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Original Article

Surgical Outcome after Dura-splitting Decompression in Chiari Malformation I

Ahmed Sherin, Wael Mahmoud Khedr, Wael Mohamed Mousa
Department of Neurosurgery, Faculty of Medicine, Alexandria University, Alexandria, EGYPT

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BACKGROUND: Most surgeons practice a suboccipital craniectomy with duraplasty for the treatment of patients with Chiari malformation I (CM-I). However, duraplasty could impose several operative hazards ranging from hypotensive headache up to fatal meningitis. Dura-splitting decompression can achieve comparable clinical outcome, yet with higher safety profile.

OBJECTIVE: The aim of this study is to analyze the clinical and radiological outcomes following dura-splitting decompression in CM-I patients, compared to the standard duraplasty technique.

PATIENTS AND METHODS: This is a retrospective study of 84 patients with CM-I who had surgery between January 2015 and August 2021. Patients were divided into two groups following bony decompression; the first group had splitting of the outer layer of the dura, whereas the second group had duraplasty. Data collected including patients' demographic data, preoperative clinical evaluation, operative data, and postoperative clinical and radiological outcomes were tabulated and analyzed.

RESULTS: The study included 84 patients with CM-I who underwent suboccipital craniectomy; 44 patients (52.4%) had dural splitting and 40 patients (47.6%) underwent duraplasty. Mean age at presentation was similar in both groups, 38 years in the dura-splitting group and 40 years in the duraplasty group. There were 59 female patients (70.2%). The mean follow-up period was 17.2 months (range, 12-37 months). Both techniques achieved comparable clinical and radiological outcomes. Dura-splitting decompression achieved less blood loss and shorter hospital stay. Dura-splitting technique had statistically significant less postoperative complications ($p > 0.05$) and less operative time ($p > 0.05$). There was no statistically significant difference as regards the clinical improvement or adequate posterior fossa decompression.

CONCLUSION: Dura-splitting technique provides comparable clinical and radiological improvement in CM-I patients compared to duraplasty, with more safety, less operative time and blood loss, and shorter hospital stays.

KEYWORDS: Cerebrospinal fluid leak, Chiari malformation I, Dura-splitting, Duraplasty, Suboccipital approach, Tonsillar herniation.

INTRODUCTION

Chiari malformations are developmental hindbrain abnormalities characterized by defective mesodermal development of the posterior fossa with herniation of part of the posterior fossa structures and defective cerebrospinal fluid (CSF) circulation through the foramen magnum (FM). Chiari malformations are graded from type I to type IV based upon the progression of caudal herniation of neural tissues through the FM. Type I Chiari malformation represents caudal herniation of the cerebellar tonsils below the FM, of at least 5 mm. Syringomyelia as well as scoliosis can associate Chiari malformation.[1-3] Chiari malformation type I has an overall low incidence, ranging between 0.5-3.5% of the general population. However, there is increasing prevalence matching with the advances in neuroimaging techniques and the accidental diagnosis during imaging for other causes. The natural history of CM-I remains controversial. Onset of symptoms may occur at the pediatric age, however, it may be delayed until adulthood, with slight female predominance.[2,4]

Correspondence:
Ahmed Sherin Hamdy
Department of Neurosurgery, Faculty of Medicine, Alexandria University, Alexandria, EGYPT
Email: ahmed.sherin@alexmed.edu.eg

Despite being the most common form, many patients with CM-I may be asymptomatic with accidental diagnosis. Wide spectrum of presentations ranging from mild headache to severe neurological deficits may occur, often with insidious onset. Presentations are not only related to direct neural compression at the craniocervical junction, but also due to the possible presence of syrinx. Occipital pressure like headache is the most common presentation, which characteristically increases with straining and is usually associated with neck pain. Long tract manifestations are also common presentations with variable sensory and motor manifestations. Patients may have cerebellar manifestations like ataxia, nystagmus, dysarthria, vertigo, and imbalance, as well as brain stem compression manifestations, or even cranial neuropathies.[3,5-8]

