Implementation of a Pediatric-Based Algorithm to

Improve Care of Symptomatic Hypoglycemia

by

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Abstract

Problem & Purpose: Hypoglycemia in childhood is a low frequency, high-risk event that can lead to coma, seizures, and even death. Symptomatic hypoglycemia occurs when plasma glucose levels are low enough to cause signs and symptoms of impaired neurological function, increasing risk of neurogenic sequalae. In the pediatric emergency department at an urban academic medical center in the Mid-Atlantic region, delays in treatment occur due to pediatric-specific barriers including time intensive, weight-based calculations for drug doses and availability of multiple dextrose concentrations. Although there is no national benchmark for comparison, the average time from identification of symptomatic hypoglycemia to treatment on this unit is 35 minutes. The purpose of this quality improvement project was to implement an algorithm for treatment of symptomatic hypoglycemia for pediatric patients between one and five years of age in the proposed setting.

Methods: An algorithm was created based on recommendations from the Pediatric Endocrine Society, the American Academy of Pediatrics, and other accredited organizations. Thirty-two small educational sessions with 59 nurses and three physician assistants were conducted over two months to provide education on algorithm use. Anonymous pre- and post-surveys were administered during the educational sessions to assess for improvements in knowledge of evidence-based care for symptomatic pediatric hypoglycemia patients. The primary outcome was to reduce time from symptomatic hypoglycemia identification to enteral or parental treatment.

Results: The sample size (N=4) was smaller than expected due to a significantly reduced census on this unit during the COVID-19 pandemic. Three males and one female met inclusion criteria, with a mean age of 2.75 years. The mean time to treatment was reduced to 6.5 minutes. The most observed symptom was nausea, which appeared in all four cases. Nearly 93% of staff demonstrated improved knowledge in caring for pediatric symptomatic hypoglycemic patients through improved survey scores after the educational sessions.

Conclusion: Findings suggest that use of a standardized algorithm contributes to reducing the time from identification of symptomatic hypoglycemia to time of treatment. All patients meeting inclusion criteria received interventions consistent with the algorithm. Future directions include expanding implementation of an algorithm to incorporate pediatric patients of all ages.

Hypoglycemia

Introduction

According to the Pediatric Endocrine Society (PES) (2017), hypoglycemia in childhood can be defined as a plasma glucose (PG) concentration that is low enough to cause signs and symptoms of impaired neurological function, including: alterations in mental status, anxiety, diaphoresis, hunger, irritability, nausea, palpitations, paresthesia, seizure, and tremors. While there is no consensus on the exact PG concentration that defines hypoglycemia, the PES (2017) recommends evaluation and intervention in children with PG levels below 60mg/dL, due to the risk of neurogenic sequalae such as coma, seizures, and even death. Despite the fact that endocrine disorders account for approximately one million emergency department (ED) visits for all populations per year, hypoglycemia continues to be a low frequency, high-risk event (Agency for Healthcare Research and Quality, 2015; Walsh et al., 2017; White et al., 2018; Pershad et al., 2018; Heeley-Ray et al., 2012). One retrospective cohort analysis conducted at an urban pediatric ED (PED) demonstrated that hypoglycemic patients presented at a rate of 6.54 per 100,000 visits (Pershad et al., 2018).

In the PED at an urban academic medical center in the Mid-Atlantic region, delays in treatment of hypoglycemia occurred due to pediatric-specific barriers including time intensive, weight-based calculations for all drug doses and the availability of multiple dextrose concentrations. Internal data gathered over the past 13 months (July 2019-August 2020) supported a need for quality improvement (QI) processes for the management of symptomatic hypoglycemia patients. Per the PED nursing informatics coordinator, internal data demonstrated that the average time from identification of symptomatic hypoglycemia to treatment of hypoglycemia was 35 minutes. The purpose of this QI project was to implement an algorithm for treatment of symptomatic hypoglycemia for pediatric patients between the ages of one and five years of age in this PED. The intended effect of this practice change was to reduce the time from identification of symptomatic hypoglycemia to the time of intervention to under ten minutes, which will ultimately improve patient outcomes and decrease the risk of adverse events.

Literature Review

Prompt identification and intervention of symptomatic hypoglycemia is imperative to prevent devastating long-term neurological sequalae for children. A comprehensive literature review (Table 1) was conducted to determine whether there is evidence to support implementation of a standardized tool, such as an algorithm, for treatment of symptomatic hypoglycemia in a PED to help improve patient outcomes. The Johns Hopkins Nursing Evidence-Based Practice Model was used to rate and grade the evidence. The review assessed for evidence of the effectiveness of standardized algorithms used in ED settings to achieve their targeted outcomes. In Bellew et al. (2016) and DeMeester et al. (2018), the primary purpose was to evaluate the impact of an atrial fibrillation (AF) algorithm on admission rates. The results of both studies demonstrated that hospital admission rates were significantly lower post-implementation of the algorithm ($p<0.001$). In Odia et al. (2020), the primary purpose of the study was to evaluate the impact of a pediatric blunt abdominal trauma (BAT) algorithm on rates of abdominopelvic-computed tomography (CTAP). The results demonstrated that the rates of pediatric patients who received CTAP were significantly lower after implementation of the algorithm ($p=0.002$) without any adverse outcomes. Although the focus of these studies was not hypoglycemia, each study implemented an algorithm and was specifically conducted in a mixed ED setting. The overall results of these studies support that implementation of algorithms in ED settings do help to achieve targeted outcomes.

