Standardized Headache Therapy in the Pediatric Emergency Department Using Improvement Methodology

Adam A. Vukovic, MD, MEd*†; Selena Hariharan, MD, MHSA*†; Michelle C. Caruso, PharmD‡; Sara M. Zellner, MSN, RN§; Marielle Kabbouche, MD, FAHS*¶; Stephen C. Porter, MD, MPH, MSc*†; Eileen Murtagh-Kurowski, MD*†

Abstract

Introduction: Primary headache is a common cause of pediatric emergency department (PED) visits. Without published guidelines to direct treatment options, various strategies lacking evidence are often employed. This study aims to standardize primary headache treatment in the PED by promoting evidence-based therapies, reducing nonstandard abortive therapies, and introducing dihydroergotamine (DHE) into practice. Methods: A multidisciplinary team developed key drivers, created a clinical care algorithm, and updated electronic medical record order sets. Outcome measures included the percentage of patients receiving evidence-based therapies, nonstandard abortive therapies, DHE given after failed first-line therapies, and overall PED length of stay. Process measures included the percent of eligible patients with the order set usage and medications received within 90 minutes. Balancing measures included hospital admissions and returns to the PED within 72 hours. Annotated control charts depicted results over time. Results: We collected data from July 2017 to December 2019. The percent of patients receiving evidence-based therapies increased from 69% to 73%. The percent of patients receiving nonstandard abortive therapies decreased from 2.5% to 0.6%. The percent of patients receiving DHE after failed first-line therapies increased from 0% to 37.2%. No untoward effects on process or balancing measures occurred, with sustained improvement for 14 months. Conclusion: Standardization efforts for patients with primary headaches led to improved use of evidence-based therapies and reduced nonstandard abortive therapies. This methodology also led to improved DHE use for migraine headache resistant to first-line therapies. We accomplished these results without increasing length of stay, admission, or return visits. (Pediatr Qual Saf 2021;6:e443; doi: 10.1097/pq9.0000000000000443; Published online July 28, 2021.)

INTRODUCTION

Headache is a common chief complaint among patients presenting to a pediatric emergency department (PED), with a large percentage of these being primary headache syndromes (38%) and headaches due to non–life-threatening diseases (49%). Migraines are the most common primary headache syndrome seen in PEDs (73.5%), but it can be difficult to diagnose migraine using existing criteria during a PED visit. Once life-threatening causes of headache are excluded, and features of migraine headache are noted, PED providers often proceed with migraine headache management to control pain and other symptoms.1

Migraine symptoms typically last 2–72 hours and can include unilateral or bilateral locations, pulsating quality, moderate or severe pain intensity, and aggravation by routine physical activity. During the headache, patients often experience nausea, vomiting, and photo-, and/or phonophobia.2,3 In the pediatric population, migraine prevalence increases with age. Among adolescents, 8%–23% experience migraine headaches, and the gender predilection shifts from boys to girls.4-7
Between 2003 and 2013, patient visits to the PED with a chief complaint of headache has steadily increased from 1.3% to 2.3%, with 7% of patients admitted secondary to refractory symptoms. Headache remains one of the most common complaints by patients 15 to 18 years of age presenting to the PED. Headache severity appears to be a critical factor for presentation. Although parents, more than patients, expect an investigation into headaches’ etiology, management’s main goal is to alleviate symptoms.

The American Academy of Neurology published recommendations on the acute management of migraine headaches; however, it focuses on self-administered therapies and does not address emergency department parenteral management. As most patients present to the PED after multiple failed abortive attempts at home, providers regularly use parenteral therapies for migraine management. Unfortunately, there is no accepted guideline for parenteral management of primary headache, including migraine, in the emergency department. Multiple parenteral treatment strategies exist, with evidence supporting the use of dopamine antagonists, intravenous fluids, nonsteroidal anti-inflammatory drugs, sodium valproate, and dihydroergotamine (DHE). Nonstandard migraine abortive medication strategies exist, though little evidence exists to support their use. Patients receiving nonstandard migraine abortive medications in the PED were more likely to experience revisit within 72 hours of their index visit.