Magnetic resonance imaging (MRI) of the brain including the craniocervical junction is the gold standard investigation for diagnosing Chiari malformations, assessing its grade, and detecting the associated syrinx or hydrocephalus. Whole spine MRI may be used to assess the extent of associated syrinx. Computerized tomography (CT) is important for assessment of any associated

atlantoaxial instability, platybasia (Welcher basal angle <1400), or even basilar impression (Wackenheim line violated by the odontoid process).[6]

Patients who are asymptomatic or those presenting with mild symptoms usually have conservative management with serial clinical and radiological follow up, however, patients with disabling symptoms should have surgical treatment. Some surgeons may recommend prophylactic surgery to guard against the late onset development of manifestations.[9,10] Till now, bony decompression on one hand and cerebellar tonsillectomy on the other hand represent, for some neurosurgeons, the appropriate neurosurgical procedures in cases with CM-I. Posterior fossa decompression (PFD) with duraplasty is the usually employed procedure, especially when CM-I is associated with large syringomyelia. Duraplasty can be performed using either autologous tissues or artificial dura, achieving adequate neuronal decompression and allowing direct exploration of CSF pathway and restoring regular CSF flow at FM. Despite being an effective option with little incidence or need for reoperation, dural opening may be associated with several complications, like CSF leak, postoperative wound infection, meningitis, formation of pseudomeningocele, or even hydrocephalus.[11-14]

Dura-splitting decompression including suboccipital craniectomy and cervical laminectomy of C1, coupled with splitting of the tough outer layer of the dura was proposed by many authors to have comparable adequate neuronal decompression while minimizing the postoperative complications associated with duraplasty technique.[15,16] The aim of this study is to evaluate posterior fossa decompression with partial dura-splitting technique compared to the traditional duraplasty technique regarding efficacy and safety in the management of CM-I surgical patients.

PATIENTS AND METHODS

Retrospective analysis of the records of 84 patients diagnosed with CM-I, who underwent posterior fossa decompression between January 2015 and August 2021, was performed to assess the efficacy and safety of the dura-splitting technique for CM-I surgical management compared to duraplasty. Patients included in this study had symptomatic CM-I with or without syringomyelia. Asymptomatic patients with CM-I, patients with higher grades of Chiari malformation, patients subjected to posterior fossa decompression only without any dural manipulations, medically infirm patients, patients with atlantoaxial instability or associated severe basilar invagination and patients with postoperative follow up period less than 12 months were excluded from this study. The study was approved by the Ethics Committee of the Faculty of Medicine of Alexandria University (Institutional review board (IRB) No.: 00012098, FWA No.: 00018699). Patients had signed an informed consent to be included in the study.

Patients were divided into two groups; the first group with little or no syringomyelia had bony decompression and splitting of the outer dural layer while in the second group with large syringomyelia (more than 3 mm diameter or more than one cervical segment extension), posterior fossa decompression and expansive duraplasty has been done. Collected data included patients' demographics, clinical presentation, associated anomalies, operative time, amount of blood loss and possible intraoperative complications. Postoperatively, data concerning clinical outcome, length of hospital stay, radiological outcome, complications and need for reoperation were obtained.

Surgical Technique

All patients received intravenous antibiotic surgical prophylaxis 30 minutes before the procedure. Patients were positioned in Concorde position with three-pin MAYFIELD® skull clamp (Integra Life Sciences Corporation, Cincinnati, OH) under general anesthesia. Local infiltration at the site of skin incision was done using lidocaine 2% and noradrenaline to minimize skin and subcutaneous bleeding. Midline skin incision was done extending from the external occipital protuberance to the level of the axis vertebra (C2), preserving its muscular attachment unless syrinx was extending beyond C2. After muscular dissection, a suboccipital craniectomy was done starting 2-3 cm above the foramen magnum and extending bilaterally allowing decompression of the cerebellar hemisphere and brain stem. Afterwards, C1 laminectomy was performed, followed by opening of the thickened atlantooccipital membrane.

