

Improving Disposition Decision-Making for Pediatric Diabetic Ketoacidosis: A Quality Improvement Study

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Abstract

Introduction: In many centers, children with diabetic ketoacidosis (DKA) receive care either in an endocrinology ward or a pediatric intensive care unit (PICU). We conducted a quality improvement (QI) initiative to reduce potentially avoidable PICU admissions of children with DKA without increasing endocrinology ward-to-PICU transfers. **Methods:** A survey of providers demonstrated opportunities to increase awareness of institutional criteria for PICU admissions of children with DKA. We created an electronic health record (EHR) dot-phrase, prepopulated with these criteria, and placed a note in the EHR for all patients with DKA as a reference for all providers. An EHR-based data report was created to monitor the disposition of DKA patients and the use of the dot-phrase (process measure). The primary outcome measure was the potentially avoidable PICU admissions for patients with DKA. Endocrinology ward-to-PICU transfers were tracked as a balancing measure to ensure safe disposition. **Results:** After the implementation of the dot-phrase, use was variable, but averaged 33.4% over 1 year. The percentage of DKA admissions classified as potentially avoidable PICU stays decreased from 4.1% to 0.5%, with a concurrent decrease in the total percentage of PICU admissions for DKA from 19.1% to 8.4%. The percentage of endocrinology ward-to-PICU transfers also declined from 0.8% to 0%. **Conclusions:** A novel EHR-based intervention increasing awareness and documentation of established pediatric DKA management guidelines can be used to safely reduce PICU admissions for DKA without increasing the rate of endocrinology ward-to-intensive care unit transfers. (*Pediatr Qual Saf* 2020;2:e260; doi: 10.1097/pq9.000000000000260; Published online February 15, 2020.)

INTRODUCTION

Background

Diabetic ketoacidosis (DKA) results from inadequate insulin administration in a

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patient with diabetes mellitus. Patients present with severe dehydration, hyperglycemia, ketonemia, and acidosis. DKA is treated with an insulin infusion and intravenous fluids titrated based on hourly blood glucose levels. Overall mortality attributed to DKA is estimated to be 0.15–0.30%; the most common cause of death is cerebral edema.¹

Some hospitals mandate pediatric intensive care unit (PICU) admission for all patients with DKA. Others, such as our own, have the infrastructure in place to care for patients with DKA on an endocrinology ward. We admit only those children with serious comorbidities or a significant concern for cerebral edema to the PICU. The International Society for Pediatric and Adolescent Diabetes recommendations for DKA treatment do not specifically advise PICU admission for DKA. Guidelines recommend experienced nursing staff trained in monitoring and management of pediatric DKA; written guidelines for pediatric DKA management; and access to a laboratory that can provide frequent and timely results.²

The widely used Pediatric Index of Mortality severity of pediatric critical illness scoring system considers DKA a “low-risk” PICU condition.³ Studies in adults have suggested that mild or moderate DKA may be better managed in a medical inpatient ward, based on lower rates of recurrence of ketosis and hypoglycemia.⁴ When compared

with general medical inpatient ward care, ICU utilization in adults with DKA was associated with increased costs and invasive procedures, with no difference in mortality.^{5,6} In our institution, the PICU census has been consistently high. We perceived that several children with DKA admitted to the PICU could have been cared for as effectively and safely on the endocrinology ward.

To minimize potentially avoidable PICU admissions of children with DKA, we conducted a quality improvement (QI) project. The institutional framework used was adapted from the Six Sigma, Lean, and Model for Improvement frameworks and adhered to the SQUIRE 2.0 QI reporting standards consisting of 4 processes: define, diagnose, test and implement, and sustain.⁷ We were able to describe a problem with implications for PICU capacity management; understand what factors caused it; design an intervention to address these factors; and monitor for improvement with electronic health record (EHR)-based data reporting.

We aimed to reduce potentially avoidable PICU admissions of children with DKA without increasing endocrinology ward-to-PICU transfers.

