplasty and subarachnoid exploration in 3 (5.4%), tonsillectomy and primary dural closure in 2 (3.6%), and duraplasty plus other procedures in 4 patients (7.1%). Other procedures included Gardner procedure with plugging of obex with muscle (2), bony decompression with C1 and C2 laminectomy and C1–2 fusion for os odontoideum (1), and fourth ventricle exploration with placement of fourth ventricle to subarachnoid shunt (1).

During this review period, six neurosurgeons practiced at BCCH. Two surgeons were excluded from the review as they had not performed initial surgeries in this study. The four included surgeons were de-identified and their patients assessed. The patterns of practice with respect to intradural versus extradural CMI decompressions varied among the four surgeons, with two surgeons performing intradural surgery in all patients (Table 2). Any variations in the indications for surgery cannot be commented on as this was a retrospective review and that information was not assessable.

Overall, tonsillectomy/tonsil shrinking was performed in 39/70 patients (55.7%). In the 52 patients with syringomyelia, tonsillectomy was performed in 32 (61.5%). The addition of tonsillectomy varied by surgeon with rates from 10.5% to 100% (Table 2).

Table 2 The initial surgical procedures performed by surgeons are described, showing variations in practice and difference in complication rates

Surgeon	Number	% of total (70)	Number of extradural surgeries (% of surgeon's cases)	Number of intradural surgeries (% of surgeon's cases)	Tonsillectomy performed ($N = 39$)	NO tonsillectomy ($N = 31$)	Patients with complication after intradural surgery (% of surgeon's intradural cases)	Patients with complication after extradural surgery (% of surgeon's extradural cases)	Total patients with complication (% of all surgeon's cases)
1	24	34.3%	5 (20.8%)	19 (79.2%)	11 (45.8%)	13 (54.2%)	2 (10.5%)	1 (20%)	3 (12.5%)
2	19	27.1%	9 (47.4%)	10 (52.6%)	2 (10.5%)	17 (89.5%)	4 (40%)	1 (11%)	5 (26.3%)
3	21	30%	0	21 (100%)	21 (100%)	0	4 (19%)	Not applicable	4 (19%)
4	6	8.6%	0	6 (100%)	5 (83.3%)	1 (16.7%)	1 (16.7%)	Not applicable	1 (16.7%)
Total	70	100%	14	56	39	31	11	2	13

Complications after initial surgery

Complications were categorized as those due to anesthesia (primarily due to endotracheal intubation and those due to the surgical intervention (Table 3). Of the 70 patients, 13 patients (18.6%) had complications, including two patients with difficulty swallowing related to the endotracheal tube (ETT), as postoperative swallowing tests for both were normal.

Table 3 Complications after initial surgery are listed by surgeon and classified as relating to intradural surgery, extradural surgery, and anesthesia

Surgeon	Number	Total patients with complication (% of all surgeon's cases)	List of the complications attributed to dural opening	Complications attributed to extradural surgery	Complications attributed to anesthesia
1	24	3 (12.5%)	1-transient pseudomeningocele 1-transient pseudomeningocele + subdural effusion	1-transient occipital paresthesia	
2	19	5 (26.3%)	1 transient pseudomeningocele 1-pseudomeningocele (surgically repaired) 1-pseudomeningocele +subdural effusion (surgically repaired) 1-transient subdural effusion		1-transient dysarthria, dysphagia, and odynophagia related to ETT (extradural)
3	21	4 (19%)	1-transient pseudomeningocele + subdural hygroma and MSSA meningitis 1-transient pseudomeningocele, headache + arrhythmia 1-transient CSF leak from Mayfield pin site and blister at incision site		1-transient difficulty swallowing related to ETT (intradural)
4	6	1 (16.7%)	1-transient pseudomeningocele, CSF leak, superficial wound infection + chemical meningitis		
Total	70	13			

For extradural surgeries, 2/14 (14.3%) had complications. One patient had transient dysarthria, dysphagia, and odynophagia due to ETT placement and the other had transient occipital paresthesia.

For intradural surgeries, 11/56 (19.6%) had complications, including 1 patient who had difficulty swallowing related to the ETT, 1 patient who had a CSF leak from Mayfield pin site and blister at the incision site, and 9 complications that could be attributed to the intradural procedure. The most common complication was pseudomeningocele, which occurred in 8 patients. One of the pseudomeningocele cases also had a CSF leak, superficial wound infection and chemical meningitis and another had methicillin-sensitive *Staphylococcus aureus* (MSSA) meningitis and a subdural hygroma. These two patients were treated with antibiotics and along with six of the other patients had resolution of the pseudomeningoceles without need for surgery. The other two patients with pseudomeningocele, one of whom also had posterior fossa subdural CSF hygroma and keratitis, had repeat surgery for the pseudomeningocele. The other intradural complication involved one patient who had headache with a subdural effusion.