In the dura-splitting group, sharp dissection of the outer layer of dura was done, with extreme caution to avoid violation of the inner layer of dura. We started by bluntly separating the periosteal membrane and the outer dura from the inner dura using Woodson elevator. This was followed by continuous sharp dissection of the outer dura from above downwards until reaching the level of C1, and from medial to lateral using Penfield dissector releasing any adhesions between the two dural leaflets with a tenotomy scissor. The two dissected leaflets of the outer dura were tented to the paraspinal muscles using 3/0 silk, thus allowing expansion of the inner layer of dura and neural decompression **(Fig. 1).** Regarding the patients in the other group, they had a Y-shaped dural incision, with the duraplasty graft obtained from the facia lata or using an artificial dura. Intraoperative ultrasound was used in all cases to check adequate tonsillar decompression and restoration of adequate CSF flow at and distal to the foramen magnum. Hemostasis was finally done using Gelfoam® (Pfizer, USA) or Surgicel® (Ethicon, Johnson and Johnson, Somerville, NJ, USA). Bipolar coagulation was avoided to guard against unintended durotomy or dural shrinkage. Closure was done in layers.

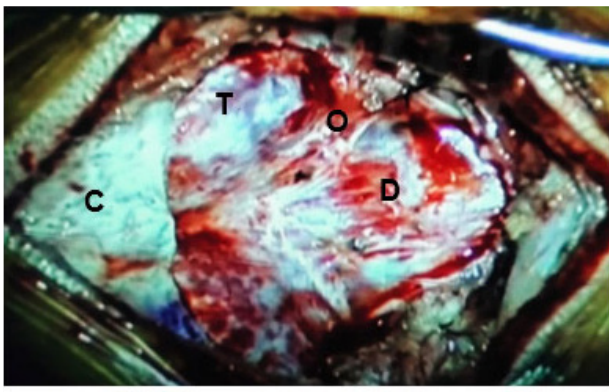

Fig 1: Intraoperative image demonstrating the partial dura-splitting technique, obtaining the two leaflets (right and left leaflets) of outer dura and tenting them to the paraspinal muscles, yet preserving the inner dura. C (cranial), T (right cerebellar tonsil), O (outer dura tended to spinal musculature), D (intact inner dura).

Patients had clinical and radiological (MRI craniocervical junction) follow up immediately postoperatively, and at 6 months intervals for the first year, then on yearly basis (Minimal follow up period was 12 months). We assessed the clinical outcome in both groups, the change in syrinx size, and the development of any complications. Syrinx size was considered decreasing if the diameter of the syrinx decreased by at least 20% of the preoperative diameter.

Statistical Analysis

Using a specially constructed sheet on Microsoft Excel, data was entered, thoroughly revised, and transferred to IBM Statistical Package for the Social Sciences version 17.0 (SPSS Inc., Chicago, IL, USA). For descriptive statistics, the mean and standard deviation were calculated. As for comparative statistics, comparison in all variables using Fisher exact test and Odd's ratio (with 95% confidence interval), when applicable, was performed. A 5% alpha error was adopted (p significance was measured at <0.05).

RESULTS

The records revealed 84 patients (59 females) diagnosed with CM-I, who underwent posterior fossa decompression between January 2015 and August 2021. The dura-splitting technique was performed in 44 patients (52.4%) and 40 patients (47.6%) had traditional expansive duraplasty. Follow up period ranged between 12-37 months (Mean follow-up, 17.2 months). There were 59 females (70.2%); 32 out of 44 patients in the dura-splitting group (72.7%) and 27 out of 40 patients in the duraplasty group (67.5%). The age in the dura-splitting group ranged between 10-55 years (Mean age, 38 years), while in duraplasty group it ranged between 9-59 years (Mean age, 40 years). No statistically significant difference appeared between both groups as regards the demographics.

Clinically, in the dura-splitting group, headache increasing on straining and cervical pain were the most common presenting symptoms in 38 patients (86.4%), followed by extremities paresthesia with or without weakness in 24 patients (54.5%). Dizziness and gait disturbance occurred in 13 patients (29.5%), while cranial nerves affection was manifest in only 3 patients (6.8%). In the duraplasty group, occipital headache was manifest in 36 patients (90%), extremities paresthesia with or without weakness in 27 patients (67.5%), followed by dizziness and gait disturbance in 10 patients (25%) and cranial nerves affection in only one patient (2.5%). There was no statistically significant difference regarding the clinical presentation between both groups.