METHODS

Setting & Context

This project took place at a large, tertiary care free-standing academic children's hospital from July 1, 2016, through March 31, 2019. At this hospital, we document and store clinical data using an EHR (Epic Systems, Verona, WI). We admit patients with DKA from an emergency department (ED) either to the endocrinology ward or to the PICU with endocrinology consultation. The endocrinology ward has trained nursing staff and DKA management protocols in place. Nurse-to-patient ratios are 1:2 or 1:3, depending on the acuity and volume of patients. Our PICU had 55 beds when this project started, with additional beds being added during our project timeline. Endocrinology fellows are consulted for all patients with DKA and actively participate in the decision to either accept a patient to the endocrinology ward or recommend PICU admission, with input from an attending endocrinologist as needed. Our institution has established clinical pathway guidelines (CPG) for the management of DKA, listing criteria for PICU admission for provider reference (Fig. 1).⁸ This pathway is freely accessible online. Patients are admitted to the PICU if there is a need for closer monitoring or escalation of care. If we admit a patient to the endocrinology ward, but on the initial evaluation, they are deemed unstable, we would initiate a PICU consult. This consult often results in a transfer to the PICU.

In 2017, of the 201 pediatric patients with DKA admitted to the hospital, 38 (19%) were PICU admissions. The PICU census routinely exceeded 96% capacity in the year leading up to our intervention and continued to increase throughout the project timeline.

We defined a PICU admission as potentially avoidable if it met at least one of the following criteria: not meeting CPG PICU "Admission Indicated" criteria (Fig. 1); no documented reason for needing PICU admission when not meeting CPG criteria; and no PICU-specific interventions (eg, airway support, vasopressor infusion therapy, hypertonic saline, or mannitol administration) anticipated/required during the admission. Those DKA patients with parameters in the PICU "Admission should be Considered" category were not considered potentially avoidable (Fig. 1). We queried the Virtual PICU Systems (VPS), LLC database registry, to determine how many PICU DKA admissions were potentially avoidable. The VPS database registry consists of over 135 participating PICUs across the world voluntarily with a subscription fee for participation. It serves as a multi-institutional repository of PICU data. Participating PICUs receive quarterly reports that benchmark PICU composition and performance against peer PICUs. We extracted PICU admissions with a primary diagnosis of DKA using VPS-specific diagnosis codes. Data for the VPS registry were collected on all PICU patients at our institution by trained staff nurses, using standardized clinical data definitions, analysis, and quality controls, with regular assessment of staff interrater reliability. We, therefore, used the VPS database to investigate the scope and magnitude of the problem relevant to our project, as it reliably tracked every PICU patient, which the EHR was unable to do without purposeful addition of functionality and quality control of data extraction. Using the VPS registry, we calculated that at baseline, 22% of PICU admissions of patients with DKA were potentially avoidable.

Planning for the Intervention

We created a multidisciplinary implementation team composed of a team lead, a PICU attending physician and nurse, a medical director of the endocrinology ward, an ED physician, a medical director of patient transport, and pediatric subspecialists with QI training. The purpose of this team was to address gaps in communication and workflow, resulting in patients being admitted to the PICU without a specified indication. A survey was administered by email to clinicians in the ED, PICU, endocrinology, and medical transport teams to assess knowledge of existing PICU admission criteria for DKA patients in the existing CPG (see Supplemental Digital Content 1, available at <http://links.lww.com/PQ9/A161>). This survey demonstrated opportunities to increase awareness of published criteria for PICU admission amongst endocrinology providers and the usage of guidelines by endocrinology and PICU providers (Fig. 2). We developed a key driver diagram from our root cause analysis (Fig. 3).

Intervention

A smart link, known as a "dot-phrase," was created for endocrinology fellows to document disposition recommendations for patients in DKA at the time of consultation (see Supplemental Digital Content 2, available at <http://links.lww.com/PQ9/A162>). A dot-phrase is a section of the text

Considerations for ICU Admission

The majority of children with DKA can be managed safely on the medical unit. ICU care is needed for patients at risk for clinically significant cerebral edema. These patients remain at risk for 24-48 hours after treatment is initiated even if laboratory measures are improving. Consider the factors listed below to decide where the patient will be best treated. The ultimate decision is determined after discussion between the ED and the Endocrinology services. For transported patients, the ED serves as Medical Command and discusses care with Endocrine as needed. The ICU serves as Medical Command if the patient is to be directly admitted to the ICU.

