Comparison of Dural Peeling versus Duraplasty for Surgical Treatment of Chiari Type I Malformation: Results and Complications in a Monocentric Patients' Cohort

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■ OBJECTIVE: **Chiari malformation type I is typified by the downward herniation of the cerebellar tonsils through the foramen magnum, which can impede cerebrospinal fluid circulation and may lead to syringomyelia. The usual symptoms of this condition are neck pain and posterior headaches on Valsalva maneuver. Different surgical procedures have been described for cranio-cervical decompression (CCD), without a consensus being reached about the best suited technique. The primary end point of this study was to compare efficacy and complications rate of CCD using dural peeling (DPe) versus duraplasty (DP). The secondary end point was to find predictive factors of success of DPe.**

■ METHODS: **Twenty-eight consecutive patients with Chiari malformation type I (12 women and 16 men) requiring CCD were enrolled at our institution between August 2011 and November 2015. Ten patients (35.7%) underwent DP, and 18 (64.3%) DPe. A standardized magnetic resonance imaging protocol was performed before and at least 3 months after surgery. Symptomatic outcome was evaluated at the last follow-up visit.**

■ RESULTS: **Overall complications were more frequent in the DP (4 patients, 70%) group than in the DPe (none) group (P <0.05). All patients in the DP group improved clinically but only 12 patients (66.7%) in the DPe group (P = 0.1). Morphologic evolution at magnetic resonance imaging was similar in both groups. A moderate trend for changes in cerebellar tonsil conformation was shown in patients with clinical improvement (P = 0.07). Predictive factors of clinical improvement after DPe cannot be identified.**

■ CONCLUSIONS: **CCD with DPe was less risky than with DP but had a lower responsive rate (66.7% vs. 100). Larger studies are therefore warranted to assess predictive factors of success of CCD with DPe.**

INTRODUCTION

Chiari malformation type I (CM-I) was first defined in 1891 by Hans Chiari in a series of autopsic examination in patients with cerebellar ectopia. He classified type I as the "elongation of the tonsils and medial parts of the inferior lobes of the cerebellum, into the spinal canal."[1] This malformation can be found in both adult and pediatric patients and was radiologically described as the herniation of the cerebellar tonsils below the foramen magnum caused by overcrowding of the posterior fossa.[2] The herniated tonsils causecerebrospinal fluid (CSF) flow disturbances at the craniocervical junction, leading to syringomyelia formation in about two thirds of patients.[2]

The usual symptoms are neck pain and/or occipital headaches, often triggered or worsened by sudden increase in abdominal pressure (i.e., on Valsalva maneuver or coughing). Patients with associated syrinx may develop dysesthesia, hypoesthesia, motor weakness, gait ataxia, and swallowing disturbances if the syrinx ascends into the brainstem.[3]

Cranio-cervical decompression (CCD) is indicated in patients with symptomatic CM-I with or without syrinx.[4] Several techniques for CCD have been described. The intradural techniques carry an increased risk for complications such as CFS leak, pseudomeningocele, meningitis, complications associated with dural graft, permanent surgical morbidity and even surgical

Key words
- Chiari malformation type I
- Complications
- Cranio-cervical decompression
- Dural peeling
- Duraplasty

Abbreviations and Acronyms
CCD: Cranio-cervical Decompression
CM-I: Chiari malformation type I
CSF: Cerebrospinal fluid
DP: Duraplasty
DPe: Dural peeling
MRI: Magnetic resonance imaging

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mortality.[5] Because of this greater risk of complications, more conservative extradural CCD have been advocated.[6-9] Recent studies have assessed the efficacy of extradural CCD (bone decompression alone or with dura-splitting) with CCD with duraplasty (DP)[6,10,11] but no consensus has emerged among experts about which surgical method should be preferred for CCD.[12-16]

The aim of our study was to analyze the outcome of a less invasive CCD in CM-I using a dural peeling (DPe) technique. Our primary end point was to compare the efficacy and the surgical complications rate with conventional CCD with DP. The secondary end point was to find predictive factors of success of DPe.

METHODS

Patients and Data Collection

Between August 2011 and November 2015, 28 consecutive patients (12 women and 16 men) aged 1.1–63 years (median age, 27 years), presenting with symptomatic CM-I morphologically confirmed at magnetic resonance imaging (MRI), underwent CCD at the Department of Neurosurgery of the Saint Luc academic hospital (Université catholique de Louvain) in Brussels, Belgium.

