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Standardizing postoperative pain control for decompression of pediatric Chiari type I malformation by limiting narcotic usage

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OBJECTIVE The aim of this study was to assess the effectiveness of a postoperative multimodal pain control protocol on perioperative pain scores in children undergoing decompression for Chiari type I malformation (CM-I).

METHODS This retrospective matched cohort study included patients < 21 years of age who underwent elective suboccipital craniectomy and C1 laminectomy for CM-I with or without duraplasty at a single center from January 2020 to July 2023. A standardized, multimodal postoperative pain protocol was implemented in August 2021 that did not use narcotic patient-controlled analgesia. Pre- and postprotocol cohorts were compared. The primary outcome was average perioperative pain score. Secondary outcomes included postoperative length of stay (LOS), narcotic usage, and antiemetic usage.

RESULTS Thirty-four children met the inclusion criteria (17 preprotocol, 17 postprotocol). Fifty-three percent were female (18/34). The mean patient age was 7.0 ± 5.0 years. After implementation of the pain protocol, noninferior average pain scores ($p = 0.08$) and less antiemetic administration ($p = 0.048$) were found across both surgery types. Equivalent inpatient LOS ($p = 0.78$), narcotic prescriptions at discharge ($p = 0.73$), and milliequivalents of morphine used ($p = 0.55$) were also found. Bone-only decompression was completed in 65% of patients (n = 22/34, 11 in each pre- and postprotocol group) with 12 of 34 undergoing duraplasty (6 in each pre- and postprotocol group). Patients who underwent posterior fossa decompression with duraplasty had a significantly longer LOS ($p = 0.003$), more overall narcotic usage ($p = 0.015$), and lower pain scores ($p = 0.047$) compared with those who underwent decompression without duraplasty.

CONCLUSIONS Patients undergoing a CM-I decompression had noninferior postoperative pain control and required less antiemetic dosing after implementation of a multimodal pain protocol. Neurosurgeons should consider a postoperative multimodal pain regimen for their patients with CM-I who undergo decompression with or without duraplasty.

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KEYWORDS Chiari type I malformation; suboccipital craniectomy; pain control; narcotic; opiate; protocol; nonsteroidal antiinflammatory drug; patient-controlled analgesia; duraplasty

More than 11 million Americans misuse opioid medications, and 81,000 Americans die annually from opioid overdose.[1] The magnitude of the opioid epidemic was brought to the forefront in the US when there were several simultaneous multibillion dollar lawsuits against prominent pharmaceutical companies,[2] and the US Office of the President declared it a "national health emergency."[3] Narcotic use in the US and around the world has substantially increased in recent years.[4] Similarly, opioid addiction and overdose deaths are on the rise.[1] Opioids are a controlled substance that are prone to abuse, but represent a major form of postoperative pain control.[5] In neurosurgery, opioid use is further propagated by studies citing adverse effects of nonsteroidal antiinflammatory drugs (NSAIDs), such as intracranial hemorrhage[6] or poor bone fusion after spinal surgery.[7] While these reports have been contradicted,[8–10] NSAIDs continue to be avoided for postoperative pain control by some neurosurgeons.

ABBREVIATIONS CM-I = Chiari type I malformation; ED = emergency department; LOS = length of stay; MME = morphine milliequivalent; NSAID = nonsteroidal antiinflammatory drug; OR = operating room; PCA = patient-controlled analgesia; PFD = posterior fossa decompression without duraplasty; PFDD = posterior fossa decompression with duraplasty.

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TABLE 1. Pain protocol developed for multimodal management of postoperative pain in children who undergo posterior fossa decompression for CM-I

Medication	Starting Dosage	When to Start
Scheduled		
Ketorolac	15 mg/kg every 6 hrs ×4 doses	In the OR during emergence
Ibuprofen	15 mg/kg every 6 hrs	After ketorolac completed
Acetaminophen	15 mg/kg every 6 hrs, timed to alternate every 3 hrs w/ NSAID	Recovery room
Diazepam	0.2 mg/kg every 8 hrs (up to 5 mg)	Recovery room
As needed breakthrough		
Oxycodone	0.05 mg/kg/dose every 4 hrs as needed (up to 0.2 mg/kg/dose or 5 mg/dose) for pain scores 3–6	Recovery room
Morphine (intravenous)	0.1 mg/kg every 4 hrs as needed (up to 2–4 mg/dose) for pain scores 7–10	Recovery room
PCA	If above regimen fails to adequately control pain	