ICU Admission Is Indicated	Age < 2 years Altered mental status: GCS \leq 13 Cranial nerve deficits VS changes c/w Cushing's Triad CT with cerebral edema Other concerns for cerebral edema, intracranial pathology Clinically Significant Cerebral Edema Persistent pH < 7 Shock state, poor perfusion Co-ingestion
ICU Admission should be Considered	Age 2-5 years pH > 7.0 with HCO ₃ on BMP < 5 Initial Glucose > 1000 mg/dL Na _{corrected} > 160 mEq/L at any time during treatment K < 3.5 mEq/L with telemetry changes

Fig. 1. Current Institutional PICU admissions criteria for patients with DKA.

intended to be inserted quickly into the body of an EHR progress note. Dot-phrases contain both prepopulated default text and areas requiring completion before the note may be signed. While an attending physician is available as a resource, first-, second-, or third-year fellow trainees execute conversations and real-time documentation for patients with DKA at our institution. The dot-phrase was prepopulated with the CPG criteria (Fig. 1) and required the consultant to list the recommended disposition for the patient and reasoning behind their decision. The team reviewed the dot-phrase before implementation.

Study of the Intervention

PDSA cycle 1 began in December 2017 when we surveyed providers about CPG criteria. PDSA cycle 2, our primary intervention, began in March 2018 with dot-phrase initiation. PDSA cycle 3 began in July 2018, when new fellows commenced their training. We placed the dot-phrase in the fellows' training manual as a standard part of the workflow for admitting patients with DKA. PDSA cycle 4 began with a reminder sent out by the implementation team lead in August 2018 in response to waning usage.

An EHR-based report was created and validated by the team lead, front-line clinician, and a data analyst. It was built using data from the institutional central data warehouse and drew from multiple sections of the EHR. We defined our cohort as all patients with DKA admitted to our institution. The cohort was narrowed down by ICD codes, diagnosis types, and patient location using an iterative process. Additional data were extracted on each patient to determine whether admission to the PICU was warranted. Data included the Glasgow Coma Score, pH, glucose and potassium levels, and medications administered. Age, date of birth, admission and discharge dates, unit locations, whether the patient was transported from a referring hospital, presenting lab values, and vital signs were also collected when available. If the transport service helped admit a patient from a referring hospital, initial values were indicated as "N/A," prompting the reviewer to interrogate the transport documentation to fill in the missing information. The report indicated whether providers ordered a CT scan at any point. Finally, the report captured whether a note was written by an endocrinology fellow in the 24

