Original Article

Complication rates following Chiari malformation surgical management for Arnold–Chiari type I based on surgical variables: A national perspective

ABSTRACT

Introduction: This study aimed to identify complication trends of Chiari Malformation Type 1 patients (CM-1) for certain procedures and concomitant diagnoses on a national level.

Materials and Methods: The Kids' Inpatient Database was queried for diagnoses of operative CM-1 by International Classification of Disease-9 codes (348.4). Differences in preoperative demographics and perioperative complication rates between patient cohorts were assessed using Pearson's Chi-squared test and *t*-test when necessary. Binary logistic regression was utilized to find significant factors associated with complication rate. Certain surgical procedures were analyzed for their relationship with postoperative outcomes.

Results: Thirteen thousand eight hundred and twelve CM-1 patients were identified with 8.2% suffering from a complication. From 2003 to 2012, the rate of complications for CM-1 pts decreased significantly (9.6%–5.1%) along with surgical rate (33.3%–28.6%), despite the increase in CM-1 diagnosis (36.3%–42.3%; all $P < 0.05$). CM-1 pts who had a complication were younger and had a lower invasiveness score; however, they had a larger Charlson Comorbidity Index than those who did not have a complication (all $P < 0.05$). CM-1 pts who experienced complications had a concurrent diagnosis of syringomyelia (7.1%), and also scoliosis (3.2%; all $P < 0.05$). CM-1 pts who did not have a complication had a greater rate of operation than those that had a complication (76.4% vs. 23.6% $P < 0.05$). The most common complications were nervous system related (2.8%), anemia (2.4%), and acute respiratory distress (2.1%). CM-1 pts that underwent an instrumented fusion (3.4% vs. 2.1%) had a greater complication rate as well as compared to those who underwent a craniotomy (23.2% vs. 19.1%; all $P < 0.05$). However, CM-1 pts that underwent a decompression had lower postoperative complications (21.3% vs. 28.9%; all $P < 0.05$).

Conclusions: Chiari patients undergoing craniectomies as well as instrumented fusions are at a higher risk of postoperative complications especially when the instrumented fusions were performed on >4 levels.

Keywords: Chiari malformation, outcomes, trends

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INTRODUCTION

Chiari Malformations (CMs) are a group of congenital hind brain anomalies caused by structural defects in the brain and spinal cord that occur during fetal development.[1] A hallmark of CM is decrease in volume of the posterior fossa of the skull resulting in cerebellar tonsillar herniation through the foramen magnum into the foramen magnum.[1,2] CM can have association with several abnormalities such as

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hydrocephalus, spina bifida, hydromyelia, syringomyelia, spinal deformity (kyphosis/scoliosis), and tethered cord syndrome.[2] Chiari Malformation type 1 (CM-1) is the most common subtype of CM; can be asymptomatic in childhood and is commonly identified on neuroimaging as an incidental finding. Patients with CM-1 tend to develop symptoms such as suboccipital headaches, unsteady gait, impaired coordination, dizziness, and/or ventral brain stem compression symptoms in early to late childhood to adolescence and many of them ultimately require surgical management to alleviate their symptoms.[1-3]

Given that symptomatic CM-1 patients require decompressive surgery and some of them may require an upfront occipitocervical fusion, further investigation into trends in complications related to surgical management of CM-1 can lead to improved perioperative and postoperative planning. The purpose of this study is to utilize the Kids' Inpatient Database (KID) to identify trends in complications and surgical variables related to surgical management of CM-1. To the authors' knowledge, this study is the largest study investigating complication rates after surgical management of CM-1. The authors hope that this study provides surgeons with the information that will allow them to minimize complications in the postoperative period and ultimately lead to more effective patient care.

MATERIALS AND METHODS

Data source

The KID is the largest pediatric accessible all-payer (age < 21 at admission) inpatient health-care database in the United States. The Agency for Healthcare Research and Quality's Healthcare Cost and Utilization Project (HCUP) created this KID database. KID sampling includes complicated and uncomplicated births, as well as other pediatric inpatient procedures from community, nonrehabilitation hospitals. The KID database contains 107 data elements, using the International Classification of Disease, Ninth Revision, Clinical Modification (ICD-9-CM) format to code all of the diagnoses and procedures. With over 3 million hospital stays per 3-year database, it is designed to allow accurate calculation of medical condition incidences using HCUP-provided trend weights.[1] A detailed overview of the KID design is available at (https://www.hcup-us.ahrq.gov/kidoverview.jsp).

