Original Article

Impacts of type 1 Chiari malformation on elderly

Amr Badary[1], Oday Atallah[2]

[1]Department of Neurosurgery, SRH Wald-Klinikum Gera, Gera, [2]Department of Neurosurgery, Hannover Medical School, Hannover, Germany.

E-mail: Amr Badary - amr.badary@hotmail.com; *Oday Atallah - atallah.oday@yahoo.de

*Corresponding author:
Oday Atallah,
Department of Neurosurgery,
Hannover Medical School,
Hannover, Germany.

atallah.oday@yahoo.de

ABSTRACT

Background: This study aims to evaluate the surgical outcomes of elderly patients with Chiari malformation (CM) who underwent suboccipital craniectomy (SC) with duraplasty (DP) or dural splitting (DS). The focus is on symptom relief, changes in syrinx size, hospital admission duration, and postoperative complications.

Methods: A retrospective study was performed to evaluate the outcomes of elderly CM patients who underwent SC with DP or dural splitting (DS). Patients older than 60 years who underwent posterior fossa decompression (PFD) together with DP or DS who underwent surgery from 1989 to 2022 were included in the study. Patients were divided into two categories based on their surgical approach – SC with DP and SC with dural splitting (DS) surgery. Demographic details, co-morbidities, clinical features, management details, Chicago Chiari Outcome Scale (CCOS), complications, and follow-up details were obtained.

Results: Of the seven patients, five were females, and two were males. The mean age at the time of the operation is 65.14 years. Among the seven patients, six had syrinx, with a mean diameter of 6.17 mm; one patient had hydrocephalus, and one had scoliosis. All the patients underwent PFD; six patients also underwent DP, and one patient underwent DS. The median CCOS at the time of discharge is 13.

Conclusion: In elderly CM patients, surgery improved symptoms for most but led to reoperations in two cases. Despite a slight increase in syrinx diameter and a drop in the CCOS score, better outcomes were associated with smaller syrinxes. Further research is needed to optimize treatment strategies for this population.

Keywords: Chiari malformation, Duraplasty, Suboccipital craniectomy, Syringomyelia

INTRODUCTION

Chiari malformation (CM), a condition where the cerebellar tonsils herniate into the foramen magnum (FM), often with associated syringomyelia resembling spinal cord lesion features, is commonly congenital, particularly in cases linked to spina bifida (type II) or without it (type I). Acquired forms may result from irregular cephalo-cranial development or disparities in cranial and spinal pressures.[1,2,54] While those with tonsillar herniations over 12 mm usually exhibit symptoms, approximately 30% with 5–10 mm herniations remain asymptomatic.[51] Syringomyelia, a complication, typically emerges in early or middle adulthood, where the condition tends to be most prevalent.[13,69]

Abnormal cerebrospinal fluid (CSF) flow in CM type I often leads to syringomyelia. Several surgical approaches exist for managing neurological symptoms linked to this condition.[63] Posterior fossa craniectomy, with or without obex plugging, has been a standard surgical procedure aimed at improving irregular CSF flow. However, it is mainly recommended

for younger and middle-aged patients.[17] Limited reports discuss the late onset of symptoms related to this condition in elderly individuals and potential surgical solutions.[17,24,36] This recounts a rare case of an older woman experiencing late-onset Arnold CM type I and syringomyelia, successfully treated with FM decompression.[37] This study aims to evaluate the surgical outcomes of elderly CM patients who underwent suboccipital craniectomy (SC) with duraplasty (DP) or dural splitting (DS).

Elderly patients with CM may experience different outcomes than younger patients due to age-related changes and comorbidities. Our study aims to evaluate postoperative complications, recovery times, and success rates in this specific age group. By focusing on elderly patients, we address a gap in neurosurgery research, as older patients are often underrepresented. This research is crucial for developing age-specific surgical strategies and improving guidelines to enhance outcomes and quality of life for elderly patients.

MATERIALS AND METHODS

Study design

A retrospective study was performed after obtaining ethical approval to evaluate the outcomes of elderly CM patients who underwent SC with DP or dural splitting (DS).

Patient selection

Patients were selected based on the following inclusion criteria: individuals aged 60 years and older with a confirmed diagnosis of CM, evidenced by craniocervical magnetic resonance imaging (MRI) showing a tonsillar descent of more than 5 mm from the FM. Only symptomatic patients presenting with CM-related symptoms such as headache, neck pain, ataxia, or paresis were included. In addition, the study focused on those who underwent posterior fossa decompression (PFD) with either DP or dural splitting (DS) between 1989 and 2022. Included patients also had to have follow-up data available from the time of surgery until at least November 2023, with a minimum follow-up duration of 12 months.

Exclusion criteria were as follows: patients with significant preexisting neurological conditions unrelated to CM that could confound the outcomes and those with incomplete preoperative or postoperative data, including follow-up information. Individuals who underwent alternative surgical approaches not involving SC with DP or DS were excluded. Also excluded were cases that did not meet the diagnostic criteria for CM, such as those lacking measurable tonsillar descent or with major anatomical abnormalities that would invalidate the standard CM diagnosis.

Treatment protocol

Symptomatic patients aged over 60, diagnosed with CM, underwent craniocervical MRI to confirm the diagnosis. The diagnostic criterion involved a tonsillar descent of over 5 mm from the FM observed on MRI. In addition, head computed tomography (CT) scans were conducted to rule out hydrocephalus, while three-dimensional CT scans were used to exclude atlantoaxial instability and severe basilar invagination. Whole-spine MRI was employed to assess syrinx extension and eliminate spinal tumors and tethered cord syndrome. Surgery was performed for symptomatic patients, regardless of syrinx formation. Asymptomatic patients incidentally diagnosed were closely monitored, and surgery was only considered if associated symptoms emerged. Patients were divided into two categories based on their surgical approach: (i) SC with DP and (ii) SC with DS surgery. Both groups underwent follow-ups at specific intervals (1 week, 1 month, 3 months, 6 months, 12 months, and 24 months) with serial MRI scans and subsequent symptomatic assessments.