The literature review also evaluated the effect of implementing a standardized hypoglycemia protocol. The primary purpose of the Arnold et al. (2015) study was to evaluate glucose variability pre- and post-implementation of the protocol. Glucose variability decreased from 49.3% to 40.9% in the post-implementation group ($p=0.048$). The primary purpose of the Van Berkel et al. (2017) study was to determine whether implementation of a standardized protocol would improve treatment frequency of hypoglycemia. In the post-implementation group, there was a statistically significant increase in patients receiving treatment for hypoglycemia ($p=0.014$). Although these two studies did not specifically focus on time to treatment of hypoglycemia and were conducted in an intensive care unit setting, both studies achieved statistically significant results when implementing a standardized tool for hypoglycemia. The overall results of these studies support that implementation of a standardized protocol to treat hypoglycemia are effective to achieve targeted outcomes.

The comprehensive literature review identified a gap in the literature regarding use of algorithms in the management of pediatric hypoglycemia in ED settings. The primary purpose of the Plummer et al. (2020) study was to determine whether implementation of a hypoglycemia algorithm could help improve patient outcomes. The results of this study demonstrated that the post-implementation group had decreased intravenous (IV) dextrose use and increased breastfeeding rates ($p<0.001$ and $p =0.003$ respectively), leading to better patient outcomes. Although this study was not conducted in an ED setting or for the targeted population, it did support that hypoglycemia algorithms are effective in improving outcomes in pediatric patients. This comprehensive literature review demonstrated that algorithms can work in ED settings, standardized protocols to treat hypoglycemia are effective to achieve targeted outcomes, and that hypoglycemia algorithms are effective at improving patient outcomes. Further synthesis and grading of the evidence is presented in Table 2.

Theoretical Framework

The theoretical framework chosen to drive this QI project was Lewin's Change Theory. This theory has three stages which include "Unfreeze", "Change", and "Refreeze". The "Unfreeze stage" involves communicating the importance of the problem to everyone affected by the change and providing an evidence-based solution to the problem. The focus of this stage is to persuade the targeted organization and key stakeholders that change is necessary (Shirey, 2013). The second stage is the "Change stage" where the intervention is implemented. Barriers may be encountered during this stage; however, adjustments to the intervention may be made to overcome these barriers (Shirey, 2013). The final stage "Refreeze", discusses the change that has been set in place and is now part of the targeted setting's culture. This stage tests the sustainability of the intervention (Shirey, 2013).

During the "Unfreeze" stage, the QI project leader explained the incidence of hypoglycemia and the significance of the delay in care of symptomatic pediatric patients between the ages of one and five years to PED nurses by utilization of internal data specific to this PED. The project leader also provided the nurses and providers with external evidence that supported implementation of an algorithm as an effective evidence-based solution to delays in care. This information was provided in-person in small groups of two to three on all shifts exclusively by the project leader. This stage helped the project reach its short-term goal of ensuring everyone was trained to use the hypoglycemia algorithm. During the "Change" stage, the algorithm was implemented for utilization during hypoglycemic emergencies. The time from identification of hypoglycemia to the time of appropriate evidence-based intervention was measured and tracked during the implementation phase. Use of the algorithm and whether interventions were consistent with recommendations from the algorithm were evaluated. The change stage also assessed whether patients experienced neurologic sequalae secondary to prolonged hypoglycemia and whether the intervention improved patient outcomes. This stage helped the project reach its mid-term goal of ensuring the hypoglycemia algorithm was being utilized consistently. The final “Refreeze” stage helped support sustainability of the algorithm in the PED through persistent improvements in time to treatment. Sustainability will be achieved by implementation of a change champion and having the PED QI committee perform monthly data analysis on symptomatic hypoglycemia trends and disseminating that information via email to PED staff on a quarterly basis.

Methods

This was a QI project of pediatric patients presenting to a PED with symptomatic hypoglycemia over a four-month period from September 2020 to December 2020. Pre-implementation data for comparison was collected from August 2019 to August 2020. It should be noted that there was a significant decrease in patient census in this PED during implementation due to the COVID-19 pandemic. This QI project was reviewed by an institutional IRB analyst. It was determined that this project meets the definition of Not Human Subjects Research.

This PED was a 33-bed unit located within an urban academic medical center in the Mid-Atlantic region with an average annual census of 25,000 patients. Eligible patients included pediatric patients between the ages of one and five years old who presented with a chief complaint of hypoglycemia, presented with signs or symptoms of hypoglycemia, and those who subsequently developed hypoglycemia during their visit; children in this age range with diabetes and other endocrine disorders were included. Exclusion criteria included children under the age of one year, older than five years, and patients found to be hypoglycemic, but not symptomatic. Children under the age of one year were specifically excluded as their parameters and tolerance for hypoglycemia are uniquely different than older pediatric patients.