As a result of the rising awareness of the opioid epidemic, neurosurgeons have sought to find ways to optimize postoperative nonnarcotic multimodal pain control.[11,12] This issue remains relevant to adult and pediatric patients. Perioperative narcotic use is known to predispose adults[13] and children[14] to chronic opioid use and addiction. Historically, narcotics have played a prominent role in pain management after posterior fossa decompression surgery for Chiari type I malformation (CM-I). Approximately 0.97%–3.6% of all children meet the imaging criteria diagnosis for CM-I, yet many do not require surgery.[15] Approximately 1000 children with CM-I undergo surgical decompression annually in the US by pediatric neurosurgeons.[16] Postoperative pain control for these patients can be challenging, the severity of which is anecdotally affected by the decision of whether to pursue duraplasty. The postoperative pain control regimen commonly includes narcotics or opioids, which have multiple adverse side effects such as sedation, constipation, and vomiting, particularly when used in high doses.

Our team implemented a multimodal postoperative pain control protocol to minimize narcotic consumption while maintaining similar postoperative pain control in children undergoing CM-I decompression with or without duraplasty. Our hypothesis was that this pain control regimen would provide noninferior pain control with reduced narcotic usage when compared to those patients whose postoperative pain was treated without using the protocol.

Methods

Study Cohort

This retrospective matched cohort study included patients < 21 years of age who underwent elective suboccipital craniectomy and C1 laminectomy for CM-I decompression with or without duraplasty at Johns Hopkins All Children's Hospital from January 2020 to July 2023. The total number of patients in each cohort was matched 1:1 by surgery type. The preprotocol group was the cohort whose surgeries were completed before protocol implementation in August 2021. The pain control protocol references can be found in Table 1. The postprotocol group included those patients whose surgeries were completed after the protocol was implemented. This study was approved by the Johns Hopkins University IRB.

A standardized, multimodal postoperative pain protocol was implemented in August 2021. The protocol included a scheduled acetaminophen, NSAID, and muscle relaxant postoperatively and intramuscular injection of 0.2% ropivacaine without epinephrine into the paraspinal muscles at the end of the procedure. Patients were excluded if the protocol was not followed. Prior to the protocol, the pain regimen was variable but frequently included scheduled acetaminophen and narcotic pain medication as needed, often in the form of a patient-controlled analgesia (PCA) pump. PCA pumps were prescribed and managed at the discretion of the hospital's pediatric pain service. PCA pumps were typically in place for 24–48 hours postoperatively and included demand-only dosing. The average postoperative follow-up duration was 30 days.

Variables

The primary outcome for this study was average inpatient pain score. There were three externally validated pain scores used by the primary institution that are used by nursing based on the patient's age: 1) a 0–10 numeric pain rating, 2) the Wong-Baker FACES Pain Rating Scale, and 3) the FLACC (face, legs, activity, crying, and consolability) behavioral pain assessment tool.[17,18] All 3 pain scale methodologies result in a pain score of 0–10 that nursing reports in the chart, which allows for averaging across different scoring systems. Due to the method of nursing chart documentation at the study site, some patients had multiple pain scores within a 6-hour period, while others had a single pain score reported; thus, the average pain score from every 6-hour period was recorded and averaged over the course of the patient's hospital stay. The threshold pain score to administer an as-needed narcotic medication to a patient was moderate (score 4–6) or severe (score 7–10).