Data collection

Patient information consisted of name, age, sex, and presenting symptoms, which included:

(1) Headache, (2) Neck pain, (3) Arm pain, (4) Ataxia, (5) Paresis, (6) Paresthesia, (7) Sleep apnea, (8) Hoarseness of voice. Hospital records entered by clinicians during the inpatient stay and outpatient follow-up were reviewed. The following conditions were noted for each patient: syrinx, preoperative hydrocephalus, scoliosis, flat posterior skull based on imaging, CSF leakage, meningitis, pseudo meningocele, wound infection, epidural or subdural hematoma (SDH), disappearance of syrinx following surgery, postoperative hydrocephalus, Chicago Chiari Outcome Scale (CCOS), and re-operation. The data were entered into a spreadsheet in Microsoft Excel 2022.

CCOS

The CCOS, a system for evaluating outcomes post-CM surgery, comprises four categories: pain, nonpain symptoms, functionality, and complications. Each category is graded on a scale of 1–4, culminating in a potential maximum score of 16 and a minimum of 4. A total score of 4 signifies incapacitation, 8 indicates a compromised outcome, 12 signifies a functional outcome, and a score of 16 denotes an outstanding outcome.[59]

Operative procedure

Following the administration of general anesthesia, the patient was positioned in the Concorde stance, securing

the head with three-pin fixators. A midline cut on the skin, ranging from 3 cm above the FM to 2 cm below it, was executed. A small SC, approximately 3 cm tall and 3 cm wide, was performed. Using a high-speed drill and a bony rongeur, the posterior arc of the first cervical vertebra was cut to reveal a space approximately 2 cm wide. Delicately dissecting and eliminating the adhesions between the craniocervical junction, the posterior atlanto-occipital membrane, and the dura followed.

Dural splitting

Decompression - An incision was made vertically on the outer layer of the dura mater. Subsequently, the lateral dissection of the outer layer from the inner layer occurred, extending from the midline up to the upper edge of C1, utilizing a blunt dissector. Coagulation was avoided to minimize the risk of dural contraction, and any minor bleeding was managed with gel foam and surgery.

DP

A Y-shaped incision in the dura exposed the cerebellar tonsils and the cervical spinal cord. Partial resection of the cerebellar tonsils was performed to alleviate compression on the medulla oblongata and superior spinal cord. In addition, the patency of the foramen of Luschka and the foramen of Magendie was visually confirmed using an operating microscope. The dura was closed with a dural patch.

Statistical analysis

The statistical analyses were conducted using the Statistical Package for the Social Sciences (SPSS) statistical software, version 26 (SPSS Inc., IBM, USA), with a significance level set at $P < 0.05$ to establish statistical significance. Patient demographics such as age, gender, and the duration of symptoms were analyzed, along with comorbidities and types of CM. Primary outcome variables included postoperative changes in symptoms, complications, and Chiari Clinical Outcome Score (CCOS). The mean values and standard deviations were computed for these variables.

Secondary outcomes involved comprehensive radiological assessments, including the analysis of syrinx diameter and its correlation with CCOS scores. Radiological assessments were conducted through preoperative, postoperative, and follow-up imaging studies.

Descriptive statistics were used to calculate frequencies for categorical variables such as gender, comorbidities, types of CM, and presence of syrinx, hydrocephalus, scoliosis, and platybasia. The statistical significance of differences in frequencies between groups was tested using Pearson's Chi-square test and Fisher's exact test where appropriate.

For continuous variables, independent sample t-tests were used to compare mean values between groups (e.g., male vs. female patients), and paired sample t-tests were used to compare variables within the same patients before and after surgery (e.g., preoperative vs. postoperative syrinx diameter).

Pearson's correlation and Spearman's correlation tests were employed to assess the relationship between changes in syrinx diameter and changes in CCOS scores. Specifically, these correlations were used to determine if smaller postsurgical syrinx diameters were associated with better CCOS outcomes. If a statistically significant difference in variances was detected through Levene's test for equality of variances, adjustments were made accordingly.

Patients' management approaches, such as the type of surgery performed (PFD, DP, or dural splitting [DS]) and the presence of complications, were also analyzed. The outcomes were evaluated through detailed follow-up data, and the incidence of complications and the need for reoperation were recorded. The statistical analysis aimed to determine the effectiveness of the surgical interventions and the relationship between radiological findings and clinical outcomes.

The mean follow-up duration was also analyzed to assess long-term outcomes and the progression of symptoms and radiological findings over time. Statistical significance for all analyses was set at $P < 0.05$.

Potential biases and reasons for surgical selection

Surgical candidacy in our study was influenced by factors such as disease severity, overall patient health, and comorbidities. Decisions were also affected by the recommendations of a multidisciplinary team, patient preferences, and institutional resources.

RESULTS

Patient characteristics

Of the seven patients, five (71.4%) were females and two (28.6%) were males. Mean age at the time of the operation is 65.14 years [Table 1]. The mean age difference between genders is not estimated due to the risk of bias. The mean duration of symptoms is around 18 months. The total hospital admission period ranged from 5 to 21 days, with a mean of 11.14 days. Cervicalgia predominates in all the patients (100%), ataxia in six patients (85.7%), brachialgia and headache in five patients (71.4%), paresthesia in extremities in four patients (57.1%), paresis in three patients (42.9%), sleep apnea in two (28.6%), and hoarseness in one patient (14.3%). Dysphagia did not present in any of the patients [Figure 1]. Three patients were diagnosed with cardiac arrhythmias, two patients with arterial hypertension,
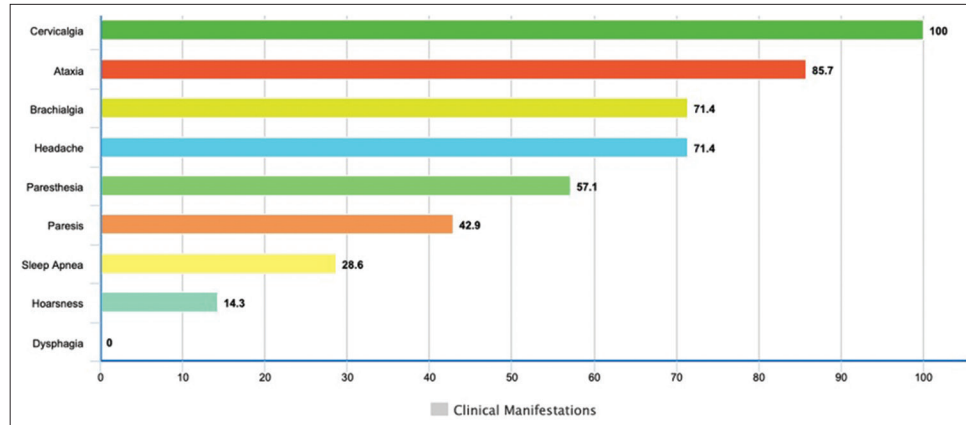
Figure 1: The prevalence of the clinical manifestation.