Syringomyelia was present in 12 (27.3%) and 18 (45%) patients in the dura-splitting and the duraplasty groups, respectively. Preoperative hydrocephalus associating CM-I was present in two patients in the duraplasty group and in no patients in the dura-splitting group. Scoliosis was present in only one patient in the duraplasty group, while no patients had scoliosis in the dura-splitting group. There was no statistically significant difference between both groups as regards the incidence of CM-I associated anomalies.

The mean intraoperative blood loss was 200 mL (Range, 150 to 400 mL) and 370 mL (range, 250 to 600 mL) in the dura-splitting and the duraplasty groups, respectively. None of the operated cases needed intraoperative or postoperative blood transfusion. Operative time from skin incision to closure was significantly lower in the dura-splitting group with a mean of 65 minutes (Range, 55-120 minutes) compared to an average of 130 minutes (Range, 100-220 minutes) in the duraplasty group. Only two patients in the dura-splitting group had an unintended durotomy that had been dealt with using fibrin glue, which was effective against possible CSF leakage.

Postoperative hospital stay ranged between 1-5 days (Mean, 3 days) in the dura-splitting group, as opposed to 2-13 days (Mean, 6 days) in the duraplasty group. None of the patients in either group needed reoperation. **Table 1** demonstrates the statistical significance of the differences between the dura-splitting group (N=44), and the duraplasty group (N=40) as regards demographics, clinical presentation, associated congenital anomalies, operative blood loss, operative time, and postoperative hospital stay.

In the dura-splitting group, clinical improvement was achieved gradually in 29 patients (65.9%) within 6 months after surgery, and in 36 patients (81.8%) within one year, while only 8 patients (18.2%) remained unchanged. Regarding the duraplasty group, clinical improvement was achieved in 30 (75%) and 34 (85%) patients within 6 and 12 months of follow-up, respectively, while only 6 patients (15%) had stationary clinical status. No statistically significant difference was found between both groups as regards the amelioration of symptoms after surgery.

Radiologically, the syrinx size decreased in 7 patients (58.3%) in the dura-splitting group within 12-18 months of follow-up after surgery, and remained unchanged in 5 patients (41.7%). Meanwhile, in the duraplasty group, the syrinx decreased in 12 patients (66.7%) within 12-18 months and was of stationary size in 6 patients (33.4%), with no statistically significant difference between both groups as regards the resolution of syringomyelia.

Postoperatively, the duraplasty group reported higher incidence of postural headache in the early postoperative period, which was recorded in 28 patients (70%). None of the dura-splitting group patients reported postural headache. Postoperative complications included pseudomeningocele in 6 patients (15%) in the duraplasty group and in two patients (4.5%) in the dura-splitting group; still none of the cases of pseudomeningocele mandated reoperation. Postoperative CSF leak was encountered in a single case (2.3%) in the dura-splitting group and in two cases (5%) in the duraplasty group, and was managed by temporary lumbar drain and medical treatment and did not require re-intervention. Postoperative superficial infections occurred in 3 patients (7.5%) in the duraplasty group and in none of the patients in the other group, while postoperative meningitis occurred in two patients (5%) in the duraplasty group and in none of the patients in the dura-splitting group. Statistical analysis revealed statistically significant difference between the dura-splitting group and the duraplasty group (p=0.032) as regards the rate of postoperative complications, in favor of the dura-splitting group. Comparison of the clinical and radiological outcomes and the complications rate between both groups and its statistical significance is illustrated in **(Table 2).**

Illustrated Cases:

Case 1:

A 43 years old female patient presented with pressure like occipital headache that was incapacitating and not responding to medical treatment. MRI brain showed CM-I. The patient underwent posterior fossa decompression, C1 laminectomy and dural splitting, coupled with tenting of the outer dural layer to the paraspinal muscles. Postoperatively, the patient showed significant improvement as regards her headache. Postoperative MRI of the brain showed adequate posterior fossa decompression, which matched with the improved clinical outcome **(Fig. 2).**

Case 2:

A 35 years old female patient presented with headache that increased with straining, dizziness, and gait disturbance. MRI brain demonstrated CM-I. The patient underwent posterior fossa decompression coupled with dural splitting. The patient showed clinical improvement, with adequate bony decompression of the cerebellar tonsils on postoperative MRI **(Fig. 3).**