Relevant preoperative parameters were recorded in the electronic medical file, including age, gender, symptoms, neurologic deficits, preoperative imaging with measurement showing the degree of tonsillar prolapses, and presence or absence of syrinx. Intraoperative notes and follow-up data including degree of clinical improvement and medical and surgical complications were also recorded for study review. The study design was cleared by the institutional ethics committee.

Surgical Procedures

Ten patients (35.7%) underwent CCD with DP and 18 patients (64.3%) using CCD with peeling of the outer layer of the dura (DPe, dura-splitting). The surgical procedure (DPe vs. DP) was chosen mainly according to the surgeon's experience, but since 2011, the main operators (e.g., C.R.) have decided to systematically propose to patients CCD with DPe as the first option to avoid potential severe complication.[5] All interventions were performed in the prone position with rigid head fixation; the neck was placed in slight flexion to allow better visualization. A midline incision extending from the inion to the upper cervical spine was made to allow a standard subperiosteal dissection of muscle from the occipital and cervical region. Bone decompression was performed encompassing the inferior aspect of the occipital bone together with a C1 laminectomy. In the DP group, the dura was opened by a linear path without cauterization or resection of cerebellar tonsils. Dural grafting was completed using various materials according to the surgeon's preference: TissuDura (Baxter, Illinois, USA) covered with DuraSeal ($n = 1$) (Integra LifeSciences, New Jersey, USA); Neuro-Patch (B Braun, Melsungen, Germany) alone ($n = 1$), covered with DuraSeal (Integra LifeSciences Corporation, New Jersey, USA) ($n = 5$) or Tisseel (Baxter) ($n = 2$); or Fascia Lata (tissue bank, UCL, Brussels, Belgium) ($n = 1$). In the DPe group, after bone removal, the outer layer of the dura was peeled carefully to avoid penetration into the subarachnoid spaces (Figure 1). Once sufficient thinning of the dura was obtained, it could be seen pulsating under the microscope (Figure 2).

No patient had peroperative ultrasonographic assessment of CSF circulation to evaluate adequacy of DPe.

After meticulous hemostasis, the wound was closed in standard layered fashion. All the patients were admitted to the intensive care unit postoperatively.

Follow-Up

All DPe patients were seen for a follow-up visit at 3 months after surgery, and thereafter between 9 and 12 months later. For some of the DP patients, follow-up had already been stopped at that point. Symptomatic outcome was evaluated at the last follow-up visit. All patients have benefited from postoperative MRI before each follow-up appointment. All significant complications were recorded too.

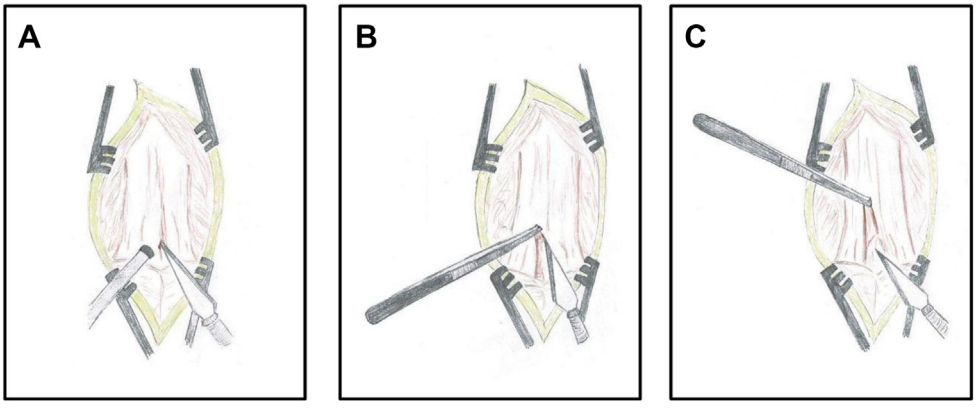

Figure 1. Simplified representation of dural peeling. (**A**) *After bone removal, small vertical incisions of the outer layer of the dura are made.* (**B** and **C**) The outer layer of the dura is peeled carefully to avoid penetration into the subarachnoid spaces.