Migraine practice guideline usage in the PED has improved pain scores, reduced length of stay (LOS), and resulted in fewer admissions for refractory symptoms. At our institution, we recognized the regular and variable use of multiple treatment strategies with little evidence to support their use. This quality improvement (QI) project was a collaborative effort between the pediatric emergency, pharmacy, and neurology divisions to standardize care, increase the percentage of patients receiving evidence-based therapies, and reduce the percentage of patients receiving nonstandard migraine abortive medications. Additionally, we aimed to implement a new process for delivering DHE in the PED to patients who failed initial parenteral abortive therapy. We chose this therapy strategy given its application in our outpatient headache infusion center, emerging evidence supporting its outpatient use, and the theory that earlier initiation of DHE might improve headache time course for admitted patients, resulting in shorter inpatient LOS.

**METHODS**

**Settings and Context**

We performed this QI initiative in a university-affiliated academic center, including an urban quaternary care PED with approximately 54,500 visits annually and a suburban, free-standing PED with approximately 37,000 visits annually. A compelement of pediatricians and advanced practice nurse practitioners (APN) independently see patients. Trainees (pediatric, combined pediatric, family medicine, and emergency medicine residents or PEM fellows) initially evaluate 79% of patients before attending physician assessment. Bedside staff include nurses in a 3–4:1 ratio, respiratory therapists, paramedics, and patient care attendants.

The suburban department includes 21 treatment rooms. PEM attendings also staff it with similar up-staffing during high-volume times. Although bedside staffing is similar, there are fewer trainee shifts; thus, PEM attendings primarily see more patients.

Our electronic medical record (EMR) is a single web-based platform capable of provider and staff documentation, inter-provider communication, order entry, and storage of laboratory and imaging results as well as results of bedside assessments, including vital signs. Clinical care algorithms are embedded into the EMR and are available for reference at the point of care (POC) by providers.

During this study, DHE administration was available only at the main ED; patients considered for this therapy at the suburban department would be transferred to the main department or directly admitted to the Neurology service.

**Interventions**

**Improvement Team**

Discussions regarding DHE in the PED began between divisional leadership and pharmacy in May 2016. In recognizing variability in the acute abortive management of primary headache in the PED, an improvement team convened, composed of PED nursing, faculty, pharmacy, and representatives from pediatric neurology representatives. The team utilized the Institute for Healthcare Improvement’s Model for Improvement in developing their theory and designing interventions.

**Theory and Key Drivers**

The improvement team met in January 2018 to discuss primary headache management variability in the PED and theories for improvement. We developed a key driver diagram (KDD, Fig. 1). The team theorized that standardized care in all treatment sites, available and well-defined management options, reliable POC decision-making support, clear communication between PEM and pediatric neurology, and buy-in from multidisciplinary staff, patient and families would contribute toward improving the percentage of primary headache patients receiving standard therapies in the PED.

Our multidisciplinary improvement team used brainstorming and informal interviews with frontline staff to generate key drivers and revisited these periodically during improvement to ensure no modifications were needed. During iterative improvement, the team felt that the most significant impact was seen with the staff’s education on indications and contraindications for DHE (use, dosing, and side effects) and POC decision support.
As there was already an inpatient and an outpatient process for giving DHE at our institution, the application of that process to the ED was relatively simple.

**Design of the Intervention**

After developing a KDD, members of the improvement team performed a literature review of acute primary headache management and met regularly to discuss their findings. This literature review informed the creation of a clinical care algorithm. Available evidence and expert consensus from neurology and PEM providers when clear evidence was unavailable also informed the algorithm. We updated a previously existing order set in our EMR in October 2018 to better align with the clinical care algorithm and include POC links to the algorithm and prompts for algorithm-adherent care (Supplemental Digital Content 1, which displays screenshot of the updated order set demonstrating prompts for algorithm-adherent care as well as preselected orders consistent with primary headache treatment algorithm (© 2021 EPIC Systems Corporation), http://links.lww.com/PQ9/A286). This order set was reviewed multiple times by key frontline stakeholders, iteratively refined, and then implemented into our EMR. In the revised order set, we preselected parenteral first-line therapies to improve the percent of patients receiving these medications. We purposefully removed from the order set nonstandard therapies with little or no evidence to support their use to reduce the providers’ likelihood of ordering these medications. This revised order set went live in November 2018. At that time, an electronic version of the clinical care algorithm was also made available to providers within the EMR (Supplemental Digital Content 2, which displays ED headache treatment algorithm, http://links.lww.com/PQ9/A287).