The secondary outcomes included postoperative length

TABLE 2. Comparison of cohorts and outcomes before versus after pain protocol implementation

Variable	Preprotocol, n = 17	Postprotocol, n = 17	Total Cohort, n = 34	p Value
No duraplasty, n (%)	11 (65)	11 (65)	22 (65)	—
Females, n (%)	9 (53)	9 (53)	18 (53)	—
Mean age ± SD, yrs	5.4 ± 4.7	8.6 ± 5.0	7.0 ± 5.0	0.07
Mean LOS ± SD, days	2.2 ± 1.2	2.3 ± 1.2	2.2 ± 1.2	0.78
Toradol received, n	9	16	25	**0.017**
PCA use, n	9	0	9	**<0.001**
Local anesthetic injection at end of case, n	13	14	27	>0.99
Mean immediate postop pain score ± SD	2.5 ± 2.3	2.5 ± 3.0	2.5 ± 2.7	>0.99
Mean average pain score ± SD	2.5 ± 1.3	1.8 ± 0.9	2.1 ± 1.2	0.08
Narcotic prescription at discharge, n (%)	8 (47)	7 (41)	15 (44)	0.73
Antiemetic usage, n (%)	11 (65)	8 (47)	19 (56)	0.30
Mean no. of antiemetic doses ± SD	3.2 ± 4.3	0.9 ± 1.3	2.0 ± 3.3	**0.048**
Overall narcotic usage, n (%)	13 (76)	9 (53)	22 (65)	0.15
Mean MME/day ± SD	9.0 ± 18.6	6.0 ± 8.5	7.5 ± 14.3	0.55
Return to ED, n (%)	0	2	2 (6)	0.49

Boldface type indicates statistical significance.

of stay (LOS), narcotic usage, and antiemetic usage. Narcotic usage was measured in morphine milliequivalents (MMEs) while an inpatient and if a narcotic prescription was given at discharge. Narcotic prescription at discharge was not standardized within the protocol and was provider dependent. Antiemetic usage was measured in number of doses of antiemetic medication used while an inpatient. The threshold to administer antiemetic medication was nursing driven. An antiemetic was given if the patient complained of nausea or vomiting at 0.1 mg/kg to a maximum of 4 mg/dose, with a dosing frequency of every 6 hours. Steroids were routinely prescribed postoperatively in patients undergoing posterior fossa decompression with duraplasty (PFDD). Additional variables of interest included basic demographic information, whether duraplasty was completed, follow-up duration, and 30-day postoperative complications.

Statistical Analysis

Pre- and postprotocol comparison analyses were performed for the full patient cohort as well as a subgroup analysis that analyzed duraplasty versus no duraplasty. The Student t-test and chi-square test were used for the analysis of continuous and categorical variables, respectively. The p value was set a priori at $p < 0.05$.

Results

A total of 34 children met the inclusion criteria (17 preprotocol, 17 postprotocol). Sixty-five percent of the patients underwent posterior fossa decompression without duraplasty (PFD) in each cohort (n = 11), and 53% were female (18/34). The mean patient age was 7.0 ± 5.0 years (5.4 ± 4.7 years in the preprotocol group and 8.6 ± 5.0 years in the postprotocol group, p = 0.07). Preprotocol, 53% (9/17) of the children received a PCA pump, while no children received a PCA pump postprotocol. Table 2 demonstrates the results of the matched cohort analysis. Between the two cohorts, there was no statistically significant difference in patient age (p = 0.07), inpatient LOS (p = 0.78), narcotic prescriptions at discharge (p = 0.73), or overall narcotics used (p = 0.15). There were notably noninferior average pain scores in the postprotocol group (p = 0.08). There was a significant reduction in number of antiemetic doses postprotocol (from 3.2 ± 4.3 to 0.9 ± 1.3, p = 0.048). There were no complications in the preprotocol group and two complications within 30 days postoperatively in the postprotocol group (p = 0.49). One patient returned to the operating room (OR) for repair of a pseudomeningocele, who underwent PFDD and required ventriculoperitoneal shunt insertion. A second postprotocol patient who underwent PFDD returned with chemical meningitis that improved with a prolonged steroid taper.

A subgroup analysis was performed that assessed patients according to the type of surgery that they received: bone-only (PFD) or PFDD (Table 3). Of the patients who underwent PFDD (12/34), there were 6 patients each in the pre- and postprotocol cohorts. Compared with PFD patients, PFDD patients had a longer LOS (p = 0.003), more narcotic usage (p = 0.015), and similar antiemetic usage (p = 0.350). In the postprotocol cohort, there was no significant difference in protocol effectiveness between PFD and PFDD patients in pain scores (p = 0.301), total antiemetic usage (p = 0.149), postoperative narcotic usage (p = 0.462), and return to the emergency department (ED; p = 0.110).