one patient with gallbladder carcinoma, and the last one was free from any comorbidities.

Imaging findings

Radiologically, CM type II predominates and is presented in four patients (57%), type I in two patients (28.6%), and type III in one patient (14.3%). Among the seven patients, six had syrinx (85.7%) with a mean diameter of 6.17 mm, and one patient (14.3%) had hydrocephalus. One patient (14.3%) had scoliosis, and no one had platybasia. Five of the six patients with syrinx (83.3%) had syrinx passing at levels C4-C7. There is no correlation between the diameter of the syrinx and its extent in the spinal cord ($P > 0.050$).

Patient management

All patients underwent PFD; six patients also underwent DP, and one patient underwent DS. One patient presented with hydrocephalus in addition to the CM and got a ventriculoperitoneal (VP) shunt in the same sitting. Of the seven patients, one patient developed cervical CSF fistula without other complications such as meningitis, pseudo meningocele, extradural hematoma, or wound infection.

Symptoms gradually improved, as shown in Table 2. Five patients (71.4%) – four with syrinx and one without – improved by the 1st month following surgery, and symptoms were relieved in their 6-month follow-up visits, whereas two (28.6%) patients worsened; pain worsening in both of them, ataxia worsening in one of them, new apnea in the other one. The median CCOS at the time of discharge is 13.

These two patients underwent reoperation due to complaint resistance after 1–2-year intervals during controls in the follow-up visits; one of them developed postoperatively hydrocephalus, and the other one developed an acute SDH, which makes an incidence of 100% complication after the reoperation. The one who developed hydrocephalus died after 2 months due to pulmonary edema and seizures.

Follow-up

Of the six patients with a syrinx [Table 2], two cases (33.3%) had an increase in diameter, one case (16.7%) of syrinx gradually reduced following the surgery, and 3 cases (50%) remained unchanged. The mean diameter of the syrinx at the last follow-up was 6.5 mm (preoperative: 6.17 mm), indicating an increase in the mean diameter following surgery.

At the last follow-up, the median CCOS decreased from 13 to 11. The patient without a syrinx showed an improvement in the CCOS score, while declines in other patients were associated with an increase in syrinx diameter. Notably, the only patient whose syrinx diameter decreased postsurgery had CM type III and did not present with scoliosis, hydrocephalus, platybasia, or basilar invagination. Patients who required reoperation due to persistent symptoms experienced an increase in syrinx diameter. This indicates that further exploration of syrinx shunting, such as VP shunts, might benefit patients with increasing syrinx size. However, the patient with hydrocephalus who received a VP shunt did not experience improvement in the CCOS score. Patients with worsened outcomes were managed conservatively. The mean follow-up duration was 121.86 months.

Excluding cases with a follow-up duration of more than 300 months, we calculated the change in syrinx diameter between admission and follow-up and correlated it with the change in the CCOS scale from surgery to follow-up. A strong Pearson's correlation (0.882; $P < 0.048$) and Spearman correlation (0.895; $P < 0.040$) were found, indicating better outcomes in terms of the CCOS scale when the syrinx diameter was smaller after surgery.

DISCUSSION

CM is traditionally identified as a condition predominantly affecting infants and adolescents and is rare in the elderly. However, some documented cases in 1941 have revealed

Table 1: Clinical and radiological manifestations of the patients.

Nr.	Gender	Age at op	Duration of symptoms (months)	Symptom									Comorbidity	CDT (I-III)	Associated features					Syrinx		
				Headache	Cervicalgia	Brachialgia	Ataxia	Paresis	Paresthesia	Sleep apnoe	Hoarseness	Dysphagia			Hydrocephalus	Basilar Invagination	Platybasia	Scoliosis		Yes/No	Location	Diameter (mm)
1	F	65	9	Yes	Yes	Yes	Yes	No	No	No	No	No	Cardiac Arrhythmia	II	Yes	No	No	No		Yes	C5–6	8
2	F	72	8	Yes	Yes	No	Yes	Yes	Yes	No	No	No	Arterial hypertension	II	No	No	No	No		Yes	C0–1	4
3	F	62	23	No	Yes	Yes	Yes	Yes	Yes	No	No	No	Carcinoma gallbladder	III	No	No	No	No		Yes	C2-T1	12
4	M	78	11	No	Yes	Yes	Yes	No	Yes	No	No	No	Cardiac Arrhythmia	I	No	No	No	No		Yes	C5-T2	6
5	F	69	>24	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	No	Cardiac Arrhythmia	II	No	Yes	No	No		Yes	C4–5	4
6	M	62	>24	Yes	Yes	Yes	No	No	No	Yes	No	No	None	I	No	No	No	Yes		Yes	C6–7	3
7	F	64	>24	Yes	Yes	No	Yes	No	No	No	No	No	Arterial hypertension	II	No	No	No	No		No	-	-

CDT: Cerebellar tonsillar descent

Table 2: The operative technique and some of the postoperative findings, along with the long-term results and follow-up findings.