The implementation team consisted of the DNP student project leader, the project faculty advisor, the PED clinical nurse specialist who functioned as the clinical site representative, the PED nurse manager who was the administrative sponsor, the medical and nursing directors, the PED nursing informatics coordinator, a PED attending who served as the institution's principal investigator, the PED pharmacist, PED physician assistants (PAs), and PED nurses on day, evening, and night shift. Implementation of this algorithm will eventually affect 18 attendings, six fellows, four physician assistants (PAs), a large team of residents that rotate through the PED, and 65 registered nurses who will all be trained on use of the algorithm. The nurses and PAs were targeted during the implementation phase due to time constraints. The Symptomatic Hypoglycemia Algorithm (see Figure 1) was developed by the project leader based on recommendations from the American Academy of Pediatrics, the PES, and other accredited organizations. Hypoglycemia definitions, parameters for intervention, recommendations for treatment, and follow-up care from these organizations were incorporated into the algorithm. A lesson plan was created by the project leader to educate targeted staff on use of the algorithm (see Appendix A). Education was completed in groups of two to three staff members due to the COVID-19 pandemic and need for social distancing. Anonymized pre/post training data was collected through a self-administered, pencil/paper knowledge assessment (see Appendix B). After completing the educational session, each participant initialed a competency sheet which was collected by the project leader (see Figure 2). Midway through the implementation phase an anonymous survey was distributed to staff to obtain barriers and opportunities for future improvement (see Appendix C). De-identified data was extracted weekly from the Electronic Health Record either via manual chart review or through an analysis of reports generated by the PED nursing informatics coordinator using the Symptomatic Hypoglycemia Audit Tool for the PED (see Appendix D). This data included information about patient age in years, glucose level, whether they were experiencing symptoms, which symptoms they were experiencing, whether the algorithm was used, whether the intervention was consistent with the algorithm, route of administration, dextrose concentration, time to order placed in minutes, time to intervention in minutes, and new glucose concentration after intervention. Run charts were used to analyze trends in the data over time and understand any variation (see Figures 3-5).

Structures and processes used to track implementation progress and assess the impact of the intervention included weekly monitoring of staff education and use of the hypoglycemia algorithm. Implementation strategies of these measures included conducting small tests of change with the PAs, using an implementation advisor, and assessing the unit culture for readiness for change. The implementation advisor assisted with predicting barriers prior to implementation. The readiness of the unit culture to change was assessed through verbal informal conversations with numerous nurses and providers on their comfort in responding to hypoglycemic emergencies. Education of staff took longer than expected due to pandemic-related restrictions on the size of educational sessions, and so the original tactic of large educational sessions at staff meetings was adjusted. The outcome measures that were tracked included duration of symptomatic hypoglycemia, utilization of correct, evidence-based interventions, and resolution of knowledge gap in care of these patients. Implementation strategies included obtaining and using feedback on any project barriers, administrative involvement, involvement of the PED QI committee as change champions, and use of a data expert. No outcome measures strategies were adjusted based on the implementation data trends due to limited patients meeting inclusion criteria during implementation.

Results

The Symptomatic Hypoglycemia Algorithm focused on pediatric patients between the ages of one and five years in the PED. By week nine of implementation, 100% of PED RNs and PAs received education on use of the algorithm. Nearly 93% of RNs and PAs demonstrated improved knowledge in caring for pediatric symptomatic hypoglycemic patients through improved survey scores after the educational sessions. The sample size (N=4) was much smaller than anticipated due a significant reduction in census in the PED secondary to the COVID-19 pandemic. Three males and one female met inclusion criteria, with a mean age of 2.75 years. The most observed hypoglycemia symptom was nausea, which appeared in all four cases. The hypoglycemia algorithm was utilized in 100% of these cases. The mean time to treatment was reduced from 35 minutes in the pre-implementation group to 6.5 minutes in the post-implementation group. The results demonstrated that implementation of a hypoglycemia algorithm in a PED was effective in reducing time to treatment ($p=0.003$). The mean time from identification of symptomatic hypoglycemia was reduced from 13.6 minutes in the pre-implementation group to 6 minutes; however, these results were not statistically significant ($p=0.135$). Implementation of the algorithm resulted in a reduction in time between identification of symptomatic hypoglycemia to time of appropriate intervention. It also resulted in utilization of the correct, evidence-based intervention in 100% of cases, a reduction in the duration of symptomatic hypoglycemia, and a resolution of the knowledge gap in care of pediatric patients with symptomatic hypoglycemia between the ages of one and five years.

An unexpected benefit of implementation was that PED nurses began searching for evidence-based interventions for symptomatic hypoglycemic patients less than one year old and greater than five years of age. PED nurses began using resources such as hospital pharmacists, the institution-specific formulary, and even searching for clinical practice guidelines for care of these patients in collaboration with the PAs and physicians. Barriers to this QI project included an overall decrease in patient census due to the COVID-19 pandemic and inability to carry out large educational sessions, resulting in a longer timeframe needed to train all nurses and PAs than originally anticipated. Additionally, plans for ongoing data dissemination were interrupted due to cancelled staff meetings secondary to the need for social distancing. One major facilitator was that the PED nursing informatics coordinator ran ongoing weekly reports on every patient in the PED who had a blood glucose measured to capture all potential patients meeting inclusion criteria. Additionally, staff were able to be educated in groups of three to four and were educated during all shifts and the QI committee held meetings via Zoom where committee members offered to help disseminate ongoing data trends.