Discussion

CM-I decompression with or without duraplasty typically requires postoperative inpatient admission for pain and/or nausea control. Our study demonstrated noninferior postoperative pain control using a multimodal pain protocol that sought to curb narcotic administration. Our hypothesis proved partially correct. Pain scores were noninferior after protocol implementation, but inpatient nar-

TABLE 3. Analysis stratified by PFDD versus PFD

Variable	PFD, n = 22	PFDD, n = 12	Total Cohort, n = 34	p Value
Mean LOS ± SD, days	1.68 ± 0.6	3.25 ± 1.4	2.2 ± 1.2	**0.003**
Mean average pain score ± SD	2.4 ± 1.3	1.7 ± 0.6	2.1 ± 1.2	**0.047**
Narcotics at discharge, n (%)	9 (41)	6 (50)	15 (44)	0.61
Antiemetic dosing, n (%)	11 (50)	8 (67)	19 (56)	0.350
Overall narcotic usage, n (%)	11 (50)	11 (92)	22 (65)	**0.015**

Boldface type indicates statistical significance.

cotic administration trended lower, although it was not significantly reduced. Antiemetic administration was also lower in patients using a multimodal regimen as opposed to a primarily PCA-driven protocol based primarily on a narcotic. As expected, PFD patients had shorter LOSs and lower narcotic usage compared to those who underwent PFDD.

Multimodal Pain Control

Postoperative Pain Scores

Pain scores were significantly reduced with the implementation of a multimodal pain management protocol that removed narcotics as the primary focus of pain control. The traditional approach to postoperative pain control of CM-I decompression at the study center included a regimen that was heavily based on narcotics, including scheduled acetaminophen and frequently PCA with morphine or hydromorphone. The commonly witnessed side effects of high narcotic usage such as nausea, constipation, and inconsistent pain control prompted our team to create a protocol. The surgeons agreed that this was a good opportunity to include multimodal pain control with a muscle relaxant or NSAID and monitor for any previously reported adverse effects such as intracranial hemorrhage. We found noninferiority in pain control and no hemorrhagic complications. One could question if noninferior pain scores were a result of multimodal pain control or simply having a protocol in general. The placebo effect is a known phenomenon in medicine in which positive or negative expectations can impact perceived pain severity.[19] Accordingly, parents in our protocol who were told "your child is on a new protocol" could have influenced perceived pain scores. Medical protocols (or checklists) have demonstrated a reduction in medical errors[20] and surgical complications in the surgical literature, such as with ventriculoperitoneal shunts.[21] Our results are therefore likely due to a combination of both a new pain protocol and the availability of multiple pain control options. Our study supports the use of a pain management protocol in children who undergo PFD or PFDD.

Postoperative Nausea and Vomiting

Our study indicated that fewer doses of antiemetics were administered during the inpatient postoperative stay in patients who were standardized on the pain protocol versus patients who were not. The proxy for nausea and vomiting was the number of antiemetic medication administrations over the course of the patient's hospital stay. Emesis is a known side effect of narcotic medications.[22] Emesis is also very common after posterior fossa surgery and occurs in 60%–70% of cases in which the CSF is accessed.[23] This condition has been attributed to the inherent anatomy of the posterior fossa and area postrema as well as anesthetic gas or intraoperative medication administration.[23] Intraoperative medications were not controlled for in this study outside of local anesthetic injection by the surgeon, but standard general endotracheal anesthesia was provided to all children at a single institution. PFD and PFDD are inherently different operations with different risk profiles. Postoperative complications in 2 patients were related to accessing the CSF space; thus, equivalent numbers of PFD and PFDD patients were included in the pre- and postprotocol cohorts in an effort to control CSF access as a confounding factor. We therefore feel it is reasonable to state that this protocol was associated with a significant reduction in postoperative nausea and vomiting. This finding should be investigated further in a larger study.