Nr.	Surgical technique			Need for VPS	Postoperative complications	Hospital stay (days)	CCOS at discharge (4–16)	Re-Operation						
	Laminiplasty	With duraplasty	Without duraplasty					Yes/No	Timing	Reason	Postoperative complication	CCOS at last follow up (4–16)	Syrinx at last follow up (mm)	Follow up (Months)
1	Yes	Yes	No	Yes	No	16	13	Yes	26 months	Worsening ataxia and brachialgia on both sides	Acute subdural hematoma	9	10	125
2	Yes	No	Yes	No	No	5	14	No	No	No	No	14	4	59
3	Yes	Yes	No	No	No	21	10	No	No	-	-	11	9	252
4	Yes	Yes	No	No	No	9	12	No	No	-	-	8	6	348
5	Yes	Yes	No	No	No	7	7	Yes	12 months	Apnoea, Worsening of pain	Cervical CSF fistula+Hydrocephalus	4	7	14 (Death after 2 months of re-operation due to hydrocephalus, pulmonary oedema, and seizures)
6	Yes	Yes	No	No	No	11	14	No	No	-	-	14	3	43
7	Yes	Yes	No	No	Yes (Cervical CSF fistula)	9	13	No	No	-	-	14	-	12

CCOS: Chicago chiari outcome scale, VPS: Ventriculoperitoneal shunt, CSF: Cerebrospinal fluid

occurrences of CM in individuals over 60 years old,[20] together with some other cases reported late onset of symptoms in an older age group than usual >40 years.[11,14,15,34,46,52,58,61] Age and other factors like obesity are thought to influence the manifestations of CM significantly.[70] The structural abnormality remains consistent across age groups, but the impact and presentation of associated symptoms often vary and might remain silent for decades.[31] The craniocervical junction angles can be significantly influenced by age, exacerbating the condition in different ways.[31,42,45] As a result, CM may only become evident as the body ages due to degenerative changes in the spine,[24] decreased brain mass, and alterations in CSF dynamics.[21,23] In our retrospective study spanning over 33 years, the median age of diagnosis was 63 years, with patients undergoing surgery at a median age of 65 years. Due to rare documentation of CM in the elderly, we performed this study, which was intended to analyze the symptoms and compare the following outcomes with those of the young patients: symptom relief postoperatively, change in the syrinx size, total hospital admission in days, and postoperative complications.

Pathophysiology and clinical presentation

Developmental trajectory and clinical manifestations of CM in older individuals may closely resemble those observed in younger patients.[16,56,58] The clinical manifestations in CM patients involve five significant mechanisms: (a) CSF outflow obstruction leading to increased intracranial pressure and associated symptoms, (b) compression at the FM causing cranial nerve palsies, (c) direct bony compression of the brainstem, (d) compression of the cervical spinal cord, (e) and manifestations due to cerebellar involvement.[64] In older individuals, signs and symptoms typically follow a consistent pattern, primarily manifesting from the last four categories (b-e).[18] The most common and consistent clinical finding is spastic tetra- or paraparesis [11,20,44,55], although this is not always present and is likely associated with compression at the cervicomedullary junction.[43] Historically, horizontal and vertical nystagmus have been frequently reported in "adult types."[46,58,64] Of particular interest is the absence of "downbeat" nystagmus on downward gaze in elderly patients in the study, a finding recently observed in eight cases of adult CM.[15] This absence is speculated to indicate a lesion in the lower end of the brainstem or cerebellum. In addition, the absence of corneal and gag reflexes, observed in adults with the malformation, is linked to direct pressure on the medulla rather than compression of the cranial nerves.[20,41,43,46,64]

In contrast, newborns and infants with the malformation do not demonstrate nystagmus or cerebellar signs.[20] In the current study, no nystagmus was documented.

The formation of a syrinx still requires further clarification. Some researchers propose that parenchymal fluid dissipates into the central canal and forms a syrinx following a blockage of the CSF flow in the subarachnoid space at the level of the FM and accumulates outside, not inside, the spinal cord.[40] Alternatively, it may result from the dissociation of pressure between the cranial and spinal CSF compartments caused by obstruction at the level of the FM.[19,65] This blockage can lead to an engorged venous system due to the increased pressure buildup and continuous accumulation of fluid beyond the resorptive capacity of the parenchyma.[40] Breaking that circle is believed to relieve the circulatory disturbance caused. Some reports show that extension of the decompression may play a role in the tonsillar herniation,[33,25] which was not observed in our study.

The CCOS system is suitable for evaluating the outcomes of patients with CM. It assesses outcomes across multiple domains, including pain, nonpain symptoms, functionality, and complications, providing a detailed picture of surgical success. In our study, the CCOS effectively tracked changes in symptoms, with a median score decline from 13 at discharge to 11 at follow-up, correlating strongly with increases in syrinx diameter. In detail, two patients exhibited symptomatic improvement following the treatment, whereas two patients witnessed a stable CCOS scale. Three patients exhibited a worsening of symptoms.

However, several factors need to be considered for elderly patients. Age-related comorbidities (ARC), frailty, and long follow-up duration contributing to the ARC may impact recovery and CCOS scores, potentially affecting the interpretation of results. In addition, while the CCOS captures immediate and short-term outcomes, it may not fully address long-term quality of life issues.

Differential diagnosis

Symptoms such as chronic headache, neck pain, balance issues, and distal sensory disturbances might be attributed to aging-related conditions, like osteoarthritis, spinal stenosis, or age-related headaches, making accurate diagnosis a complex endeavor. Tumors at the FM manifest the most striking similarities to those of the CM.[67] The clinical syndrome of tetraparesis, nystagmus, decreased corneal and gag reflexes, and a propensity to occur in the elderly are all hallmarks of neoplasm at the craniovertebral border.[8,67] However, nuchal pain and predilection for upper extremity paresis are almost constant findings in tumors of the FM.[3,68] At the same time, these are not prominent in the CM and should serve as significant differential points in the clinical evaluation.