Discussion

The Symptomatic Hypoglycemia Algorithm brought increased awareness of the knowledge gap in care for pediatric symptomatic hypoglycemic patients in the PED. This was demonstrated through decreased variability in prescribed interventions and improved clarity on treatment for symptomatic hypoglycemia. Although symptomatic hypoglycemia is not a relatively common occurrence, it is very high-risk due to the potential for neurogenic sequalae that can occur in the presence of prolonged hypoglycemia. During the implementation of the algorithm, there was a significant reduction in time from identification of symptomatic hypoglycemia to time of intervention. There is a gap in the literature regarding algorithms decreasing time to treatment; however, the literature did support that algorithms are effective in achieving targeted outcomes in ED settings (Bellew et al., 2016; DeMeester et al., 2018) which was demonstrated by this QI project. It took a total of nine weeks to educate all RNs and PAs in the PED due to the need for social distancing. The majority of RNs and PAs demonstrated an increase in knowledge in care for this population after the educational sessions. Every patient that met inclusion criteria received interventions that were consistent with the evidence-based algorithm, which resulted in decreased duration of symptomatic hypoglycemia. No patients included in the sample experienced any neurogenic sequalae, which therefore improved patient outcomes. The results of this QI project were consistent with evidence supporting the efficacy of implementation of algorithms for pediatrics and in ED settings. A limitation to this QI project was that there is a gap in the literature specific to pediatric hypoglycemia algorithms in PEDs. There was also limited generalizability as the algorithm was specifically designed for the purpose of this PED. The anticipated outcome was that there would be a reduction in time to intervention. Although the sample size was significantly reduced due to the COVID-19 pandemic, this anticipated outcome was achieved and reached a level of statistical significance.

Conclusions

Implementation of a standardized algorithm contributes to reducing the time from identification of symptomatic hypoglycemia to time of treatment. This information is highly relevant and useful in the delivery of health care as this begins to fill the literature gap for use of pediatric hypoglycemia algorithms in PEDs. It is beneficial to patient outcomes as it decreases the amount of time a patient is hypoglycemic, thereby making neurogenic sequalae less likely and improving quality of care.

This QI project used numerous tactics for implementation that greatly contributed to its success. Conducting small tests of change, using a mid-implementation survey to assess for ongoing barriers, use of an implementation advisor, and assessing for unit readiness to change prior to implementation were all imperative to this project's success. The PED QI committee has adopted symptomatic hypoglycemia as a core measure in the PED and plans to monitor data trends and disseminate this information on a quarterly basis or more frequently if needed. The QI committee has designated a unit champion to ensure sustainability of this practice change.

Future directions for this QI project include extending educational sessions to PED residents, fellows, and attendings. Integration of the algorithm into the electronic health record would be another consideration to promote sustainability. The algorithm should be expanded to incorporate pediatric patients of all ages and should further be implemented beyond the PED to all pediatric inpatient units. Use of this standardized algorithm in pediatric patients of all ages throughout this urban academic medical center in the Mid-Atlantic region will lead to improved patient outcomes and higher quality of health care. The Symptomatic Hypoglycemia Algorithm can be adapted for use at other institutions to address setting-specific barriers for care of pediatric symptomatic hypoglycemia patients.

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Tables

Table 1

Evidence Review

Citation: Arnold, P., Paxton, R. A., McNorton, K., Szpunar, S., & Edwin, S. B. (2015). The effect of a hypoglycemia treatment protocol on glycemic variability in critically ill patients. *Journal of Intensive Care Medicine, 30*(3), 156–160. http://doi.org/10.1177/0885066613511048					Level IV
Purpose/ Hypothesis	Design	Sample	Intervention	Outcomes	Results
"The purpose of this study is to evaluate the resolution of hypoglycemia and determine glucose variability prior to and following implementation of this protocol."	Retrospective cohort analysis, quality improvement	**Sampling Technique:** Convenience **Eligible:** Adult patients admitted to a 772-bed community teaching hospital in Detroit, Michigan **#Accepted:** Adult patients admitted to an ICU with a blood glucose less than 70mg/dL, who were subsequently treated with 50% IV dextrose N= 105 **Excluded:** Patients who were admitted for diabetic ketoacidosis, were pregnant, or intentionally overdosed on insulin, beta blockers, or insulin secretagogues were excluded from this study.	**Control:** 52 pre-protocol implementation patients with blood glucose less than 70mg/dL who were treated with the current practice of prescriber discretion **Intervention:** 53 post-protocol implementation patients with blood glucose less than 70mg/dL who were treated with a standardized nurse-driven hypoglycemia treatment protocol, of which both nurses and providers received education prior to implementation **Intervention Fidelity:** The standardized nurse-driven hypoglycemia treatment protocol was modeled after another	**DV:** glucose variability from time of initial hypoglycemic level to four hours after administration of 50% IV dextrose, amount of dextrose administered, time between dextrose administration and the next blood glucose value, total number of blood glucose measurements after the initial hypoglycemic level, degree of blood glucose overcorrection, and ICU mortality **Method of Measurement:** Prior to implementation of the protocol, electronic medical records (EMRs) of patients that met inclusion criteria were reviewed from April 1, 2011, to June	Chi-Square: The primary outcome of glucose variability was significantly decreased in the post-protocol implementation group from 49.3% to 40.9% as compared to the pre-protocol implementation group (P=0.048). The amount of 50% dextrose administered following a hypoglycemic event was significantly reduced from 21.2g in the pre-protocol implementation group to 11.5g in the post-protocol implementation group (P<0.001). The time between dextrose administration and the next blood glucose value