**Dissemination**

Representatives from the team presented the algorithm, EMR order set updates, and data in fellow clinical updates, divisional staff meetings between September and October 2018. These updates, including electronic versions of the clinical care algorithm and screenshots of updates to the order set, were available via email. Improvement representatives from neurology presented these interventions at their divisional meetings, and providers notified patients and families of standardization efforts during their scheduled pediatric neurology clinic visits.

Also, we provided frequent updates after the initial implementation of educational modules and the revised order set. Individual education was provided as needed. A single PED pharmacist, who was a part of the improvement team, communicated regularly with pharmacy staff. Nurse educators developed required education modules for nurses.
**Study of the Interventions**
We collected data monthly from July 2017 to December 2019. These data included 16 months (July 2017 through October 2018) of baseline data—during which time the PED used an unmodified order set with no standardized algorithm. The baseline period was followed by 14 months of improvement data. We included all patients presenting to the PED with primary complaints of headache or migraine and associated billing diagnoses with peripheral intravenous (IV) catheters inserted regardless of the initial treatment strategy. Patients were included if they had previously been treated for headaches at other facilities or were not established Neurology patients at our institution. We included patients up to 21 years of age, the usual age for the transition to adult care at our institution. We excluded patients if they were less than 6 years old or greater than 21 years old or if their headache was secondary to any cause other than mild head injury or non–life-threatening illness.

We extracted data from our EMR using diagnosis codes and a chief complaint of headache. Initially, we reviewed a sample of charts to ensure that the data were representative of our population of interest, patients presenting with primary headache or headache with migraine features due to mild head injury or non–life-threatening illness. Team members refined the definition to ensure that definition was consistent with the charts extracted from the EMR. Given the time-consuming nature of individual chart review, this did not continue after the initial data validation.

**Measures**

**Primary and Secondary Outcome Measures**
Primary outcome measures included the percentage of patients with IV insertion receiving evidence-based therapies, nonstandard migraine abortive therapies, and DHE as second-line therapy. We established our departmental benchmarks based on historical success with standardization processes with 80%–90% compliance goals. In patients who had an IV inserted, we aimed to increase the percentage of patients receiving evidence-based therapies, defined as a normal saline bolus, ketorolac, and prochlorperazine, from a baseline of 69% to 90%. In the same cohort, we intended to reduce the percentage of patients receiving nonstandard migraine abortive therapies, specifically magnesium sulfate and levetiracetam, from a baseline of 2.5% to 1%. In patients in whom evidence-based, first-line abortive therapies were unsuccessful and providers administered second-line IV therapies, we intended to introduce and sustain the use of DHE in the PED from a baseline of 0% to 50%. Last, we tracked LOS in eligible patients, regardless of disposition, defined as time between patient arrival in the department and discharge. The baseline was 247.5 minutes.

**Process Measures**
Process measures included the percent use of EMR order set and the percent of eligible patients who received IV medications (when ordered) within 90 minutes of arrival in the PED. In all headache patients undergoing IV insertion, we aimed to increase EMR order set use from a baseline of 61.7% to 80%. In the same cohort, we intended to increase the percentage of patients with first-line abortive therapies started within 90 minutes, measured as the time between patient arrival to the PED and the initiation of first IV therapy, from a baseline of 34.9% to 50%.

**Balancing Measures**
Balancing measures included (1) the percent of eligible patients who were admitted (baseline 3.6%) and (2) those who returned to the PED with a chief complaint of headache within 72 hours of their index visit (baseline 4.5%). The team’s a priori goal was to not increase the balancing measures with any of the described interventions.

**Analysis**
We constructed and updated statistical process control charts to track the outcome, process, and balancing measures using the QI-Charts Add-in (Version 2.0.23, 2009) in Microsoft Excel (2008). We annotated the charts with interventions to demonstrate their impact over time. The rules of interpretation of a Shewhart chart identified special cause variation (SCV). Eight consecutive points above or below the centerline were considered SCV leading to a shift. For eligible patients, P charts tracked all outcome, balancing, and process measures except for PED LOS, in which we used an X bar/S chart.