Diagnosis

Imaging techniques, notably MRI and CT scans, remain essential in diagnosing CM.[27] Plain skull and cervical

spine X-rays are no longer effective but might detect some deformities,[16,46,52,61] although a widened cervical canal, occipito-vertebral fusion, platybasia, and basilar invagination have also been described.[20,44] Interpretation can be challenging due to age-related changes in the brain and spine, requiring meticulous assessment and correlation with clinical findings.[60] MRI of the brain and spinal cord is indispensable in recognition of the deformity in the elderly, where obliteration of the retro-cerebellar CSF spaces, tonsillar herniation to varying extent, and varying degrees of cranial base dysplasia are the usual characteristics of CM.[33,39] In our study, no cases of platybasia were observed.

A high-resolution spiral CT can replace the MRI in patients with contraindications to MRI.[26] Posterior displacement of the intracranial portion of the vertebral artery due to herniated cerebellar tonsils,[18] deflected posterior inferior cerebellar artery (PICA) by the tonsil into the cervical canal, and the forward displacement of the basilar artery against the clivus[52] are some angiographic findings in these patients.

Developmental arrest causes a small posterior fossa, leading to the downward shift of the *Torcular Herophili* (or *confluens sinuum*) and inferior displacement of sinuses in obstructive hydrocephalus[16,22,32,41] and in 26 cases, noting the consistently small posterior fossae and large incisura.[22] Recognizing these preoperatively is crucial for neurosurgeons, especially in elderly patients showing CM, distinguishing primary from degenerative causes.

A report showed that in the younger population affected with CM type II, with a mean age of 24.9 years, syrinx was found in 60%, scoliosis in 25%, and basilar invagination in 12%.[39] Some reports also show that the scoliosis rate in CM type I may reach up to 22.4% and syrinx in 14% of the cases.[10,28,29,57] Another report in patients with CM type I showed that scoliosis was present in 24% of patients and syrinx in 40–65%.[33,51] Our study showed similar results; syrinx was presented in 85.7%, scoliosis in 14.3%, basilar invagination in 14.3%. CM type II was presented in four patients (57%), type I in two patients (28.6%), and type III in one patient (14.3%).

Management

In cases where typical clinical and imaging findings are present, the surgeon would best serve by advising surgical intervention at that point without subjecting the patient to further potentially dangerous diagnostic studies.

Treatment strategies in the elderly with CM aim to alleviate symptoms and improve quality of life. While medication and physical therapy remain viable options, surgical intervention might pose additional risks in this age group.[30] Preexisting comorbidities and the overall health status of these individuals often factor into decision-making

regarding surgical candidacy and the associated risks of interventions.[4,62]

The surgical treatment strategy aim is decompression of the FM blockage. It can usually be accomplished by SC, which includes the removal of the posterior rim of the FM, the upper cervical laminae, and the release of the dura. Abnormal tissue needs not to be excised,[20] and results are usually good.[20,44,46,55,58,61] PFD with or without partial resection of the tonsils plus DP is the primary treatment used by many neurosurgeons.[5,38,53] A shunting method[60] can treat hydrocephalus present before decompression or as a consequence. Some or all of the following are supplementary and may be appropriate in exceptional circumstances: reduction of the syrinx cavity using shunts, shrinking the tonsils with bipolar cautery, and/or dividing adhesions to separate the tonsils from each other as well as from the underlying medulla – which has risks of injuring vital structures such as PICAs and medulla.[12,35,50] In our study, we conducted PFD with DP or DS without other supplementary techniques.

When assessing outcome in terms of the disappearance of syrinx, we observed six patients with a syrinx [Table 2]; two cases (28.6%) witnessed an increase in diameter despite using a shunt in one of them due to associated hydrocephalus, one case (14.3 %) of syrinx gradually resolved following the surgery, and three cases (42.9%) remained unchanged. A strong Pearson's correlation (0.882; *P* < 0.048) and Spearman Correlation (0.895; *P* < 0.040) indicated better outcomes in terms of the CCOS scale when the syrinx diameter was smaller after the surgery. Although the younger people had a reduced syrinx size after the operation, the elderly in our study did not witness the same results, indicating that better CCOS results may be better pursued by reducing the syrinx diameter in this population.

Three patients showed worsening in the follow-up visits using the CCOS scale, comparing the values at the time of discharge and the follow-up visits. The first patient with persistent preoperative symptoms continued to receive conservative management due to the age and associated cardiac arrhythmia with infeasibility of re-operation. The other two patients underwent re-operation after 1–2-year intervals due to persisting pain, ataxia, worsening in one of them, and occurrence of apnea in the other. Postrevision surgery, one of them developed a CSF fistula and hydrocephalus, and the other developed an acute SDH, which makes an incidence of 100% complication rate after the re-operation. The patient who developed hydrocephalus succumbed 2 months later to pulmonary edema and seizures.

PFD with DS or DP is equally beneficial when observed in terms of scaling the symptomatic outcome.[4,9] However, others showed less favorable outcomes regarding complications in the DP group.[6,66] In our study, the choice

to perform dural splitting (DS) was based on intraoperative conditions. If swelling was present or the edges could not be adapted, we opted for DP instead, which was the case for the other six patients. In favorable conditions, the patient who underwent DS showed postoperative improvement and maintained a stable CCOS during follow-up visits. It was suggested that the decrease in syrinx size was better for patients treated with PFD with DP than those treated with PFD alone.[4,7,48,49] Our study shows that PFD with DP or DS is not entirely effective regarding syrinx size and symptom relief.

A study analyzed 30-day outcomes for adult Chiari I malformation surgeries from 2005 to 2016. Out of 672 patients, predominantly female (80%), the readmission rate was 9.3%, and 6.8% required reoperation. Obesity was linked to higher readmission and reoperation risks, while CSF leaks were the main cause of reoperation.[4] In a comprehensive meta-analysis of 23 studies involving 1541 adult patients treated with various dural grafts in DP, postsurgical meningitis occurred in 2.7% of patients, with CSF leaks and reoperations observed in 2% and 3%, respectively. Autografts were significantly associated with a lower rate of meningitis compared to synthetic grafts; however, no significant differences were found in rates of CSF leaks or revision surgeries among the different types of dural grafts.[47]

In our study, one patient developed a CSF fistula. This was promptly revised and sutured, with no subsequent CSF leakage. Another patient with preoperative hydrocephalus was treated with a VP shunt, and there were no postoperative complications. Postoperative recovery and rehabilitation also necessitate a tailored approach in the elderly, considering their physiological frailty and potentially slower recovery rates compared to the younger cohorts.