		#Control: 52 pre-protocol patients **#Intervention:** 53 post-protocol patients **Power Analysis:** N/A **Group Homogeneity:** The intervention and control groups were homogenous based on the p-values from Table 1 for baseline characteristics. The only baseline characteristic that was statistically different between the two groups was weight (p=0.02).	published treatment algorithm and was adapted by consensus from the multidisciplinary team.	30, 2011 to assess the targeted outcomes based on the current practice of prescriber discretion. After implementation of the protocol, which began on February 1, 2012, post-implementation data was collected via chart review for patients that met inclusion criteria from February 1, 2012, to March 31, 2012.	measurement was significantly reduced in the post-protocol implementation group as compared to the pre-protocol implementation group from 61 to 36 minutes (p=0.003). The total number of glucose measurements was not significant between both groups. The degree of blood glucose overcorrection in the post-protocol implementation group was significantly decreased from 86.3% in the pre-protocol group to 54.5% in the post-protocol group (p=0.009). ICU mortality in the pre-protocol group was 25% and in the post-protocol implementation group was 22.6%; results were not statistically significant.
Citation: Bellew, S. D., Bremer, M. L., Kopecky, S. L., Lohse, C. M., Munger, T. M., Robelia, P. M., & Smars, P. A. (2016). Impact of an emergency department observation unit management algorithm for atrial fibrillation. *Journal of the American Heart Association*, *5*(2), 1–10. http://doi.org/10.1161/JAHA.115.002984					Level IV
Purpose/ Hypothesis	Design	Sample	Intervention	Outcomes	Results

The purpose of this study was to evaluate the impact of the implementation of an emergency department observation unit AF algorithm on admission rates and patient outcomes.	Retrospective cohort study, quality improvement	**Sampling Technique:** Convenience **Eligible:** This ED sees 80,000 patients annually. **#Accepted:** Patients who presented to the ED with a primary final diagnosis of AF between July 2011 through June 2012 and July 2013 through June 2014 were included in this study. The authors separated the cohorts by one year to avoid extraneous influence caused by preliminary discussions about the algorithm during its creation. N= 1,190 **Excluded:** Patients were excluded from the study if they were under 18 years of age or if they did not provide consent for retrospective review. **#Control:** 627 **#Intervention:** 563 **Power Analysis:** N/A	**Control:** 627 pre-algorithm patients with a primary final diagnosis of AF **Intervention:** 563 post-algorithm implementation patients with a primary final diagnosis of AF **Intervention Fidelity:** The AF algorithm was developed through collaboration of a multidisciplinary team from emergency medicine, cardiology, primary care, and thrombophilia. This team worked together to create a standardized algorithm for management of patients who presented to the ED with a primary diagnosis of symptomatic AF.	**DV:** inpatient admission rate, short-term (within 30 days) events **Method of Measurement:** EMRs with a primary final diagnosis of AF were reviewed by a data quality analyst. Focused chart reviews were conducted by an emergency medicine resident and a registered nurse quality improvement coordinator. Charts of patients included in this study were further reviewed within 30 days for outpatient follow-up, hospital admissions, and any major adverse events.	Wilcoxon rank sum, Fisher exact, and Chi-Square: The rate of hospital admissions was significantly lower in the post-algorithm implementation group. These rates decreased from 45% to 36% ($p<0.001$). The control and intervention groups did not demonstrate statistically significant differences in rates of return emergency department visits, hospitalizations, or adverse events within 30 days. The authors did not discuss whether return visits or hospitalizations were from the same diagnosis.

		Group Homogeneity: The intervention and control groups were homogenous based on the p-values from Table 1 for baseline characteristics.			
Citation: DeMeester, S., Hess, R. A., Hubbard, B., LeClerc, K., Ferraro, J., & Albright, J. J. (2018). Implementation of a novel algorithm to decrease unnecessary hospitalizations in patients presenting to a community emergency department with atrial fibrillation. *Academic Emergency Medicine, 25*(6), 641–649. http://doi.org/10.1111/acem.13383					Level IV
Purpose/ Hypothesis	Design	Sample	Intervention	Outcomes	Results
"The objective of this study was to examine whether implementation of an ED algorithm for patients with AF/atrial flutter (AFL) could decrease hospital admission rates measured over a 1-year period. Our secondary outcomes were rates of ED return visits within 3 and 30 days for patients who were discharged from the index ED encounter."	Retrospective cohort analysis, quality improvement	**Sampling Technique:** Convenience **Eligible:** This ED sees 80,000 patients annually. **#Accepted:** Patients who presented to the ED with a primary diagnosis of new or recurrent AF or AFL of all acuities, including those who were already on anticoagulants were included in this study. N= 1,108 **Excluded:** Individuals who presented with a different primary diagnosis and a secondary diagnosis of AF were excluded from this study. Individuals who were under 18 years old, pregnant, or	**Control:** 586 pre-algorithm implementation patients with primary diagnosis of AF **Intervention:** 522 post-algorithm implementation patients with primary diagnosis of AF **Intervention Fidelity:** The AF algorithm was developed through the collaboration of the emergency and cardiology departments by electrophysiologists, general cardiologists, emergency physicians, and quality nurse leaders. The algorithm included information about evaluation, diagnosis, treatment, and follow-up of	**DV:** hospital admission rates, rates of ED return visits within 3 and 30 day after discharge **Method of Measurement:** Data was collected retrospectively through electronic clinical, pharmacy, and administrative databases. Data from the pre-algorithm implementation group was obtained from March 2013 to February 2014. Data from the post-algorithm implementation group was obtained from March 2015 to February 2016. Discharge diagnoses, return visits, and hospital admissions were screened and flagged for manual	Chi-Square: The admission rates after implementation of the algorithm decreased from 80.4% for patients presenting with AF/AFL to 67.4% ($p<0.001$). The rates of ED return visits within 3 days of discharge, regardless of reason for visit, remained stable at 1.19% pre-intervention and 1.0% post-intervention ($p=0.92$). The rates of ED return visits within 30 days of discharge, regardless of reason for visit, also remained stable at 3.8% pre-intervention and 3.6% post-intervention ($p=0.99$).