Patient sample

The KID was queried for patients with E-Codes (ICD-9-CM codes) pertaining to CM-1 from 2003 to 2012 (348.4).

Statistical analysis

Multi- and univariate analyses, identified basic demographics, and surgical characteristics for CM-I patients. Trends in surgical and complication rates as well as surgical invasiveness were assessed from the year 2003 to 2012. Differences of those CM-1 patients that experienced a complication versus those who did not were assessed through Chi-square and *t*-tests, as appropriate. Binary logistic regression was performed to find significant factors associated with the complication rate. Decision tree analysis was utilized for the associated predictive variables of postoperative complications to identify significant thresholds. All statistics were done using SPSS Statistics version 23.0 (IBM Corp., Armonk, NY, USA). A statistical cut off value of $P < 0.05$ was considered statistically significant.

RESULTS

Demographic overview

Thirteen thousand eight hundred and twelve CM-1 patients were isolated. Average age was 10.12 ± 6.3 years, 49.2% were female, and the average Charlson Comorbidity Index (CCI) was. 063 ± 1.3. Of these Chiari patients, 56.5% had private insurance, 34.4% had Medicaid, 2.6% were self-pay, 0.2% were medicare, and 7.3% were other [Table 1]. Patients diagnosed with M1 were older (10.12 years vs. 3.62 years) and had a higher Charlson Comorbidity Score (0.62 vs. 0.53; all $P < 0.05$) than those that were not diagnosed with CM-I.

Surgical overview

By surgical approach, 1.3% of CM-1 patients received a posterior approach, 0.1% received an anterior approach, and 0.1% received a combined approach. 27.8% of CM-I patients underwent a laminectomy, 28.3% a decompression, and 2.2% had a spinal fusion.

Complication rate

About 8.2% (1, 1128) of CM-I patients experienced a postoperative complication. The most common complication was nervous system related (2.8%), anemia (2.4%), and acute respiratory distress (2.1%). CM-1 pts who had a complication were younger (9.73 ± 6.8 years vs. 10.2 ± 6.3 years), and had a lower invasiveness score (0.35 ± 1.0 vs. 0.41 ± 1.0);

Table 1: Basic demographic

Chiari malformation 1 demographics	
Age (years)	10.12±6.3
Sex (female)	49.2%
CCI	063±1.3
Insurance type (%)	
Private insurance	56.5
Medicaid	34.4
Self-pay	2.6
Medicare	0.2
Other	7.3

CCI - Charlson comorbidity index

however, they had a larger CCI (1.10 ± 1.6 vs. 0.6 ± 1.3) than those who did not have a complication (all $P < 0.05$). Significantly different comorbidities are shown in Table 2. CM-1 pts that underwent a fusion (3.4% vs. 2.1%) had greater complication rates as well as those that underwent a craniectomy (23.2% vs. 19.1%; all $P < 0.05$). However, CM-1 pts that underwent a decompression had lower postoperative complications (21.3% vs. 28.9%; all $P < 0.05$).

Trends in surgical characteristics

From 2003 to 2012, the rate of CM-I diagnosis increased while the surgical rate and postoperative complications significantly decreased during this time period [Table 3; $P < 0.05$]. However, the rate of adverse events (superficial site infection, urinary tract infection (UTI), venous embolism and thrombosis [venous thromboembolism (VTE)]) increased. More specifically, UTI significantly increased from 1.9% to 2.6% ($P = 0.03$).

Factors associated with postoperative complications

After controlling for baseline differences, CM-1 patients who received a fusion were significantly associated with having a postoperative complication (1.4 [1.0–2.1]) as well as if, the fusion was 2–3 levels (2.1 [1.2–3.6]; all $P < 0.05$). Patients who underwent a suboccipital craniectomy were associated with an increased risk of complications (1.32 [1.1–1.5]; $P < 0.001$). Having a postoperative complications were significant increased risk of prolonged length of stay (11.7 [10.9–12.4]; $P < 0.001$).

DISCUSSION

Despite decades of experience and research, the management of CM-1 continues to raise more questions than answers. Controversy abounds in every aspect of management, including the indications, timing, and type of surgery, as well as clinical and radiographic outcomes.[4] The lack of conclusive evidence in the literature calls for further investigation into the management of CM-1 and its associated complications. This study aims to identify complication trends and surgical variables related to CM-1 for specific procedures and concomitant diagnoses on a national level.