Our results may suggest that supplementary syrinx shunts in the elderly may support the decrease in syrinx size in these patients and, thus, better outcomes. However, any conclusions might be premature once an accurate comparison is performed with a larger cohort. Determining the underlying factors in the elderly, whether primary or secondary CM, is essential for decision making as physiotherapy may be a noninferior management if the cause is degenerative.

Limitations and suggestions

The reliance on historical medical records and clinical documentation introduces potential biases and gaps in data, which may affect the completeness and accuracy of our findings. In addition, the relatively small sample size limits the generalizability of the results and the ability to detect subtle differences in outcomes. These factors suggest that our conclusions should be interpreted with caution.

To build on the findings of this study, future research should focus on conducting larger, prospective, and controlled studies to enhance the generalizability and robustness of the results. Specifically, investigations with more extensive sample sizes would provide greater statistical power and allow for more detailed subgroup analyses. In addition, incorporating a control group of younger patients or those undergoing different treatment modalities could offer valuable comparative insights. Advanced imaging techniques and standardized outcome measures could further elucidate the effects of different surgical approaches on elderly patients with CM. These steps will help to refine clinical guidelines and improve patient outcomes through evidence-based practice.

Considering the above facts and limitations, under an experienced surgeon in a well-equipped neurosurgical facility, PFD and syrinx shunting in old patients may effectively improve CCOS score and syrinx size.

CONCLUSION

In this study of elderly patients with CM (mean age 65.14 years), surgical intervention primarily involving PFD with DP or DS led to mixed outcomes. Most patients saw some symptom relief, though two required reoperation later due to persistent symptoms. Postoperative complications were minimal, with only one CSF fistula observed. The mean syrinx diameter slightly increased from 6.17 mm to 6.5 mm, and the median CCOS score, indicating worsening condition, decreased from 13 to 11. A significant correlation was found between a smaller syrinx diameter and better CCOS outcomes (Pearson's r = 0.882, $P < 0.048$; Spearman's $P = 0.895$, $P < 0.040$). These results suggest that while surgery can improve symptoms, additional strategies like syrinx shunting may be needed for better outcomes. Further research with larger cohorts is required to validate these findings and enhance treatment approaches for elderly patients with CM.

Credit authorship contribution statement

Conception and design: A.B. Acquisition of data: A.B. and O.A. Analysis and interpretation of data: A.B. Drafting the article: all authors. Critically revising the article: O.A. and A.B. Reviewed submitted version of manuscript: O.A. and A.B. Approved the final version of the manuscript on behalf of all authors: O.A. and A.B.

Ethical approval

The following study was performed in accordance with the ethical standards detailed in the Declaration of Helsinki. In view of the retrospective nature of the study, formal approval of the institutional ethics committee was not required at the author's institution.

Declaration of patient consent

The authors certify that they have obtained all appropriate patient consent.

Financial support and sponsorship

Nil.

Conflicts of interest

There are no conflicts of interest.

Use of artificial intelligence (AI)-assisted technology for manuscript preparation

The authors confirm that there was no use of artificial intelligence (AI)-assisted technology for assisting in the writing or editing of the manuscript and no images were manipulated using AI.