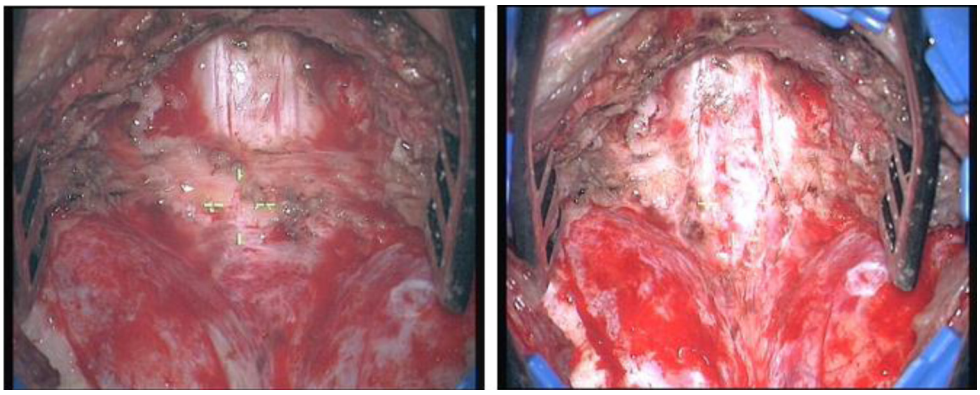

Figure 2. Craniocervical transition before (*left*) and after (*right*) decompression by dural peeling.

Statistical Analyses

Statistical analyses were performed using SPSS version 24 (IBM Corp., Armonk, New York, USA). Continuous and ordinal variables were compared using the χ^2 test, categorical variables were compared using the Fisher exact test. Any P value <0.05 was considered significant.

RESULTS

Patients

A total of 28 patients (16 males and 12 females) underwent a CCD during the study period. Ten patients (35.7%) underwent CCD with DP, whereas 18 (64.3%) underwent a less invasive extradural CCD using DPe. Demographic data, syringomyelia incidence, tonsillar ectopia, and median follow-up are reported in Table 1.

There were no statistically significant differences in age and gender distribution between the 2 groups even if the median age was 13 (range, 1.1–53 years) in the DP group and 31 (range, 3.7–63) in the DPe group ($P = 0.09$). The most common symptoms were headaches in both groups (90% in the DP group, 72.2% in the DPe group), frequently with effort-related acutization, then nausea and vomiting (30%) in the DP group and hypoesthesia/paresthesia (55.5%) in the DPe group. The signs and symptoms, as well as the baseline MRI characteristics, are shown in Table 2. The average duration of surgical procedure was 2 hours 56 minutes in the DP group and 4 hours 3 minutes in the DPe group.

Clinical Outcome

All patients in the DPe group had at least a 9-month follow-up visit. This was not the case in the DP group, in which only 5 patients (50%) had a clinical outcome evaluation date available after less than a 7-month follow-up period.

The DP and DPe group had divergent clinical outcomes. All patients in the DP group clinically improved, with half (50%) having complete resolution of symptoms and the remaining half having partial improvement. In the DPe group, only 66.7% of patients had clinical improvement, 28% with total resolution and 39% with partial improvement (Table 3).

Six patients (33%) in the DPe group have not benefited from any clinical improvement. The first of these patients showed the beginning of a syringomyelia on the last follow-up MRI examination but did not pursue his follow-up.

The second and third patients had stable MRI but did not accept a second surgery. The fourth patient showed significant improvement on MRI but after neurologic and psychiatric workup, her residual complaints were considered more probably psychosomatic because of personal difficulties. The fifth patient was reoperated on with a DP for nonresolutive hypoesthesia/paresthesia with stable syringomyelia at the last follow-up examination. Five months after the second surgery with DP, she still had residual preoperative symptoms. The sixth patient was reoperated on in another hospital with partial tonsillar resection and cranioplasty. Three months postoperatively, the preoperative symptoms were reputed to have resolved.

MRI Findings

Postoperative follow-up MRI examinations were available for review in 26 patients (100% of the DPe group and 80% of the DP group) (Table 3). Morphologic improvement was evaluated by a board-certified neuroradiologist (T.D.) and was assessed by reappearance of CSF at posterior and/or inferior aspect of the

Table 1. Demographic and Clinical Data for the Two Surgical Groups

	Duraplasty (n = 10)	Dural Peeling (n = 18)	*P*
Median age, years (range)	13 (1.1–53)	31 (3.7–63)	0.09
Ratio men/women	8:2	8:10	0.11
Tonsillar ectopia, n (%)			
<10 mm	4 (44.4)*	11 (61.1)	0.4
≥10 mm	5 (55.6)*	7 (38.9)	
Syringomyelia, n (%)	4 (44.4)*	9 (50.0)	1

*Data not available for 1 patient.