This study was determined to be a QI initiative by the Institutional Review Board at Cincinnati Children’s Hospital Medical Center. Therefore, this study was exempt from further institutional review board review.

**RESULTS**
Between July 2017 and December 2019, 5,286 patients 6–21 years of age presented to the PED and met study inclusion criteria: 2,895 patients (55%) baseline data and 2,391 (45%) improvement data.

**Primary and Secondary Outcome Measures**
The percent of patients receiving evidence-based, first-line therapies increased from 69% to 73.6% (Fig. 2), with SCV resulting in a shift in October 2018. The percent of patients receiving nonstandard abortive therapies decreased from 2.5% to 0.6% (Fig. 3), with SCV resulting in a shift in November 2018. Of patients in the baseline group, 12.9% received any second-line treatment, compared with 12.3% in the improvement group. In patients offered second-line therapies, the percent of patients receiving DHE increased from 0% to 37.2% (Fig. 4), with SCV resulting in a shift in November 2018. All 3 measures sustained performance through December 2019.

The mean LOS for eligible patients, 247.5 minutes, remained unchanged throughout the study period (Supplemental Digital Content 3, which displays Average
Fig. 2. Percent of patients presenting to the PED with primary headache who received evidence-based first-line therapies (P chart).

Fig. 3. Percent of patients presenting to the PED with primary headache who received nonstandard abortive headache therapies (P chart).
monthly LOS for patients treated for primary headache in the PED (X bar chart), http://links.lww.com/PQ9/A288). There were individual points of SCV in July 2017, January 2018, and June, July, and December 2019 without any overall LOS change.

**Process and Balancing Measures**

The percent of patients with EMR order set use increased from 61.7% to 80.1% (Fig. 5), with SCV resulting in a shift in October 2018. The percent of patients with IV medications started within 90 minutes of arrival increased from 34.9% to 41.3% (Fig. 6), with SCV resulting in a shift in March 2019. There were additional points of SCV in July 2017, January 2018, and June 2019. The percent of eligible patients admitted to the hospital remained unchanged at 3.6% throughout the study period (Supplemental Digital Content 4, which displays percent of patients presenting to the PED admitted for refractory headache symptoms (P chart), http://links.lww.com/PQ9/A289). The percent of patients who returned to the PED with a chief complaint of headache within 72 hours of their index visit remained unchanged at 4.5% throughout the study period. However, the 5 most recent data points are above the centerline (Supplemental Digital Content 5, which displays percent of patients returning to the PED with headache recurrence within 72 hours of index visit (P chart), http://links.lww.com/PQ9/A290).

**DISCUSSION**

This study used improvement methodology to increase evidence-based first-line therapies for patients presenting to the PED with primary headache symptoms. We believe that our modest endpoint is partly due to our algorithm having broad inclusion criteria for both headache type and patient comorbidities. These criteria likely resulted in the inclusion of patients who refused first-line therapy components, such as patients with previous akathisia with prochlorperazine. We made a conscious decision to include all patients with a primary headache complaint even if they did not meet formal criteria for migraine diagnosis. Patients who present with migraine-like headaches symptoms will often be treated similarly in the acute setting once secondary causes of headache are excluded.

We demonstrated a reduction in the use of nonstandard abortive therapies from 2.5% to 0.6%. We focused on reducing the most common nonstandard therapies used in our institution, magnesium sulfate and levetiracetam. Institutions using other nonstandard approaches to headache management may benefit from this methodology to improve management standardization.

We introduced DHE into our clinical care algorithm, when previously it was only administered after admission to the neurology service, increasing its use from 0% to 37.2% over the study period in all patients offered second-line therapies. We suspect that persistent
provider preferences contributed to under-administration (study goal, 50%) when indicated. We intend to develop Pareto charts of common causes of practice variation and perform targeted education with infrequent DHE users.