REFERENCES

1. Alfieri A, Pinna G. Long-term results after posterior fossa decompression in syringomyelia with adult Chiari Type I malformation. J Neurosurg Spine 2012;17:381-7.
2. Almotairi FS, Andersson M, Andersson O, Skoglund T, Tisell M. Swallowing Dysfunction in Adult Patients with Chiari I Malformation. J Neurol Surg B Skull Base 2018;79:606-13.
3. Alzate JC, Kothbauer KF, Jallo GI, Epstein FJ. Treatment of Chiari I malformation in patients with and without syringomyelia: A consecutive series of 66 cases. Neurosurg Focus 2001;11:E3.
4. Bhimani AD, Esfahani DR, Denyer S, Chiu RG, Rosenberg D, Barks AL, et al. Adult Chiari I malformations: An analysis of surgical risk factors and complications using an international database. World Neurosurg 2018;115:e490-500.
5. Chai Z, Xue X, Fan H, Sun L, Cai H, Ma Y, et al. Efficacy of posterior fossa decompression with duraplasty for patients with Chiari malformation type I: A systematic review and meta-analysis. World Neurosurg 2018;113:357-65.e1.
6. Chen J, Li Y, Wang T, Gao J, Xu J, Lai R, et al. Comparison of posterior fossa decompression with and without duraplasty for the surgical treatment of Chiari malformation type I in adult patients: A retrospective analysis of 103 patients. Medicine (Baltimore) 2017;96:e5945.
7. Chotai S, Medhkour A. Surgical outcomes after posterior fossa decompression with and without duraplasty in Chiari malformation-I. Clin Neurol Neurosurg 2014;125:182-8.
8. Das KK, Kumar R, Ashish K, Bettaswamy G, Mehrotra A, Jaiswal S, et al. Extramedullary foramen magnum tumors and their surgical management: An experience with 29 cases. Asian J Neurosurg 2014;9:223-32.
9. Davidson KA, Rogers JM, Stoodley MA. Syrinx to subarachnoid shunting for syringomyelia. World Neurosurg 2018;110:e53-9.
10. Deng X, Wu L, Yang C, Tong X, Xu Y. Surgical treatment of Chiari I malformation with ventricular dilation. Neurol Med Chir (Tokyo) 2013;53:847-52.
11. Dones J, De Jesús O, Colen CB, Toledo MM, Delgado M. Clinical outcomes in patients with Chiari I malformation: A review of 27 cases. Surg Neurol 2003;60:142-7.
12. Duddy JC, Allcutt D, Crimmins D, O'Brien D, O'Brien DF, Rawluk D, et al. Foramen magnum decompression for Chiari I malformation: A procedure not to be underestimated. Br J Neurosurg 2014;28:330-4.
13. Elster AD, Chen MY. Chiari I malformations: Clinical and radiologic reappraisal. Radiology 1992;183:347-53.
14. Gad KA, Yousem DM. Syringohydromyelia in patients with Chiari I malformation: A retrospective analysis. AJNR Am J Neuroradiol 2017;38:1833-8.
15. Geroldi C, Frisoni GB, Bianchetti A, Trabucchi M, Bricolo A. Arnold-Chiari malformation with syringomyelia in an elderly woman. Age Ageing 1999;28:399-400.
16. Gilmer HS, Xi M, Young SH. Surgical decompression for Chiari malformation type I: An age-based outcomes study based on the Chicago Chiari outcome scale. World Neurosurg 2017;107:285-90.
17. Goel A, Desai K. Surgery for syringomyelia: An analysis based on 163 surgical cases. Acta Neurochir (Wien) 2000;142:293-301.
18. Hadley DM. The Chiari malformations. J Neurol Neurosurg Psychiatry 2002;72 Suppl 2:i38-40.
19. Heiss JD, Patronas N, DeVroom HL, Shawker T, Ennis R, Kammerer W, et al. Elucidating the pathophysiology of syringomyelia. J Neurosurg 1999;91:553-62.
20. Hekman KE, Aliaga L, Straus D, Luther A, Chen J, Sampat A, et al. Positive and negative predictors for good outcome after decompressive surgery for Chiari malformation type 1 as scored on the Chicago Chiari Outcome Scale. Neurol Res 2012;34:694-700.
21. Hidaka Y, Hashimoto M, Suehiro T, Fukuhara R, Ishikawa T, Tsunoda N, et al. Impact of age on the cerebrospinal fluid spaces: High-convexity and medial subarachnoid spaces decrease with age. Fluids Barriers CNS 2022;19:82.
22. Hidalgo JA, Tork CA, Varacallo M. Arnold-Chiari malformation. StatPearls; 2023. Available from: https://www.ncbi.nlm.nih.gov/books/NBK431076 [Last accessed on 2023 Dec 02].
23. Hussain I, Winston GM, Goldberg J, Curri C, Williams N, Chazen JL, et al. Impact of imaging modality, age, and gender on craniocervical junction angles in adults without structural pathology. J Craniovertebr Junction Spine 2019;10:240-6.
24. Isu T, Sasaki H, Takamura H, Kobayashi N. Foramen magnum decompression with removal of the outer layer of the dura as treatment for syringomyelia occurring with Chiari I malformation. Neurosurgery 1993;33:845-9.
25. Kahn EN, Muraszko KM, Maher CO. Prevalence of Chiari I malformation and syringomyelia. Neurosurg Clin N Am 2015;26:501-7.
26. Khan AA, Bhatti SN, Khan G, Ahmed E, Aurangzeb A, Ali A, et al. Clinical and radiological findings in Arnold Chiari malformation. J Ayub Med Coll Abbottabad 2010;22:75-8.
27. Klekamp J, Batzdorf U, Samii M, Bothe HW. The surgical treatment of Chiari I malformation. Acta Neurochir (Wien)

1996;138:788-801.

28. Krieger AJ, Rosomoff HL, Kuperman AS, Zingesser LH. Occult respiratory dysfunction in a craniovertebral anomaly. J Neurosurg 1969;31:15-20.

29. Krieger MD, Falkinstein Y, Bowen IE, Tolo VT, McComb JG. Scoliosis and Chiari malformation Type I in children. J Neurosurg Pediatr 2011;7:25-9.

30. Labuda R, Nwotchouang BS, Ibrahimy A, Allen PA, Oshinski JN, Klinge P, et al. A new hypothesis for the pathophysiology of symptomatic adult Chiari malformation Type I. Med Hypotheses 2022;158:110740.

31. Lam S, Auffinger B, Tormenti M, Bonfield C, Greene S. The relationship between obesity and symptomatic Chiari I malformation in the pediatric population. J Pediatr Neurosci 2015;10:321-5.

32. Langridge B, Phillips E, Choi D. Chiari malformation type 1: A systematic review of natural history and conservative management. World Neurosurg 2017;104:213-9.

33. Lee J, Kim HJ. Normal aging induces changes in the brain and neurodegeneration progress: Review of the structural, biochemical, metabolic, cellular, and molecular changes. Front Aging Neurosci 2022;14:931536.

34. Leu RM. Sleep-related breathing disorders and the Chiari 1 malformation. Chest 2015;148:1346-52.

35. Lin W, Duan G, Xie J, Shao J, Wang Z, Jiao B. Comparison of results between posterior fossa decompression with and without duraplasty for the surgical treatment of Chiari malformation type I: A systematic review and meta-analysis. World Neurosurg 2018;110:460-74.e5.

36. Logue V, Edwards MR. Syringomyelia and its surgical treatment--an analysis of 75 patients. J Neurol Neurosurg Psychiatry 1981;44:273-84.

37. Matsumoto T, Symon L. Surgical management of syringomyelia--current results. Surg Neurol 1989;32:258-65.

38. McGirt MJ, Attenello FJ, Datoo G, Gathinji M, Atiba A, Weingart JD, et al. Intraoperative ultrasonography as a guide to patient selection for duraplasty after suboccipital decompression in children with Chiari malformation Type I. J Neurosurg Pediatr 2008;2:52-7.

39. Milhorat TH, Chou MW, Trinidad EM, Kula RW, Mandell M, Wolpert C, et al. Chiari I malformation redefined: Clinical and radiographic findings for 364 symptomatic patients. Neurosurgery 1999;44:1005-17.

40. Mohanty SP, Kanhangad MP, Saifuddin S, Narayana Kurup JK. Pattern of syringomyelia in presumed idiopathic and congenital scoliosis. Asian Spine J 2021;15:791-8.

41. Moncho D, Poca MA, Minoves T, Ferré A, Cañas V, Sahuquillo J. Are evoked potentials clinically useful in the study of patients with Chiari malformation Type 1? J Neurosurg 2017;126:606-19.