Table 2. Preoperative Findings in 28 Patients With Symptomatic Chiari Malformation Type I Treated With CCD With Duraplasty or Dural Peeling

			Tonsillar Ectopia (mm)				Preoperative Symptoms											
Case Number	Age (years)	Sex	<5	5–10	>10	Syringomyelia Location	Headache	Nausea/ Vomiting	Hydrocephalus	Hypoesthesia/ Paresthesia	Muscular Weakness	Gait Disorder	Diplopia	Nystagmus	Muscular Pain	Sphincter Disorders	Vertigo	Surgery
1	23	M			+	–	+	–	–	–	–	–	–	–	–	–	+	DP
2	14	M			+	C0-T9	+	–	+	–	–	–	–	–	–	–	–	DP
3*	11	M			+	C4-T1 and T3-9	–	–	–	–	–	–	–	–	–	–	–	DP
4	1.1	F		+		–	+	–	+	–	–	–	–	+	–	–	–	DP
5	31	M	+			C3- T5	+	+	–	+	+	–	–	–	–	–	–	DP
6*	10	M		NA		NA	+	–	–	–	–	–	–	–	–	–	–	DP
7	10	M			+	–	+	+	–	–	–	–	–	–	–	–	–	DP
8	10	F		+		–	+	+	+	–	–	–	–	–	–	–	–	DP
9	53	M		+		C2	+	–	–	–	–	+	+	–	–	–	–	DP
10	43	M			+	–	+	–	–	–	–	–	–	–	–	–	–	DP
11*	3.7	M			+	–	+	–	–	–	–	–	–	–	–	–	–	DPe
12	34	F		+		–	+	+	–	+	+	–	–	–	–	–	–	DPe
13	44	F		+		–	+	–	–	+	–	–	–	–	–	–	–	DPe
14	50	M	+			C1/2-T1	+	+	–	–	–	–	–	–	–	–	+	DPe
15	58	F	+			–	+	–	–	–	–	–	–	–	–	–	–	DPe
16	19	F			+	–	+	–	–	+	–	–	–	–	+	–	–	DPe
17	39	M			+	C2-T1	+	–	–	+	–	–	–	–	–	–	–	DPe
18	41	F		+		–	+	–	–	–	–	–	–	–	+	–	–	DPe
19	35	M	+			C1-L1	–	–	–	+	+	–	–	–	+	–	–	DPe
20	17	F		+		C4–T5	–	–	–	+	–	–	–	–	–	+	–	DPe
21	28	F		+		–	+	–	–	–	–	–	–	–	–	–	–	DPe
22	26	M			+	C2-L1/2	+	–	–	–	–	–	–	–	–	–	–	DPe
23	10.8	M		+		C5-7 and T9-12	+	+	–	–	–	–	–	–	–	–	–	DPe
24	25	F		+		C5-T3	+	–	–	+	+	–	–	–	+	–	+	DPe
25	18	F		+		C3/4-T12/L1	–	–	–	+	–	–	–	–	–	–	–	DPe
26	42	M			+	–	–	–	–	+	+†	–	–	–	–	–	–	DPe
27	63	M			+	C3-7	–	–	–	+	–	–	–	–	+	–	–	DPe
28	45	F			+	–	+	–	–	–	–	–	–	–	–	–	–	DPe

DP, duraplasty; NA, data not available; DPe, dural peeling; CCD, cranio-cervical decompression.
*Lost to follow-up.
†and spastic paresis.

Table 3. Postoperative Findings in 28 Patients With Symptomatic Chiari Malformation Type I Treated With Duraplasty or Dural Peeling

	CCD with Duraplasty*, n (%)		CCD with Dural Peeling, n (%)		*P*
Clinical evolution					
Improvement	10 (100.0)		12 (66.7)		0.1
Stable	0		6 (33.3)		
Appearance of cerebrospinal fluid behind amygdala					
Improvement	6 (75.0)		16 (88.9)		0.56
Stable	2 (25.0)		2 (11.1)		
Amygdala morphotype change					
Improvement	7 (87.5)		13 (72.2)		0.62
Stable	1 (12.5)		5 (27.8)		
Hydrosyringomyelia					
Improvement	3 (100.0)		4 (44.4)		0.2
Stable	0		5 (55.6)		
	SR	**SS**	**SR**	**SS**	***P***
Complications					
Pseudomeningocele	3 (30.0)	1 (12.5)	0		<0.05
Wound infection	0	1 (12.5)	0		
Hydrocephalus	0	2 (20.0)	0		
Total	3 (30.0)	4 (40.0)	0		
Median follow-up, months (range)	8.5 (2–29)		40 (15–56)		0.002

Magnetic resonance imaging analysis performed by senior neuroradiologist.
SR, spontaneous resolution; SS, second surgery needed; CCD, cranio-cervical decompression.
*Two patients did not receive magnetic resonance imaging follow-up.

amygdala ($P = 0.56$); morphologic change of cerebellar tonsils (from conic to round caudal aspect) ($P = 0.62$); and subsidence of syringomyelia in patients in whom it was present preoperatively ($P = 0.2$).