		incarcerated were also excluded. **#Control:** 586 **#Intervention:** 522 **Power Analysis:** N/A **Group Homogeneity:** The intervention and control groups were homogenous based on the p-values from Table 1 for demographics and acuity. The only baseline comorbidity that was statistically different between the two groups was the presence of CHF.	patients presenting to the ED with AF/AFL.	review of all patients presenting to the ED during this timeframe with the primary presenting diagnosis of AF or AFL.	Note that rates of ED return for any diagnosis were included in outcome evaluation, regardless of whether they were related to AF/AFL.
Citation: Odia, O. A., Yorkgitis, B., Gurien, L., Hendry, P., Crandall, M., Skarupa, D., & Fishe, J. N. (2020). An evidence-based algorithm decreases computed tomography use in hemodynamically stable pediatric blunt abdominal trauma patients. *American Journal of Surgery*. http://doi.org/10.1016/j.amjsurg.2020.01.006					Level IV
Purpose/ Hypothesis	Design	Sample	Intervention	Outcomes	Results
"Therefore, this objective of this study was to compare CTAP use, clinical outcomes, and hospital resource utilization before and after implementation of an evidence-based pediatric BAT algorithm."	Retrospective cohort study, quality improvement	**Sampling Technique:** Convenience **Eligible:** Pediatric trauma patients less than or equal to 14 years of age. **#Accepted:** Patients 14 years and younger who were evaluated for blunt abdominal trauma (BAT) who were hemodynamically	**Control:** 65 patients pre-BAT algorithm implementation **Intervention:** 50 patients post-BAT algorithm implementation **Intervention Fidelity:** The BAT algorithm was developed with input from key stakeholders from the	**DV:** percentage of patients with a CTAP performed, measured before and after implementation of the BAT algorithm, ED length of stay (LOS), hospital LOS, return visits within 7 days **Method of Measurement:** Data was obtained from the institutional trauma	Chi-Square, Fisher Exact tests, Students t-test, Wilcoxon-rank-sum test: The percentage of patients who had a CTAP performed decreased significantly after implementation of the algorithm from 72.3% to 44% (p=0.002). ED LOS decreased significantly in the

		stable were included in this study. N=115 **Excluded:** Patients who were older than 14 years of age and patients who were 14 years old or less but were hemodynamically unstable were excluded from this study. Patients who had penetrating trauma or who were transferred from another facility who had already undergone abdominopelvic-computed tomography (CTAP) were also excluded from this study. **#Control:** 65 **#Intervention:** 50 **Power Analysis:** N/A **Group Homogeneity:** The intervention and control groups were homogenous based on the p-values from Table 1 for age, gender, race, mechanism of injury, GCS, injury severity score, signs of chest trauma, abdominal	departments of pediatric emergency medicine and trauma surgery. The initial draft of the algorithm was developed, and subsequently revised incorporating feedback from emergency department faculty.	registry. Data from the pre-algorithm implementation group was obtained retrospectively from March 2016 to March 2017. Data from the post-algorithm implementation group was obtained from the institutional trauma registry from April 2017 to April 2018. This trauma registry contains information about patients including whether they were admitted, discharged, transferred, or deceased. The trauma registry also included demographic and clinical information on each trauma patient.	post-algorithm implementation group from 256 minutes to 203 minutes (p=0.003). There were no statistically significant differences between the two groups in regards to hospital LOS and return visits within 7 days.