42. Nalbant A, Duygu OB, Temelci H, Oner Z, Oner S. Evaluation of craniovertebral junction anatomy by gender and age in the anatolian population; 2023. Available from: https://www.ejmi.org [Last accessed on 2023 Dec 03].

43. Nohria V, Oakes WJ. Chiari I malformation: A review of 43 patients. Pediatr Neurosurg 1990;16:222-7.

44. Novegno F, Caldarelli M, Massa A, Chieffo D, Massimi L, Pettorini B, et al. The natural history of the Chiari type I anomaly. J Neurosurg Pediatr 2008;2:179-87.

45. Papadakis M, Sapkas G, Papadopoulos EC, Katonis P. Pathophysiology and biomechanics of the aging spine. Open Orthop J 2011;5:335-42.

46. Payner TD, Prenger E, Berger TS, Crone KR. Acquired Chiari malformations: incidence, diagnosis, and management. Neurosurgery 1994;34:429-34.

47. Perrini P, Lorenzini D, Vercelli A, Perrone A, Di Carlo DT. Post-operative complications after foramen magnum decompression with duraplasty using different graft materials in adults patients with Chiari I malformation: A systematic review and meta-analysis. J Clin Med 2023;12:3382.

48. Pistone G, Malaguarnera M, Motta M, Vecchio I, Raffaele R, Rampello L. Dementia due to acute hyponatremic encephalopathy in an elderly patient with Arnold-Chiari-I syndrome. Arch Gerontol Geriatr Suppl 2002;8:279-82.

49. Ramnarayan R, Praharaj MS, Jayakumar PN. Chiari 1 malformations: An Indian hospital experience. Singapore Med J 2008;49:1029-34.

50. Sabba MF, Renor BS, Ghizoni E, Tedeschi H, Joaquim AF. Posterior fossa decompression with duraplasty in Chiari surgery: A technical note. Rev Assoc Med Bras (1992) 2017;63:946-9.

51. Sathi S, Stieg PE. "Acquired" Chiari I malformation after multiple lumbar punctures: Case report. Neurosurgery 1993;32:306-9.

52. Schijman E, Steinbok P. International survey on the management of Chiari I malformation and syringomyelia. Childs Nerv Syst 2004;20:341-8.

53. Shweikeh F, Sunjaya D, Nuno M, Drazin D, Adamo MA. National trends, complications, and hospital charges in pediatric patients with Chiari malformation type I treated with posterior fossa decompression with and without duraplasty. Pediatr Neurosurg 2015;50:31-7.

54. Spena G, Fontanella MM. Management of chiari malformation. In: Surgery of the cranio-vertebral junction. Germany: Thieme; 2020. p. 483-99.

55. Stevenson KL. Chiari Type II malformation: Past, present, and future. Neurosurg Focus 2004;16:E5.

56. Strahle J, Muraszko KM, Kapurch J, Bapuraj JR, Garton HJ, Maher CO. Natural history of Chiari malformation Type I following decision for conservative treatment. J Neurosurg Pediatr 2011;8:214-21.

57. Strahle J, Smith BW, Martinez M, Bapuraj JR, Muraszko KM, Garton HJ, et al. The association between Chiari malformation Type I, spinal syrinx, and scoliosis. J Neurosurg Pediatr 2015;15:607-11.

58. Strayer A. Chiari I malformation: Clinical presentation and management. J Neurosci Nurs 2001;33:90-6, 104.

59. Takigami I, Miyamoto K, Kodama H, Hosoe H, Tanimoto S, Shimizu K. Foramen magnum decompression for the treatment of Arnold Chiari malformation type I with associated syringomyelia in an elderly patient. Spinal Cord 2005;43:249-51.

60. Tam SK, Chia J, Brodbelt A, Foroughi M. Assessment of patients with a Chiari malformation type I. Brain Spine 2021;2:100850.

61. Tubbs RS, Iskandar BJ, Bartolucci AA, Oakes WJ. A critical

analysis of the Chiari 1.5 malformation. J Neurosurg 2004;101:179-83.

62. Türkmen C, Köse N, Bal E, Bilgin S, Çetin H, Zengin HY, *et al*. Effects of two exercise regimes on patients with Chiari malformation type 1: A randomized controlled trial. Cerebellum 2023;22:305-15.

63. van Gijn J, Giesbergen PC, Hoogenraad TU. Attacks of pain in the leg from classic syringomyelia. J Neurol Neurosurg Psychiatry 1997;63:410.

64. Weber PC, Cass SP. Neurotologic manifestations of Chiari 1 malformation. Otolaryngol Head Neck Surg 1993;109:853-60.

65. Williams B. Pathogenesis of syringomyelia. Lancet 1972;2:969-70.

66. Xu H, Chu L, He R, Ge C, Lei T. Posterior fossa decompression with and without duraplasty for the treatment of Chiari malformation type I-a systematic review and meta-analysis. Neurosurg Rev 2017;40:213-21.

67. Yamada S, Ito H, Tanikawa M, Ii S, Otani T, Wada S, *et al*. Age-related changes in cerebrospinal fluid dynamics in the pathogenesis of chronic hydrocephalus in adults. World Neurosurg 2023;178:351-8.

68. Yasuoka S, Okazaki H, Daube JR, MacCarty CS. Foramen magnum tumors. Analysis of 57 cases of benign extramedullary tumors. J Neurosurg 1978;49:828-38.

69. Zhang ZQ, Chen YQ, Chen YA, Wu X, Wang YB, Li XG. Chiari I malformation associated with syringomyelia: A retrospective study of 316 surgically treated patients. Spinal Cord 2008;46:358-63.

70. Zhao JL, Li MH, Wang CL, Meng W. A systematic review of Chiari I Malformation: techniques and outcomes. World Neurosurg 2016;88:7-14.

Disclaimer

The views and opinions expressed in this article are those of the authors and do not necessarily reflect the official policy or position of the Journal or its management. The information contained in this article should not be considered to be medical advice; patients should consult their own physicians for advice as to their specific medical needs.