Overall, of the 13 patients with complications, 11 had transient complications that resolved without surgical interventions and 2 had complications requiring surgical repair. There were no permanent neurological deficits and no mortalities.

The complication rate varied among surgeons (Table 2). Complications were noted in one patient each for surgeon 1 (11%) and 2 (20%) after extradural surgeries. Complications were noted in 2 (10.5%), 4 (40%), 4 (19%), and 1 (16.7%) patient for surgeons 1, 2, 3, and 4 respectively after intradural surgeries.

Outcome of syringomyelia

There was no significant difference in the percentage of patients with improvement of syrinx based on extradural versus intradural surgery (Table 4) and whether tonsillar resection/shrinkage was added to the intradural operation. Of the 52 patients with syringomyelia, 45 (86.5%) decreased in size, 3 (5.8%) had no change, and 4 (7.7%) increased in size. Of those 45 syringes that decreased in size, 5 had totally resolved, 23 had almost resolved (< 3.5 mm), and 17 were smaller. All four patients with increased size of syrinx had intradural surgeries.

Outcome of scoliosis

Of the 28 patients, where the degree of scoliosis was measured, 8 (28.6%) improved and 8 had no change. Twelve worsened, of which 8 had spinal fusion and 4 were managed with bracing or observation. Outcome was also assessed by angle of scoliosis (Table 5). Forty-four percent of patients with an angle over 40 degrees had a fusion compared to 21% of those with an angle of less than 40 degrees. The patient with scoliosis angle of 80 degrees was planned for fusion prior to the decision to perform surgery for CMI.

Outcome using CCOS after first surgery

Outcome at the end of the first surgery was assessed using the Chicago Chiari Outcome Score, CCOS. The duration of follow up after the initial surgery ranged from 0.8 to 164.8 months. The CCOS was assessed as good (CCOS scores 13–16), moderate (CCOS 9–12), and poor (CCOS 4–8). Overall, a good score was seen in 63/70 (90%), moderate in 6/70 (8.6%), and poor in 1/70 (1.4%). The CCOS ranged from 6 to 16 (mean 13.9).

The CCOS based on the type of surgery was slightly different. For extradural surgeries, a good CCOS score was noted in 13 (93%) and moderate in 1 (7%) whereas for intradural surgeries, a good score was noted in 50 (89.3%), moderate in 5 (8.9%), and poor score in 1 patient (1.8%) (Table 6). Overall, for extradural cases, the CCOS ranged from 12 to 15 (mean 13.7) while for intradural cases, the CCOS ranged from 6 to 16 (mean 14).

The CCOS score was also assessed by individual surgeons (Table 7). For extradural surgeries, surgeon 1 patients had a good CCOS in 4/5 (80%) and moderate CCOS in 1/5 (20%) while surgeon 2 had a good CCOS in 9 patients (100%). For intradural surgeries, surgeon 1 noted good CCOS in 17/19 (89.5%) and moderate in 2/19 (10.5%); surgeon 2 noted good CCOS in 8/10 (80%), moderate in 1/10 (10%), and poor CCOS in 1/10; surgeon 3 noted good CCOS in 20/21 (95.2%) and moderate in 1/21 (4.8%), while surgeon 4 noted good CCOS in 5/6 (83.3%) and moderate CCOS score in 1 patient (16.7%). For extradural cases, the CCOS ranges for

Table 4 Outcome of syrinx by surgery type performed

Outcome of syrinx	Extradural $N = 7$ (% of extradural surgeries)	Intradural $N = 45$ (% of intradural surgeries)	Total $N = 52$ (%total syringes)
Smaller/resolved	6 (85.7%)	39 (86.7%)	45 (86.5%)
No change	1 (14.3%)	2 (4.4%)	3 (5.8%)
Increased	0	4 (8.9%)	4 (7.7%)

Table 5 Outcome of scoliosis by angle

Outcome of scoliosis	Equal or < 40 degrees (%)	> 40 degrees (%)	Total (%)
Improved/no change	11 (58%)	5 (55.6%)	16 (57.1%)
Worse and fused	4 (21%)	4 (44.4%)	8 (28.6%)
Worse-braced/observed	4 (21%)	0	4 (14.3%)
Total ($N = 28$)	19 (68% of total)	9 (32%)	28 (100%)

surgeons 1 and 2 were 12–15 (mean 13.2) and 13–15 (mean 14) respectively. For intradural cases, the CCOS ranges for surgeons 1, 2, 3, and 4 were 12–16 (mean 14), 6–15 (mean 13.1), 12–16 (mean 14.2), and 12–16 (mean 14.3) respectively.