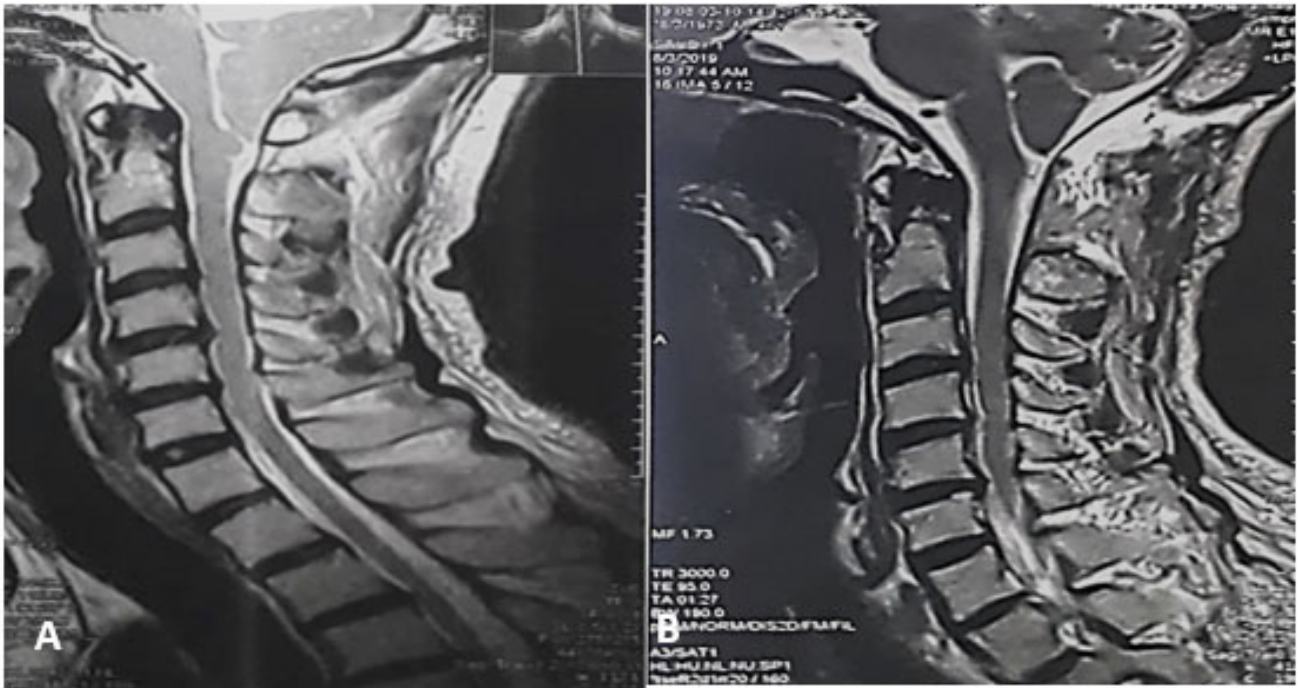

Fig 2: (A) Preoperative sagittal MRI T2-weighted image of the craniocervical junction showing CM-I. (B) Postoperative sagittal MRI-T2 weighted image after suboccipital craniectomy and dural splitting with adequate decompression of posterior fossa structures.