There was no statistical difference between the 2 groups for those parameters. The tonsil was shown to have a tendency to round up in patients who presented with clinical improvement ($P = 0.07$) in both surgical groups.

Fifteen patients (53.6%) presented with a syrinx, 9 in the DPe group and 3 in the DP group. A reduction in size of the cavity was shown on MRI in 44.4% of the patients in the DPe group and in all patients in the DP group. One patient in the DPe group developed de novo a syrinx after the surgery.

Complications

Overall complications were more frequent in the DP (70%) than in the DPe (0%) group ($P < 0.05$) (Table 3). Four patients (40%) in the DP group required multiple interventions because of complications (1 pseudomeningocele, 1 wound infection, and 2 hydrocephalus). In the DPe group, 2 patients needed a late second surgery with DP because of the nonresolution of the preoperative symptoms.

DISCUSSION

Surgical CCD is overall recommended for patients with symptomatic CM-I. The conventional technique consists of a CCD with suboccipital craniectomy and C-1 laminectomy, a dural opening, and a DP with or without suturing the dural graft.[17] Some investigators coagulate or resect cerebellar tonsils, and others advocate addressing the patency of the foramen of Magendie.[18-20] Our senior coauthor (C.R.) obtained effective re-expansion of CSF spaces and shrinking of hydrosyringomyelia by performing dural opening with preservation of the subarachnoid spaces.[17,21,22] Partisans of dural opening sustain that this procedure increases the probability of symptom and syrinx improvement, although it has been linked with higher complication rates.

Clinical Improvement

In the recent literature, clinical improvement after CCD without dural opening has been reported in the range of 61.5%–86% (Table 4).[7,10,11,14] Chotai and Medhkour[6] conducted a retrospective review of the medical records of all patients undergoing CDD during 12 years (Table 4). These investigators performed CDD with dura-splitting in patients without syringomyelia at neuroimaging and DP if syringomyelia was present. They described an overall clinical improvement in 86% of their patients' series. A history of previous extradural decompression was associated with unfavorable outcome.

In our series, 66.7% of the patients operated on with an extradural technique experienced general improvement regarding preoperative symptoms and the remainder were stable at the last follow-up. No patient had worsening of preoperative symptoms after surgery. There was no statistically significant difference in long-term outcome between the DP and DPe groups.

Some reviews[7,13] have described a higher degree of syringomyelia subsidence in patients who had intradural procedures. Therefore, numerous surgeons avoid extradural decompression alone in patients who have shown syringomyelia.

Statistical analysis in our patients' series failed to show any significant difference in improvement of syringomyelia between the DP and DPe subgroups (Figure 3).

Reoperation and Complications

To better evaluate efficacy of CCD with DP versus DPe, many studies have reported the reoperation rate.[6,23] It seems more reasonable to advocate reoperation in unimproved patients initially treated by DPe than in those initially treated by DP, in whom fewer treatment options are available.[2] In our study, only 2 patients (11.1%) were reoperated on in the DPe group for no resolution of preoperative symptoms. All patients in the DP group had at least partial improvement of preoperative symptoms, but 4 (40%) needed a second surgery for postoperative complications.

Table 4. Literature Review, Clinical Outcomes After CCD with Duraplasty or Dural Peeling