Second surgeries

A second operation for CMI was performed in 13/70 (18.6% of patients). All operations involved opening the dura and included 11 posterior fossa decompressions and duraplasty, 1 patient had both posterior fossa decompression, duraplasty, and syringosubarachnoid shunt and 1 patient had T1 laminectomy and syringosubarachnoid shunt.

The reasons for the second surgery varied and the time to second operation ranged from 0.8 to 55 months (mean 20 months, median 14 months). Thirteen patients had new, persistent, worsening, or recurrent symptoms including 1 patient with inadequate decompression on repeat MRI, 2 with scarring and repeat blockage at the obex, 1 with subdural effusion and pseudomeningocele, and 4 with increase in syringomyelia. Repeat surgery was done in 4/14 (28.6%) extradural and 9/56 (16%) of intradural surgery patients.

Complications after second surgery

Complications were noted in 7 patients (53.8%) after the second surgery. There was no difference in the complication rate based on whether the initial surgery was intradural or extradural; however, the nature of the complications differed. Two patients (2/4) with previous extradural surgeries had complications, which included one patient with stitch abscess and one patient with aseptic meningitis and pseudomeningocele, which resolved spontaneously. Five (5/9) patients who had prior intradural surgery had complications: two patients had cerebellar infarcts (one also had posterior fossa subdural hematoma and aseptic meningitis); one patient had wound infection; one patient had minimal wound erythema; one patient who had laminectomy and syringosubarachnoid shunt had subsequent shunt dislodgement with enlargement of syrinx and later underwent C1–2 fusion with clinically improvement.

Of the 13 patients having a second surgery, 11 had syringomyelia. In follow up, 7 improved, 3 had no change, and 1 had enlargement of the syrinx (patient noted above). Of the 7 syringes that improved, 1 had totally resolved, 1 had almost resolved (< 3.5 mm), and 5 were smaller in size.

Final CCOS

After final review of all cases irrespective of the number of surgeries, the CCOS ranged from 11 to 16 (mean 14). The final CCOS was good (range13–16) in 60/70 (86%) and moderate (range 11–12) in 10/70 (14%). There were slight variations in final CCOS by surgeon (Table 8). Surgeon 1 patients had good CCOS in 21 (87.5%) and moderate score in 3 patients. Surgeon 2 patients had good CCOS in 15 (79%) and moderate score in 4 patients. Surgeon 3 patients had good CCOS in 19 (90%) and moderate score in 2 patients while surgeon 4 patients had good CCOS in 5 (83.3%) and moderate score in 1 patient.

Discussion

International surveys by Schijman et al. in 2003 and Singhal et al. in 2016 showed that despite a consensus that decompressive surgery at the craniocervical junction was indicated

Table 6 The Chicago Chiari Outcome Score (CCOS) at last follow up after the first surgery is tabulated based on the type of surgery performed. The CCOS was assessed as good (CCOS scores 13–16), moderate (CCOS 9–12), and poor (CCOS 4–8)

CCOS	Extradural $N = 14$	Intradural $N = 56$	Total $N = 70$(%)
Good (13–16)	13 (93%)	50 (89.3%)	63 (90%)
Moderate (scores all 12)	1 (7%)	5 (8.9%)	6 (8.6%)
Poor (score of 6)	0	1 (1.8%)	1 (1.4%)
Total	14	56	70

Tables 7 The CCOS score after the initial surgery is tabulated according to individual surgeons and type of initial surgery.

Type of surgery	Surgeon	Total number of patients for the specified surgery type	Number (%) of patients with good CCOS (13–16)	Number (%) of patients with moderate CCOS (9–12)	Number of patients with poor CCOS (4–8)
Extradural	1	5	4 (80%)	1 (20%)	0
Extradural	2	9	9 (100%)	0	0
Extradural	3	0	Not applicable	Not applicable	Not applicable
Extradural	4	0	Not applicable	Not applicable	Not applicable
Intradural	1	19	17 (89.5%)	2 (10.5%)	0
Intradural	2	10	8 (80%)	1 (10%)	1 (10%)
Intradural	3	21	20 (95.2%)	1 (4.8%)	0
Intradural	4	6	5 (83.3%)	1 (16.7%)	0

in symptomatic CMI, there were variations in the choice of surgery [6, 7]. The surgical objectives are to resolve the differential craniospinal pressure, to restore the subarachnoid space in the posterior fossa, to resolve the syrinx, to alleviate brainstem compression, and to ameliorate the symptoms and signs [6, 62]. These goals have been achievable in several studies with both intradural and extradural surgeries [9, 11–13, 20, 55]

Most of the surgeries performed in this series were intradural operations (80%). However, there was significant variation in the practice between surgeons at this institution. Two surgeons did only intradural operations, whereas two surgeons did both extradural and intradural surgeries.