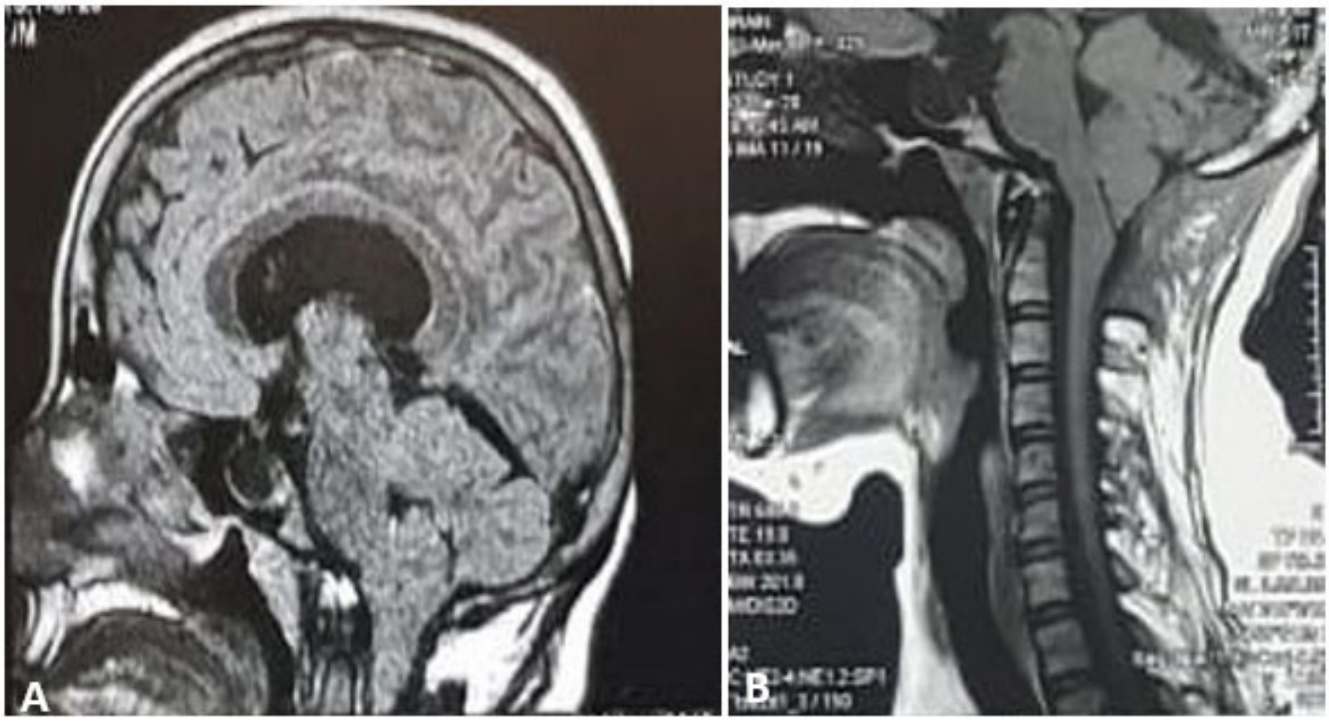

Fig 3: (A) Preoperative sagittal MRI T1-weighted image of the craniocervical junction showing CM-I with tonsillar descent more than 5 mm. (B) Postoperative sagittal MRI T1-weighted image showing adequate decompression.

Table 1: Comparison between the dura-splitting group (n=44), and the duraplasty group (n=40) as regards demographics, clinical presentation, associated congenital anomalies, intraoperative blood loss, operative time, and postoperative hospital stay

Variables	Dura-splitting Number (%)	Duraplasty Number (%)	p value (> 0.05) *
Female	32 (72.7%)	27 (67.5%)	1.027
Age at diagnosis (years)			
Range	10-55	9-59	0.425
Mean	38	40	
Presentation			
Occipital headache+/-cervical pain	38 (86.4%)	36 (90%)	0.096
Extremities paresthesia +/- weakness	24 (54.5%)	27 (67.5%)	
Vertigo, dizziness, gait disturbance	13 (29.5%)	10 (25%)	
Cranial neuropathies	3 (6.8%)	1 (2.5%)	
Association			
Syringomyelia	12 (27.3%)	18 (45%)	0.604
Hydrocephalus	0	2 (5%)	
Scoliosis	0	1(2.5%)	
Intraoperative blood loss (mL)			
Range	150-400	250-600	0.282
Mean	200	370	
Operative time (minutes)			
Range	55-120	100-220	0.037*
Mean	65	130	
Postoperative hospital stays (days)			
Range	1-5	2-13	0.472
Mean	3	6	

Variables are statistically significant at p value > 0.05 *.