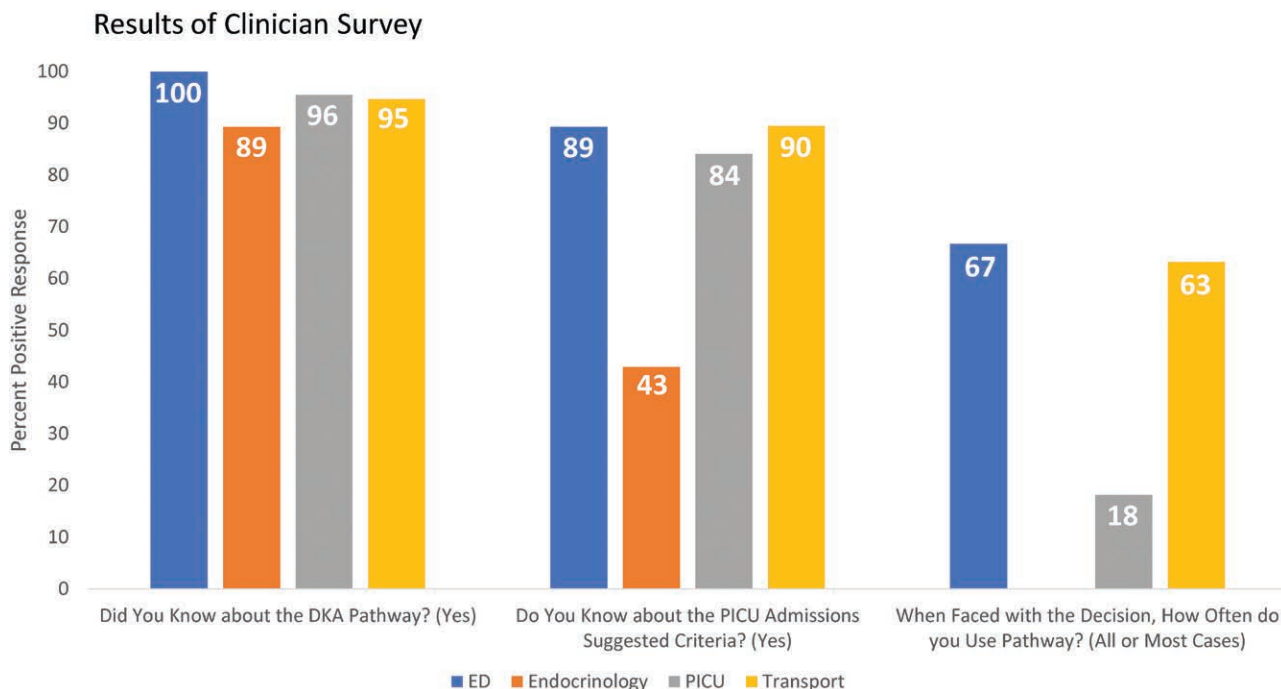


Fig. 2. Results of clinician survey inquiring about awareness of published institutional criteria for PICU admission for patients with DKA.

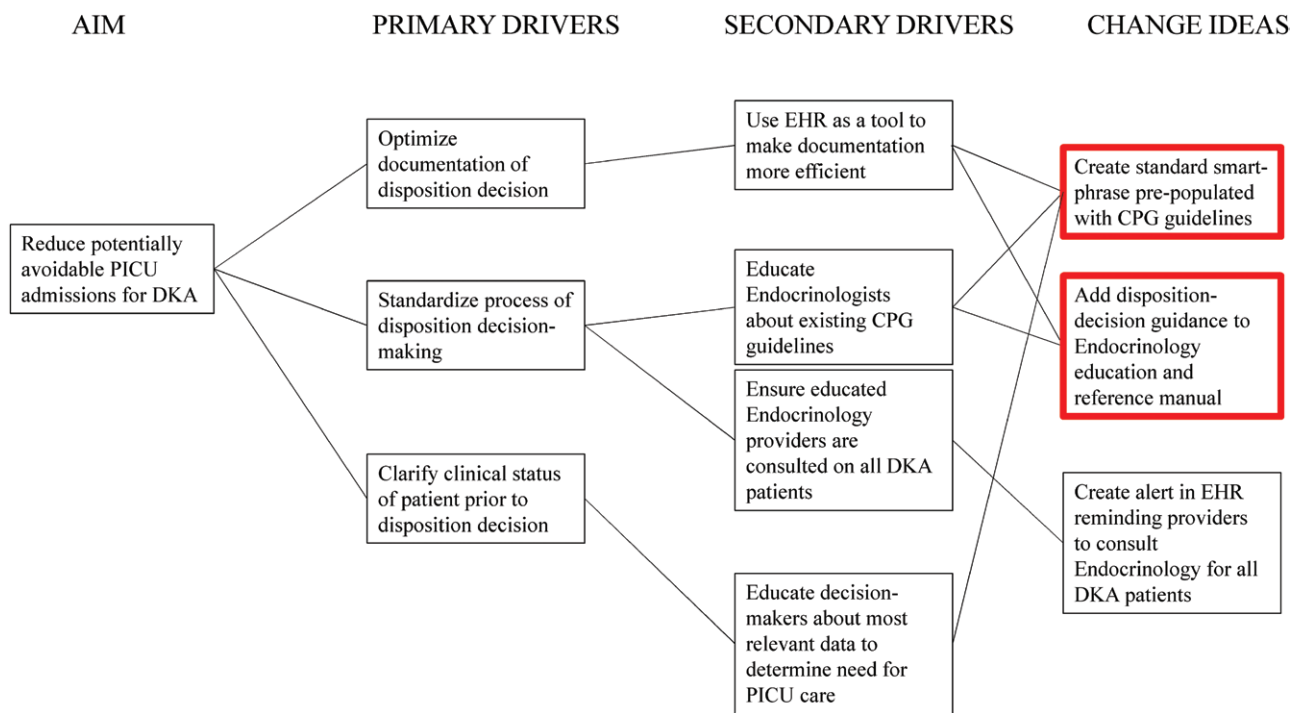


Fig. 3. Key driver diagram used for root cause analysis.

hours surrounding the time of admission, and indicated dot-phrase use.