Table 2: Comorbidities of Chiari patients based on postoperative complication

	Complication (%)	No complication (%)	*P*
Bad liver	0.5	0.2	<0.05
Malignancy	11.6	6.7	
Renal problems	7.2	2.4	
Plegic	13.3	5.4	
Cerebrovascular	16.7	6.5	
Myocardial infarction	1.6	0.5	
Pulmonary vascular disease	0.8	0.4	

Table 3: Trends in Chiari patient outcomes

	2003 (%)	2009 (%)	2012 (%)	*P*
CM-1 diagnosis	28.6	30.0	41.2	<0.001
Surgical rate	87.7	86.4	85.6	
Complication rate	9.6	11.1	5.1	
Never events	2.8	3.9	3.7	

Previous studies have reported that the rate of surgical treatment for CM-1 in pediatric patients has increased significantly, reflecting a rise in CM-1 diagnosis.[4] Our analysis similarly discovered a significant increase in CM-1 diagnosis, however, we have found a significantly decrease in rate of surgery, perhaps revealing that more CM-1 patients are being managed conservatively in recent years. The most commonly performed procedures were laminectomies, decompressions, and spinal fusions. 8.2% of the patients in our cohort experienced a postoperative complication, the most common being related to nervous system issues, anemia, and respiratory distress. Patients who experienced complications were younger and had a greater comorbidity index than those who did not experience complications. The most prevalent comorbidities in patients who experienced complications were malignancy, cerebrovascular, pulmonary, and renal issues. Our findings suggest that delaying elective procedures until patients are more physically mature and addressing associated comorbidities prior to the surgery may decrease complication rates in CM1 patients.

Scoliosis and syringomyelia were the two most prevalent concomitant diagnoses in the cohort of patients who experienced complications. Scoliosis is frequently associated with CM-1, and is even more frequently associated with CM-1 in the setting of syringomyelia.[5] Spinal fusion and decompression procedures are commonly utilized to manage CM-1 patients with spinal deformities. Our analysis revealed that CM-1 patients who underwent spinal fusion procedures, especially fusions of 4 or more levels, had significantly higher complication rates. Previous studies have also shown that spinal fusion in cases of scoliosis associated with CM-1 reported higher rates of perioperative complications.[5] Therefore, surgeons may want to further weigh the risks and benefits of spinal fusions prior to operating on CM-1 patients to reduce complication rates. Conversely, patients who underwent decompression procedures had significantly lower complication rates, thus surgeons may consider utilizing decompression procedures over alternative procedures when deemed appropriate.

Our analysis revealed an overall decrease in complication rates over the course of the study; however, the rate of never events such as surgical site infection (SSI), UTI, and VTE have

increased. SSI and UTI are common complications in spine surgery that may lead to increased morbidity, readmission to the hospital, reoperation, poorer outcomes, and increased costs.[6,7] Prolonged intraoperative and postoperative immobilization in spine surgery places patients at increased risk for VTE, but strategies such as mechanical compression, and prophylactic anticoagulation have been developed to reduce perioperative and postoperative VTE.[8] The overall decrease in complications suggests that management strategies for CM-1 are improving with time and current management of CM-1 and is more effective than it was a decade ago. However, the increase in adverse events should be taken seriously and quality improvement programs should focus on reducing rates of SSI, UTI, and VTE to further minimize complications in CM-1 patients.

As with most studies that are retrospective in nature, this study was subject to selection biases and confounding variables. Although analysis of a large, nation-wide database lends our study to increased generalizability; it also may result in a biased patient population, as patients are identified exclusively by ICD-9 codes. Similarly, complication outcomes were also tracked using ICD-9 codes, introducing the possibility of coding bias in outcomes analysis. Although this study represents a step forward, no prospective randomized studies have been performed investigating complication trends, and surgical variables for specific procedures and concurrent diagnoses in the setting of CM-1. Well-designed prospective studies exploring complications related to CM-1 treatment are needed to reinforce the findings that our analysis identified.

CONCLUSIONS

Patients with CM-1 who are younger and have a greater comorbidity index are significantly more likely to experience a perioperative or postoperative complication, most commonly nervous system issues, anemia, and respiratory distress. Patients who underwent a spinal fusion procedure and a suboccipital craniectomy are more likely to experience a complication, whereas those who underwent a decompression procedure are less likely to experience a complication. Although an overall complication rates have decreased throughout in our study, emphasis should be placed on preventing never events such as SSI, UTI, and VTE.

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Conflicts of interest

There are no conflicts of interest.

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