Table 2: Comparison of clinical and radiological outcomes and complications between the dura-splitting group (n=44) and the duraplasty group (n=40) and its statistical significance

Outcome	Dura-splitting Number (%)	Duraplasty Number (%)	p value (> 0.05) *
Clinical outcome			
Improved at 6 months follow up	29 (65.9%)	30 (75%)	0.384
Improved at 12 months follow up	36 (81.8%)	34 (85%)	
Stationary	8 (18.2%)	6 (15%)	
Syrinx	12	18	
Decreased or resolved	7 (58.3%)	12 (66.7%)	0.073
Stationary	5 (41.7%)	6 (33.3%)	
Complications			
Postural headache	0	28 (70%)	0.032*
Pseudomeningocele	2 (4.5%)	6 (15%)	
Cerebrospinal fluid leak	1 (2.3%)	2 (5%)	
Superficial skin infection	0	3 (7.5%)	
Meningitis	0	2 (5%)	
Need to re-operate	0	0	0.683

Variables is statistically significant at p value at > 0.05 *.

DISCUSSION

The ideal procedure to treat CM-I should achieve effective decompression of the posterior fossa structures and restore the regular CSF flow across the foramen magnum, with the most affordable safety for patients. Till now, there has been no agreement about the ideal surgical technique to achieve such goals, and this controversy comes from the complicated pathophysiology of CM-I. Some authors consider posterior fossa bony decompression solely sufficient for treatment of CM-I, with low complication rate and favorable outcome. On the contrary, other authors consider posterior fossa decompression alone without dural opening is insufficient and is usually associated with frequent need to re-operate because of inadequate decompression. Posterior fossa decompression with augmentation duraplasty is the commonly adopted procedure by many surgeons. This technique, despite being effective, with appreciable clinical and radiological outcomes, and with better resolution of syringomyelia, may be associated with non-negligible postoperative complications including aseptic meningitis, CSF leak, pseudomeningocele, and superficial wound infection.[8,11,16-19] This study shows the high therapeutic potential of bony decompression with dural splitting for treatment of CM-I as regards the clinical and radiological outcomes, with a significantly lower complications rate, less operative time, less blood loss, and shorter postoperative hospital stay compared to the traditional expansive duraplasty procedures.

This study showed female predominance in both groups (72.7% and 67.5%), which is similar to the female predominance reported in other studies. Several studies documented equal distribution between males and females in pediatric age presentation, with female predominance in adulthood presentation. Chen et al. reported that 68.9% of their adult patients with CM-I were females, while 71.8% of the adult patients with CM-I in Oral et al. study were females.[14,16] The age at clinical presentation is variable in patients with CM-I. In the current study, the mean age at presentation was 38 years and 40 years in the dura-splitting and the duraplasty groups, respectively. This was similar to the age at presentation in the series of Oral et al., but older than the reported mean age at presentation in Chauvet et al. series, which was 32 years.[16,20] There was no statistically significant difference between both groups as regards the demographic data.

Occipital pressure like headache was the commonest presentation in our study occurring in 86.4% of the patients in the dura-splitting group and in 90% of the patients in the duraplasty group. Paresthesia was a common clinical finding in patients with associated syringomyelia, manifesting in 54.5% and 67.5% of the patients in the dura-splitting group and the duraplasty group, respectively. This was in accordance with Nikoobakht et al. and De Vlieger et al. series, that demonstrated that occipital headache was the commonest presentation of CM-I followed by paresthesia.1,21 Syringomyelia was the commonest association of CM-I in both groups, followed by hydrocephalus, then scoliosis. This was in accordance with Aslan et al. and Pandey et al. studies, where CM-I was associated with syringomyelia, hydrocephalus, and scoliosis.[19,22]

In our study, the dura-splitting technique achieved less blood loss (Mean, 200 mL versus 370 mL) and less operative time (Mean, 65 minutes versus 130 minutes) than duraplasty. The difference was statistically significant as regards the operative time between both groups (P=0.037). This comes from the added duraplasty, which increases the risk of infection and may be also

associated with higher risk of bleeding. Several studies reported statistically significant difference between both techniques as regards the operative time in favor of the dura-splitting technique.[15,23-25]

The duraplasty technique was associated with longer hospital stay, which may correlate with patients' preoperative bad clinical status and the higher possibility of development of postoperative complications associating the duraplasty technique. The duration of postoperative hospitalization was clearly different between both groups in our study, average 3 days with the dura-splitting technique versus 6 days with duraplasty, however the difference was not statistically significant (P=0.472). Similar results regarding the shorter period of hospital stay with the dura-splitting technique were reported by several authors.[15,23,24,26]