Narcotic Reduction Goal

Narcotics have several side effects, most commonly constipation and nausea. The literature cites that opioid-induced constipation occurs in up to 80% of patients and nausea in as many as 40% of patients.[22,24] Initiation of narcotics frequently requires adding multiple other medications, including an escalated bowel regimen and antiemetic usage. Our study demonstrated that implementation of a multimodal pain management protocol reduced antiemetic usage postoperatively regardless of the index operation. The literature clearly demonstrates—and it is common knowledge—that narcotic overuse is problematic. Yet, it is also becoming clear that complete narcotic elimination is also problematic and does not improve care, based on a narcotic-free anesthetic randomized controlled trial in gynecological surgery.[25] While our protocol attempted to reduce narcotic usage, there was no statistically significant reduction. Seventy-six percent (13/17) of patients received narcotics postoperatively in the preprotocol cohort compared with 53% (9/17) in the postprotocol cohort ($p = 0.15$). This finding suggests that alternative medications to narcotics can play a substantial role in postoperative neurosurgical pain in children. We also suspect that the reduced intake of antiemetics is likely related to no PCA usage given that no other aspect of care was modified (such as the bowel regimen for constipation or intraoperative antiemetic use) and an equivalent number of patients underwent PFD and PFDD.

Limitations of the Study

This study is limited by several factors. The small sample size limits the ability to adequately power the study and a multiinstitutional study would further clarify the findings. This would require multiple centers to adapt a similar protocol, which could be feasible in the future given the safety of the protocol demonstrated in this study. Multicenter involvement would also augment the external validity of the results. As discussed previously, surgery type is a major confounder. PFD and PFDD complications and outcomes have been extensively studied, with a demonstrated higher surgical morbidity associated with PFDD.[26] Ideally, this study would have occurred in a larger cohort where each surgery type could be directly compared, and a post hoc analysis could also be performed to determine the effect of violating the protocol. It is also important to consider that we focused on postoperative narcotic usage, but pre- and intraoperative analgesia were not controlled for. Studies have highlighted the importance of preoperative pain medications in neurosurgery.[27] A prominent 2023 study in *JAMA Surgery* indicated that intraoperative use of opiates can reduce long-term opiate usage,[5] contradicting the current medical ambition to use fewer opiates. In neurosurgical patients, we feel that this finding emphasizes the importance of multidisciplinary collaboration. A recent study in the *Journal of Neurosurgery: Pediatrics* focused on the utility of dexmedetomidine in postoperative pain control in pediatric Chiari malformation decompression.[28] Pediatric neurosurgeons recognize the need for an optimized approach to postoperative pain control, and a multimodal pain protocol is one way to achieve that goal.

Conclusions

A protocol is safe and effective in the management of postoperative pain for children who undergo PFD or PFDD. Although our multimodal pain protocol did not decrease narcotic usage in a statistically significant fashion, the patients who underwent PFD or PFDD demonstrated noninferior postoperative pain scores and reduced postoperative nausea and vomiting. Surgeons should try to reduce but not eliminate narcotic usage with their postoperative pain regimen and leverage the use of nonnarcotic pain medications to assist with optimized postoperative pain control.

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Disclosures

Dr. Smyth reported receiving personal fees from Monteris Medical and Zimmer Biomet ROSA outside the submitted work.

Author Contributions

Conception and design: Reynolds, Battick, Rodriguez, Jallo, Akbari, Smyth. Acquisition of data: Reynolds, Battick, Rodriguez, Akbari. Analysis and interpretation of data: Reynolds, Jenson, Battick, Rodriguez, Jallo, Akbari, Smyth. Drafting the article: Reynolds, Jenson, Battick. Critically revising the article: all authors. Reviewed submitted version of manuscript: all authors. Approved the final version of the manuscript on behalf of all authors: Reynolds. Statistical analysis: Reynolds, Akbari. Administrative/technical/material support: Battick. Study supervision: Hartnett-Wright, Jallo, Smyth.

Supplemental Information

Previous Presentations

These data were previously presented as a poster at the 2022 AANS/CNS Pediatric Neurosurgery Section Annual Meeting in Washington, DC, November 30–December 4, and at the 2023 AANS/CNS Pediatric Neurosurgery Section Annual Meeting in Oklahoma City, OK, November 29–December 2.

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