Complications tend to be more frequent and involve CSF after intradural surgery, and these were more severe. Most complications were managed without surgery. There were no operative mortalities. The aggregate complication rate of 19.6% for intradural surgeries was in the middle range reported in literature of 0–33.3% [9–11, 13, 18, 47, 49, 63–70].

The most common complication after intradural surgery was pseudomeningocele. Parker et al. (2013) noted that patients who developed symptomatic pseudomeningocele had decreased quality of life and decreased benefits from surgery [71]. This is potentially avoidable with extradural approach.

Like previous reports, reoperation rates in this study were higher after extradural surgery [9, 10, 13, 14, 31, 72]. In this study, there was no difference in clinical improvement between extradural and intradural surgery, in keeping with other reports [10, 11, 13, 26, 28, 46, 73]. Lu et al., Limonadi et al. (2004), Tubbs et al. (2011), Litvack et al. (2013), Sweikeh et al. (2014), Pisapia et al. (2016), Jiang et al. (2018), and Honeyman et al. (2019) noted significant increased operating time, length of hospital stay, and complications with intradural compared to extradural surgeries [8, 11, 22, 26, 63, 66, 74, 75]. Litvack et al. (2013) proposed no dural opening only if there was no syrinx [11]. However, Durham et al. (2008), Lee et al. (2014), Forander et al. (2014), Lu et al., Narenthiran et al. (2016), Pisapia et al. (2016), and Jiang et al. (2018) found no difference in resolution of syrinx based on intradural or extradural surgery [8, 10, 13, 14, 26, 58, 74]. Kennedy et al. (2015) noted symptomatic improvement in all patients and delayed syrinx resolution in extradural surgery with 70% syrinx improvement at mean follow up of 31 months [76]. Similar to Lu et al., in this study, there were no significant difference in resolution of syringomyelia or scoliosis improvement between intradural or extradural surgeries, suggesting that extradural surgery is a reasonable option for treatment of CMI with syringomyelia [8].

Most patients in this study had a good outcome with good CCOS noted at last follow up. The mean CCOS of 14 is comparable with the literature [38, 40]. Overall, despite the differences in surgical practice, there were only slight variations in CCOS outcomes by surgeon. Additionally, the complication rates varied among surgeons. Given the variations in practice and the severity of intradural complications, a change in practices towards offering more extradural surgery may be considered where feasible with close follow up for improvement in symptomatology and imaging.

To our knowledge, this is the first report that discusses individual surgeon's outcome at the same institution for CMI management. Providing patients with this information during the consent process may enhance patient decision-

Table 8 Final CCOS scores by surgeons. After final review of all cases irrespective of the number of surgeries, the final CCOS at last follow up was calculated

Surgeon	Number of patients	% Of total /70	Good CCOS (13–16)	Moderate CCOS (9–12)
1	24	34.3%	21 (87.5%)	3 (12.5%)
2	19	27.1%	15 (79%)	4 (21%)
3	21	30%	19 (90.5%)	2 (9.5%)
4	6	8.6%	5 (83.3%)	1 (16.7%)

making and autonomy [77]. In addition, the ability of individual surgeons to compare their results with their peers in the same institution may be a strong motivator for change leading to quality improvement.

There are many limitations in this study. This was a retrospective review, and some data was not available in chart. The CCOS was applied retrospectively. Some patients had medical co-morbidities such as depression, concussion, developmental delay, and migraine that confounded the clinical picture and affected the CCOS. This is an observational study with a small number of patients. As such, it does not allow the traditional statistical analysis.

Conclusion

This study illustrates the variability in the outcome at a single institution based on surgeons performing CMI decompressions. The knowledge of one's own complication and success rates can guide discussion as part of the informed consent process. It is important that surgeons in general audit their individual outcomes and complications to allow the best recommendations, to facilitate accurate informed consent and to guide quality improvement activities.

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Compliance with ethical standards

Ethics approval This study was approved by the University of British Columbia Children's and Women's Research Ethics Board, approval number: H15-03215

Conflict of interest On behalf of all authors, the corresponding author states that there is no conflict of interest.

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