	CCD with Duraplasty			CCD with Dural Peeling				
Reference	**Patient Number**	**Mean Age (years)**	**Clinical Improvement (%)**	**CCD Alone**	**Patient Number**	**Mean Age (years)**	**Clinical Improvement (%)**	***P***
Chotai and Medhkour, 2014*,[6]	12	33.8 (16–58)	9 (75.0)		29	33.8 (16–58)	25 (86.2)	>0.05
Lee et al., 2014†,‡,[23]	25	9.9 (standard deviation 5.3)	14.6 (NA)	+	19	8.9 (standard deviation 5.2)	14.7 (NA)	0.7
Förander et al., 2014‡,[2]	*426*	*NA*	*330 (77.5)*	+	*51*	*NA*	*40 (78.4)*	*0.8*
Xu et al., 2017[23,16],‡	*191*	*NA*	*165 (86)*	+	*84*	*NA*	*59 (70)*	*<0.05*
Gürbüz et al., 2015‡,§,[24]	13	32	11 (84.6)	+	12	32	4 (33.3)	<0.013
Zhao et al., 2016[25],‡	*721*	*36.34 (0.2–70)*	*593 (82.2)*	+	*216*	*36.34 (0.2–70)*	*159 (73.6)*	*<0.05*
Saint Luc	10	19.5 (1.08–53)	10 (100)		18	33.3 (3–63)	12 (67)	0.1

Meta-analyses in italic.
NA, not available; CCD, cranio-cervical decompression.
*Duraplasty in patients with hydrosyringomyelia, dural peeling in patients without hydrosyringomyelia.
†Clinical outcome = Chicago Chiari Outcome Scale; dural peeling group had bone decompression alone (pediatric study).
‡Bone decompression alone no duraplasty and no dural peeling.
§All patients had hydrosyringomyelia; dural peeling group had bone decompression alone.

In a meta-analysis of 582 cases, Durham et al.[7] showed that patients who had a DP had a lower risk of reoperation than those who had a simple bone decompression (Table 5). However, the intradural technique carried a greater risk of CSF-related complications. In addition, there was no significant difference between the 2 operative techniques with respect to clinical improvement or decrease in size of the syrinx.

Yilmaz et al.[26] reviewed 82 patients with surgical correction of CM-I. These investigators did not perform manipulation of the subarachnoid space or resection of the tonsils because of the risk of complications. The complication rate was significantly higher in the DP group (12.0%) than in the non-DP group (8.3%) ($P < 0.05$).

The complication rate for a DP have been reported to be higher than for a laminectomy alone in previous studies.[13,20,27] Our study showed similar results (40% surgical complication rate for DP compared with 0% for DPe).

Limitations

The main limitation of the work was the small sample size of both patient groups (CCD using DP vs. DPe) but with the benefit of a small group of trained operators. A larger study recruiting more

Figure 3. Preoperative (*left*) and 31 months postoperative (*right*) magnetic resonance imaging of a patient operated on by dural peeling technique.

Table 5. Literature Review, Summary of Complications After Duraplasty or Dural Peeling

	CCD with Duraplasty			CCD alone or with Dural Peeling			
		Complications, n (%)			Complications, n (%)		
Reference	Patient Number	SR	SS	Patient Number	SR	SS	*P*
Chotai and Medhkour, 2014[6]	12	2 (16.5)	2 (16.5)	29	0	1 (3.4)	0.004
Lee et al., 2014*,[23]	25	0	7 (28.0)	19	0		<0.001
Förander et al., 2014[2]	*472*	*14 (2.9)*	*18 (3.8)*	*41*	*0*		*0.21*
Xu et al., 2017[*,16]	*747*	*15 (2.0)*	*28 (3.8)*	*566*	*1 (0.1)*	*5 (0.8)*	*<0.05*
Gürbüz et al., 2015*,[24]	13	4 (30.8)		12	1 (8.3)		0.186
Zhao et al., 2016[*,25]	*888*	*183 (20.7)*		*22*	*1 (4.55)*		*<0.05*
Saint Luc	10	3 (30.0)	4 (40.0)	18	0		<0.05

Meta-analyses in italic.
SR, spontaneous resolution; SS, second surgery needed; CCD, cranio-cervical decompression.
*Bone decompression alone no duraplasty and no dural peeling.

patients in each group should have enough statistical power to draw robust conclusions about the superiority of one decompression technique over the other and to define predictive factors of success of DPe through a multivariate analysis.

CONCLUSIONS

General consensus on which surgical procedure is best suited to which patients with CM-1 is still lacking. CCD using DPe or bone removal alone is clearly a less risky procedure compared with CCD with DP (40% of surgical complications), but with the penalty of a lower success rate (67%). Because two-thirds of our patients showed clinical improvement after CCD with DPe without any complication, we believe that it is appropriate to propose this approach as the first treatment option to avoid as much as possible CSF-related complications of more invasive procedures. However, analysis of larger series of patients is mandatory to identify predictors of success of DPe to more appropriately choose DPe versus DP in individual patients with CM-1.

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