<table>
<tr><td></td><td></td><td>tenderness, and abdominal pain. There were statistical differences between both groups in regards to mode of arrival, mechanism of injury, trauma level, abdominal guarding, and presence of seatbelt sign that are demonstrated in Table 1.</td><td></td><td></td><td></td></tr>
<tr><td colspan="5">Citation: Plummer, E. A., Ninkovic, I., Rees, A., Rao, R., Bendel, C. M., & Stepka, E. C. (2020). Neonatal hypoglycemia algorithms improve hospital outcomes. The Journal of Maternal-Fetal & Neonatal Medicine: The Official Journal of the European Association of Perinatal Medicine, the Federation of Asia and Oceania Perinatal Societies, the International Society of Perinatal Obstetricians, 1–8. https://doi.org/10.1080/14767058.2020.1785421</td><td>Level

IV</td></tr>
<tr><td>Purpose/
Hypothesis</td><td>Design</td><td>Sample</td><td>Intervention</td><td>Outcomes</td><td>Results</td></tr>
<tr><td>“The objective of this study was to assess if implementation of the hypoglycemia algorithm improved outcomes including decreased IV dextrose use, decreased NICU admissions, increased breastfeeding rates, and decreased length of stay in our hospital system.”</td><td>Retrospective cohort study, quality improvement</td><td>Sampling Technique: convenience

Eligible: 36,062 infants born with gestational age ≥ 36 weeks between January 2010 and July 2016

Accepted: 4,666 asymptomatic infants identified as at risk for neonatal hypoglycemia (risk factors included infants of diabetic mothers, infants large or small for gestational age, infants with intrauterine growth restriction, and premature birth</td><td>Control: 1,008 infants born between January 2010-December 2011 prior to hypoglycemia algorithm implementation

Intervention: 1,485 infants born between January 2012-December 2013 post-hypoglycemia algorithm implementation; 2,173 infants born between January 2014-June 2016 post-updated hypoglycemia algorithm

Intervention fidelity: Prior to implementation</td><td>DV: rates of IV dextrose use, breastfeeding rates, NICU admission rates, length of stay

Method of Measurement: Data was collected retrospectively through analysis of a data set compiled from the hospital’s electronic medical records using Microsoft SQL server and the Electronic Data Warehouse of all infants born between January 2010 and June 2016. Data from the pre-algorithm group was obtained from</td><td>Segmented regression: The rate of breastfeeding increased from 47.3% pre-algorithm implementation to 62.4% post-algorithm implementation (p=0.02). This rate increased further to 77.7% after the algorithm was updated in the second intervention group (p=0.015).
The odds of NICU admission decreased post-algorithm implementation by 0.5 times (p<0.001) and decreased further by 0.6 times in the updated</td></tr>
</table>

		between 36 to 37 weeks gestation) **Excluded:** infants born <36 weeks gestation, infants with five-minute Apgar scores less than five, infants whose mothers were diagnosed with chorioamnionitis **# Control**: 1,008 infants pre-algorithm implementation **# Intervention**: 1,485 infants post-hypoglycemia algorithm implementation; 2,173 infants post-updated hypoglycemia algorithm implementation **Power analysis**: N/A **Group Homogeneity**: Both intervention groups and the control groups were homogenous based on the p-values from Table 1 for baseline characteristics.	of the algorithm, this hospital had no formal protocol in place for managing infants at risk for hypoglycemia and management was based on provider preference. The initial hypoglycemia algorithm was created based on the American Academy of Pediatrics neonatal hypoglycemia guidelines published in 2011. In 2014, the algorithm was updated to include dextrose gel as first-line treatment for neonatal hypoglycemia.	January 2010 to December 2011. Data from the first post-algorithm group was obtained from January 2012 to December 2013. Data from the updated post-algorithm group was obtained from January 2014 to June 2016.	post-algorithm implementation group (p=0.002). The length of stay decreased by 0.18 days in the post-algorithm implementation group (p<0.001) and by 0.12 days in the updated post-algorithm implementation group (p<0.001). ANOVA t-test: IV dextrose use decreased from 3.9% pre-algorithm implementation to 2.5% post-algorithm implementation (p<0.001). This rate further decreased in the updated post-algorithm implementation group to 1% (p<0.001).
Citation: Van Berkel, M. A., MacDermott, J., Dungan, K. M., Cook, C. H., & Murphy, C. V. (2017). Tiered protocol implementation improves treatment of hypoglycaemia in a neurosciences critical care and surgical intensive care unit. *Intensive & Critical Care Nursing, 43,* 6–11. http://doi.org/10.1016/j.iccn.2017.06.006					Level IV

Purpose/ Hypothesis	Design	Sample	Intervention	Outcomes	Results
"We hypothesized that implementation of a nurse-driven, tiered protocol would improve treatment frequency of hypoglycaemia, and that sustainability of the protocol would be achieved."	Retrospective cohort study, quality improvement	**Sampling Technique:** Convenience **Eligible/#Accepted:** Adult patients with at least one blood glucose less than 70mg/dL while admitted to the surgical intensive care unit (SICU) or neurosciences critical care unit (NCCU). For patients who experienced multiple hypoglycemic events, only the first event was included in the data analysis. N=176 **Excluded:** Patients who were incarcerated, pregnant, less than 18 years of age, or older than 89 years were excluded from this study. **#Control:** 35 pre-protocol patients **#Intervention:** 19 post-protocol patients; 122 extended post-protocol patients **Power Analysis:** N/A	**Control:** 35 pre-protocol implementation patients **Intervention:** 19 post-protocol implementation patients; 122 extended post-protocol implementation patients **Intervention Fidelity:** This nurse-driven hypoglycemia treatment protocol was adapted from previously published data and treatment protocols from other hospitals.	**DV:** hypoglycemia treatment rates, time to follow-up blood glucose level, time to treatment of hypoglycemia, sustainability of the protocol **Method of Measurement:** A retrospective data analysis was conducted from the pre-protocol implementation group from January 1, 2013, and January 21, 2013. After implementation of the protocol data analysis was conducted between May 7, 2013, and May 21, 2013. Data analysis was run on an additional cohort between May 22, 2013 and December 31, 2013 to assess long-term sustainability of the protocol.	Chi Square: There was a statistically significant increase in patients receiving treatment for hypoglycemia in the post-protocol implementation group that increased from 20% of patients being treated to 52.6% ($p=0.014$). While there was no statistically significant difference between groups for time to treatment, the average time to treatment for the pre-protocol group was 22 minutes, which decreased to 15 minutes in the post-protocol group. Wilcoxon rank-sum testing: There was a statistically significant difference in the time to follow-up blood glucose level. The time decreased in the post-protocol implementation group from 122 minutes pre-protocol to 25 minutes post-protocol ($p<0.0001$).