We designed the report to run biweekly to ensure that there was no increase in Endocrinology ward-to-PICU transfers as a result of the intervention. The report captured all DKA admissions for the indicated

period, with PICU admissions highlighted. The goal was for the reviewer to quickly peruse the report and determine whether a PICU admission was avoidable. Occasionally, if the reviewer could not discern avoidability from the report (eg, if we admitted a patient from a referring hospital), the reviewer may have had to

interrogate the EMR. The reviewer could easily assess for an increase in the balancing measure of endocrinology ward-to-PICU transfers using the report.

Measures

The primary outcome measure was potentially avoidable PICU admissions for patients with DKA. We defined potentially avoidable PICU admissions as those who met 1 or more of the following criteria: not meeting CPG recommendations for PICU admission; no documented reason for requiring PICU care when not meeting CPG guidelines; and no PICU-level interventions anticipated/required during the admission.

We defined the process measure as the usage of the dot-phrase by the endocrinology consultant 24 hours after admission.

The balancing measure was endocrinology ward-to-PICU transfers: when a patient was accepted to the inpatient endocrinology unit but required transfer to the PICU. These patients were tracked to ensure that efforts to reduce admissions to the PICU did not adversely result in patients admitted to the endocrinology ward who were unable to be appropriately cared for there.

Measures were tracked initially from the VPS data, then from biweekly EHR reports run in real time. Before the switch to EHR-based reports, we validated the data using VPS and the EHR.

Analysis

We used a time-series design to study the impact of the 12-month intervention. Data from 26 months before the start of the primary intervention were reviewed and tracked forward for 12 months after implementation of the primary intervention. Thus, we analyzed a total of 38 months of data for patients admitted to the hospital with DKA. The p-chart, a statistical process control chart using the binomial distribution, was utilized to assess the impact of the intervention. Positive special cause variation—unnatural variation not previously seen in the regular process—was determined using the following criteria: ≥ 8 values below the baseline mean or ≥ 6 values in a row, steadily decreasing.⁹

Ethical Considerations

This study met the institutional criteria for QI and not human subjects research. Therefore, it did not require

review and approval from the institutional review board. As the intervention impacted fellow trainees, the endocrinology fellowship director approved the intervention before implementation.

RESULTS

The primary outcome metric, potentially avoidable PICU admissions for patients with DKA, decreased from 4.1% to 0.5% post-intervention (ie, PDSA 2). The mean percentage of DKA admissions to the PICU decreased from 19.1% to 8.4%. The balancing measure, endocrinology ward-to-PICU transfers, decreased from 0.8% to 0%, and the number of total DKA admissions to the hospital remained relatively unchanged before and after the intervention (Table 1). The overall yearly dot-phrase usage was 33.4%. Table 2 shows dot-phrase usage by PDSA cycle. Mean usage of dot-phrase by month over the intervention period was 40.2% (SD 24.6%).

Using the statistical process control chart, we found a decrease in PICU admissions for DKA from 18.8% to 8.8% (Fig. 4). Extending this baseline mean, we see over 13 points below the mean line, meeting criteria for positive special-cause variation following this intervention.

DISCUSSION

This study describes a novel and replicable QI intervention where the use of a dot-phrase in the EHR was associated with a decrease in potentially avoidable PICU admissions of patients with DKA without increasing ward-to-PICU transfers, while also resulting in a significant decrease in overall PICU admissions for DKA. The intervention was simple, inexpensive, and benefited patients, providers, and the healthcare system. While PDSA 2 was the primary intervention, we defined PDSA 1 as when we distributed the provider survey. Presumably, inquiring about existing CPG criteria to providers with limited knowledge of this resource may have increased awareness and use.

No prior study has evaluated using a dot-phrase in the EHR to reduce potentially avoidable PICU admissions. There have been studies in pediatrics using templates pre-populated with known guidelines to facilitate adherence. For example, Cooper et al. (2019) used an EHR template to increase education and pregnancy screening for teratogenic medications.¹⁰ In pediatric primary care, the use of

Table 1. Pre- and Postintervention Admissions for DKA.