Theoretically, duraplasty could achieve more decompression, better reduction of syrinx size and better dealing with any intradural offending pathology that may interfere with normal CSF flow at the foramen magnum. This might correlate with more significant clinical improvement as compared to dural splitting. Strikingly, there was no statistically significant difference as regards the clinical outcome between the dura-splitting group and the duraplasty group, where both groups achieved comparable clinical improvement after one year follow up, reaching up to 81.8% and 85%, respectively (P=0.384). Limonadi and Selden compared the clinical outcome between dural splitting and expansive duraplasty and concluded that there was no statistically significant difference between both groups.[23] Similarly, Litvack et al. concluded that dural splitting and dural expansion attained similar clinical outcome in cases without significant syringomyelia.[24] This emphasizes the efficacy of the dura-splitting technique for posterior fossa decompression. On the contrary, Xu et al., in their systematic review comparing posterior fossa decompression with or without duraplasty, concluded that clinical improvement was significantly better with duraplasty than with PFD alone, but with a significantly higher incidence of complications.[27] Chai et al. concluded that despite better syrinx resolution with posterior fossa decompression and duraplasty, similar clinical improvement was achieved by only PFD.[28]

Both treated groups achieved similar radiological outcomes as regards adequate posterior fossa decompression with no statistically significant difference between them. This was in accordance with other studies who showed no significant radiological differences related to adding duraplasty to posterior fossa decompression in treatment of CM-I, but documented higher rate of complications, hospital stay, cost of treatment and operative time with duraplasty.[29,30] In our study, there was a difference as regards the postoperative resolution of syringomyelia between both groups in favor of duraplasty technique (66.7% in the duraplasty group versus 58.3% in the dura-splitting group), however, this was not statistically significant (P=0.073). Navarro et al. similarly found no significant relationship between dural opening and syrinx improvement.[31] In their systematic review comparing the dura-splitting and the duraplasty techniques, Tavallaii et al. reported similar rates of radiological improvement in both groups.[30]

This study showed statistically significant superiority of dura-splitting technique over duraplasty regarding postoperative complications (P=0.032). Complications included postural headache, pseudomeningocele, CSF leak, superficial skin infection and meningitis, and they occurred predominantly in the group having expansive duraplasty. Similarly, Litvack et al demonstrated higher incidence of CSF-related complications (8.5%) with dural expansion in the form of pseudomeningocele or aseptic meningitis, as opposed to no CSF-related complications in the dura-splitting group, confirming the higher safety profile of the dura-splitting technique over dural expansion.24 Similar results regarding low incidence of complications with dura-splitting technique have been reported by several authors.[15,19,20,25,30] Arnautovic et al. reported much higher overall complications rate of 41%.4

This comparative study between the dura-splitting technique and the duraplasty technique in terms of evaluating efficacy as regards the clinical and radiological outcomes, proved that posterior fossa decompression coupled with dural splitting is an efficient procedure in treatment of selected cases of CM-I with no or minimal syringomyelia. Furthermore, it affords minimal blood loss, shorter operative time, and shorter postoperative hospital stay coupled with significant lower risk of postoperative complications.

Limitations of the study

Being a retrospective study with a relatively short follow-up period were limiting factors in this study. A randomized clinical trial will provide a higher-grade evidence-based decision than a retrospective study.

CONCLUSION

Adequate bony decompression coupled with dural splitting for treatment of CM-I can achieve remarkable postoperative clinical and radiological improvement in selected cases with CM-I having no or minimal syringomyelia, yet avoiding the higher rate of complications associated with duraplasty, together with reduction of intraoperative blood loss, operative time, and postoperative hospital stay.

List of Abbreviations

CM-I: Chiari malformation type I.
CSF: Cerebrospinal fluid.
CT: Computerized tomography.
FM: Foramen magnum.
IRB: Institutional review board.
MRI: Magnetic resonance imaging.
PFD: Posterior fossa decompression.
SPSS: Statistical package for the social sciences.

Disclosure

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