We identified improvement in 2 of our process measures, order set use (Fig. 5) and IV medication started within 90 minutes (Fig. 6), without any untoward effects on PED LOS (Supplemental Digital Content 2, http://links.lww.com/PQ9/A287). There was no increase in the percentage of patients admitted nor patients requiring readmission within 72 hours of the index visit.

We note that patients re-presenting to the PED within 72 hours trended toward increased readmission. There is no SCV resulting in a shift; however, we will continue to follow this metric closely and, if the trend continues, determine drivers of this change.

We chose to use 90 minutes as our target for IV medication administration by both the potential for an oral analgesic trial on arrival to the PED and our local triage system, which uses the Emergency Severity Index (ESI). ESI scores highlight patient acuity and anticipated resource needs and range from 1 to 5, with lower numbers identifying higher acuity or more significant resource needs. Our triage staff assign patients with primary headaches an ESI of 3; other common painful chief complaints requiring a shorter optimal time to analgesics are assigned an ESI of 2 (eg, long bone fractures or veno-occlusive disease in patients with sickle cell disease).

The development of a clinical care algorithm in this study involved a multidisciplinary team and an in-depth review of available literature, crucial components in designing decision-support tools for providers. The baseline use of evidence-based first-line therapies in this study is likely high, given the pre-existing order set, which has been present and available to providers shortly after the institution transitioned to this EMR in 2009. Order sets increase the level of reliability of completing a task; however, this order set allowed for persistent variability in provider practices in its initial form. We demonstrated improvement in our baseline measures using interventions that further increased our level of reliability beyond provider education, including an updated, preselected order set and an embedded clinical care algorithm within our EMR. These targeted design changes can affect provider practices and reduce variation.

Seasonal variation appeared to affect specific process measures, including the percentage of patients with IV medication started within 90 minutes and PED LOS, resulting in SCV. Regarding IV medication started within 90 minutes, we noted SCV in July 2017 and June 2019, likely reflecting lower volumes of patients with migraine symptoms and reduced departmental volumes, contributing to more rapid initiation of therapies. Performance decreased in January 2018, when PED volumes were higher.

We noted similar results for PED LOS, which were shorter in summer months (July 2017, June, and July...
and more prolonged in winter months (January 2018 and December 2019), demonstrating nonsustained SCV.

We introduced a novel therapy in our PED for patients requiring second-line treatment, DHE, into the clinical care algorithm. DHE is a useful inpatient therapy, and it has treated refractory headache in outpatient infusion centers.20–22 Offering this therapy during a PED stay may have several implications, including preventing admission for some patients and improving outcome measures such as time to pain reduction and overall inpatient LOS for patients with refractory headache after DHE. As the administration of DHE was a novel therapy in the PED, all patients receiving this therapy were admitted initially. Still, a vast majority of patients who receive an initial dose of DHE in the PED are admitted at the current time. Before this process, all patients would have been admitted to the hospital. Some patients may have had improvement or resolution in their headache resulting in only brief hospitalizations. We anticipate that, absent adverse outcomes, patients with improved pain scores or the resolution of headache can be discharged from the PED, similar to infusion center protocols.22

This study has several limitations. We performed it in 2 free-standing PEDs within a single academic center with a large focus on QI and multiple available disciplines for pediatric-specific improvement initiatives; the results may not be generalizable to all institutions treating pediatric patients with headaches. Given the impact of these measures on a busy PED, future efforts should specifically focus here. We did not report on patient-centered outcomes, including overall pain reduction or efficacy of DHE administration. Our initial goal was to reduce unintended variation by implementing this clinical care algorithm; with reduced variation, we can begin to identify interventions that may impact these and other patient-centered outcomes. Lastly, our baseline data were collected retrospectively and included a period when some decision aids were already in place, contributing to relatively elevated baselines.

CONCLUDING SUMMARY
This QI initiative introduced a clinical care algorithm focused on standardizing primary headache management in the PED, resulting in an increased percentage of patients receiving evidence-based first-line therapies and reducing nonstandard abortive medication use; these changes were sustained in part through the use of a preselected order set embedded in the EMR. A collaborative, multidisciplinary approach introduced a novel therapy in the PED setting. We accomplished this without any untoward effect on the system.

DISCLOSURE
The authors have no financial interest to declare in relation to the content of this article.
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