	Baseline: Jan 1 2016–Mar 7 2018—Mean Number of Patients Per Year Pre-intervention (% of All DKA Admissions)	Intervention: Mar 7 2018–Mar 31 2019—Number of Patients Over 1 Year Post-intervention (% of All DKA Admissions)
All DKA Admissions	213	214
PICU DKA Admissions	40.6 (19.1%)	18 (8.4%)
Avoidable PICU DKA Admissions	8.8 (4.1%)	1 (0.5%)
Endocrinology ward-to-PICU transfers	1.8 (0.8%)	0 (0%)
% Usage of dot-phrase	0%	33.4%

Table 2. Dotphrase Usage and DKA Admissions by PDSA Cycle Over 1 Year.

Intervention	Dot-Phrase Used	Total No. DKA Admissions	% Usage
PDSA 1	N/A	72	N/A
PDSA 2	20	60	33.3%
PDSA 3	7	19	36.8%
PDSA 4	49	119	41.1%

PDSA1: provider survey; PDSA 2: dot-phrase (primary intervention); PDSA 3: new fellows start; PDSA 4: reminder. "Total number of DKA admissions" includes both PICU and endocrinology ward admissions.

prepopulated EHR templates has been shown to increase the diagnosis and monitoring of obesity and concussion.^{11,12}

The reduction in PICU admissions in this cohort likely represents a reduction in cost to the healthcare system. At our institution, a PICU bed generates approximately twice the charges that an inpatient unit bed would generate, regardless of the interventions or degree of monitoring required during the admission. During the timeline of this project, the total charges per day for the management of patients with DKA at our institution decreased by 2% from the fiscal year 2017 to the fiscal year 2018.

There was no direct cost to create the dot-phrase. The development and monitoring of the EHR-based report by a data analyst, however, resulted in indirect costs. Fellows were asked to add a documentation step to their

workflow. However, the dot-phrase was designed to be efficient and user-friendly and allowed recommendations to be visible to all staff caring for a patient in real time. Dot-phrase use was relatively consistent by PDSA cycle and increased over time (Table 2).

An unintended positive consequence of this intervention was the 100% reduction of ward-to-PICU transfers. This outcome may have been due to the immediate accessibility of criteria in the dot-phrase, resulting in more just-in-time information elicited by endocrinology fellows, ensuring that only those patients who truly required intensive care were admitted to the PICU. It is well known that unplanned transfers to intensive care are associated with increased mortality, illness severity, and longer ICU length of stay.¹³⁻¹⁵ This result is another way in which the dot-phrase had a positive impact.

Limitations

Our project has a few limitations. An EHR with the capability to accommodate custom note templates and generate detailed reports was critical to this intervention. These study results would not be generalizable to hospitals without advanced EHR capability or those that mandate PICU admission for patients with DKA, irrespective of severity. The endocrinology ward is relatively unique to our institution; however, many hospitals have an intermediate care unit that may be comparable. Ours is a teaching institution that prioritizes QI and builds it into the culture,

Percent of Patients with DKA Admitted to the Intensive Care Unit

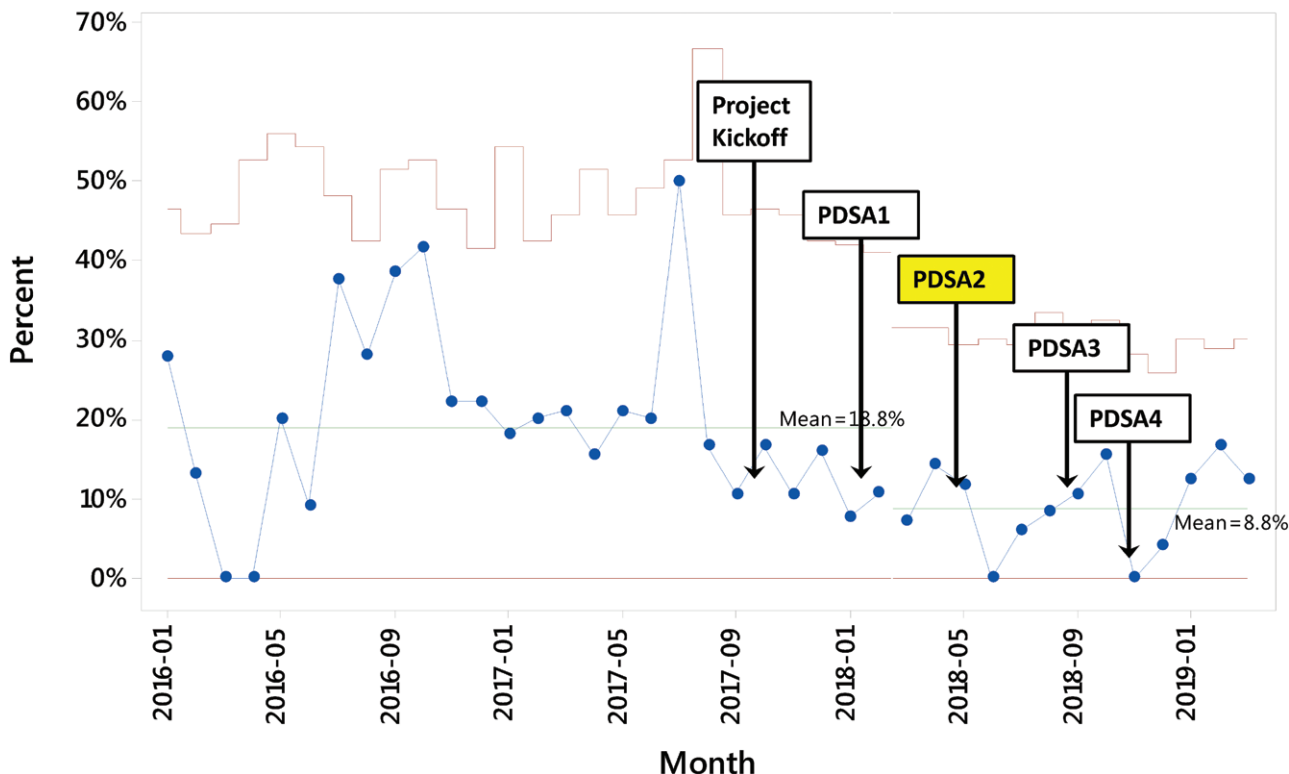


Fig. 4. PICU DKA admissions by month.

which is evident in the institutional support of the project with data analyst effort. Trainees and staff are accustomed to changes in the workflow to promote quality and safety.

Admissions could have decreased due to capacity strain and resulting pressure to reduce the use of intensive care services; however, the number of patients admitted to the PICU with DKA decreased despite an increase in PICU capacity. Admissions to PICU for DKA decreased slightly just after project kickoff. Discussion of CPG and prompts to consider our process could have caused changes in workflow. The numbers continued to decrease significantly post-intervention. The process of accepting a patient to the PICU is complex and influenced by many hospital, unit, personnel, and patient factors, so it is not certain that the results were due to the intervention alone. Compliance with the use of the dot-phrase never reached 100% despite the addition to the fellow trainee guidebook and e-mail reminders. The relatively low adherence could result from multiple factors. Fellows nearing the end of their training may have developed an established workflow for documentation from prior years, making it difficult for them to adopt another step. As we have previously highlighted, the hospital census was high during the study period; a higher workload for the on-call physicians could have led to fellows missing this documentation step. In the future, dot-phrase use could also be expanded to other categories of providers such as ED physicians to enhance overall use. Despite varying dot-phrase usage, there was a clear decrease in the number of patients admitted to the PICU with DKA. We observed with the provider survey that there was a knowledge gap; perhaps increased awareness closed this gap, allowing providers to make more consistent decisions by referring directly to the open-access CPG, even without documentation. The EHR, in contrast, is behind a secure firewall and requires multiple steps to log in for documentation. This barrier may have limited documentation without restricting access to the CPG when on-call remotely. Institutions with complex and limited remote access to the EHR could consider creating open-access resources for ease of reference.

In transitioning from the validated registry-based VPS database to the real-time EHR report, there was a potential loss of accuracy. However, the EHR-based reports were regularly reviewed by a clinician with QI training, so major errors such as misclassification of DKA diagnosis would be recognized. The EHR-based monthly data report continues to be sent to study team members to monitor for unusual increases in potentially avoidable PICU admissions or ward-to-PICU transfers.

CONCLUSIONS

This study demonstrates that a novel EHR-based intervention can reduce potentially avoidable PICU admissions for children with DKA without a concurrent increase in endocrinology ward-to-PICU transfers. Effects continued to be sustained 1 year post-intervention with continued monitoring. Others can use this example of clinical

decision support to manage other chronic conditions in which disposition decision-making to a busy PICU or subspecialty-managed inpatient ward is critical.

DISCLOSURE

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

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