		Group Homogeneity: Baseline characteristics of pre-protocol and post-protocol cohorts can be found in Table 2. P-values were not provided, so the reader is unable to determine whether there are statistical differences between the two cohorts.			In the extended post-protocol cohort, treatment occurred in 79.5% of hypoglycemic cases, and 93.8% of patients with hypoglycemia received the correct amount of dextrose based on the protocol. Time to treatment remained similar to the pre- and post-protocol implementation groups. Time to follow-up remained similar to the post-protocol implementation group, with a median time of 29 minutes.

Table 2

Synthesis Table

Evidence Based Practice Question (PICO): In pediatric patients between ages one to five years experiencing symptomatic hypoglycemia, does the implementation of a standard hypoglycemia algorithm decrease time to treatment in a pediatric emergency department at an urban academic medical center?			
Level of Evidence	**# of Studies**	**Summary of Findings**	**Overall Quality**
IV	**6**	Bellew et al. (2016), DeMeester et al. (2018), and Odia et al. (2020) found that implementation of a standardized algorithm in an ED setting was effective to achieve their targeted outcomes. The purpose of the Bellew et al. (2016) and DeMeester et al. (2018) studies was to evaluate the impact of an AF algorithm on hospital admission rates. Both studies resulted in decreased rates of admission post-algorithm implementation. The Odia et al. (2020) study specifically targeted the effectiveness of an algorithm in a pediatric population in an ED setting. The results of this study demonstrated that implementation of an algorithm in an ED setting for a pediatric population was effective to decrease rates of CTAP, which was the intended outcome. Arnold et al. (2015) and Van Berkel et al. (2017) found that implementing a standardized hypoglycemia protocol was effective to achieve their targeted outcome. The primary purpose of the Arnold et al. (2015) study was to evaluate the impact of a standardized hypoglycemia algorithm on glucose variability. The result of this study demonstrated that the protocol was effective in decreasing glucose variability. The Van Berkel et al. (2017) was conducted to evaluate whether implementation of a standardized hypoglycemia protocol would improve treatment frequency of hypoglycemia. The results of this study demonstrated that there was increased frequency in patients receiving treatment for hypoglycemia post-implementation. Both of these studies, although not conducted on pediatric patients in an ED setting, demonstrated that standardized hypoglycemia protocols are effective for achieving their targeted outcomes.	B, these studies had no power analysis to conceptualize adequacy of sample size, findings were consistent, there was an evaluation of the limitations of each of the studies, recommendations were clear, studies demonstrated statistically significant results, there was some control, each of the algorithms were developed through multidisciplinary efforts of which expertise appears to be credible, these were QI projects so there was limited generalizability. B, the Arnold et al. (2015) study had no power analysis to conceptualize adequacy of sample size, findings were consistent, there was an evaluation of the limitations of the study, recommendations were clear, study demonstrated statistically significant results, some control, algorithm developed was based on previously published literature and was further developed through multidisciplinary efforts of which expertise seems to be credible, these were QI projects so there was limited generalizability. C, there Van Berkel et al. (2017) study had no power analysis to conceptualize adequacy of sample size, findings were consistent, there was limited generalizability due to study being conducted only in SICU and NCCU, algorithm was developed through previously published data and treatment protocols from other hospitals, study demonstrated statistically significant results, recommendations were aimed at further research.

		Plummer et al. (2020) found that implementation of a hypoglycemia algorithm could help improve patient outcomes. The results of this study demonstrated that the post-implementation group had decreased IV dextrose use and increased breastfeeding rates, leading to improve patient outcomes. This study, although not conducted for the targeted population in the targeted setting, demonstrated that hypoglycemia algorithms are effective in improving patient outcomes.	B, this study had no power analysis to conceptualize adequacy of sample size, findings were consistent, there was an evaluation of the limitations of the studies, recommendations were clear, the study demonstrated statistically significant results, there was some control, the algorithms were developed based on the American Academy of Pediatrics 2011 published guidelines which supports its credibility, this was a QI project so there was limited generalizability.

Table 3

Number of Patients Meeting Inclusion Criteria by Month

Month/ Year	Number of Patients
August 2019	3
September 2019	5
October 2019	3
November 2019	3
December 2019	2
January 2020	2
February 2020	2
March 2020	1
April 2020	1
May 2020	0
June 2020	0
July 2020	5
August 2020	1
September 2020	1
October 2020	1
November 2020	1
December 2020	1

Figures

Figure 1

Symptomatic Hypoglycemia Algorithm

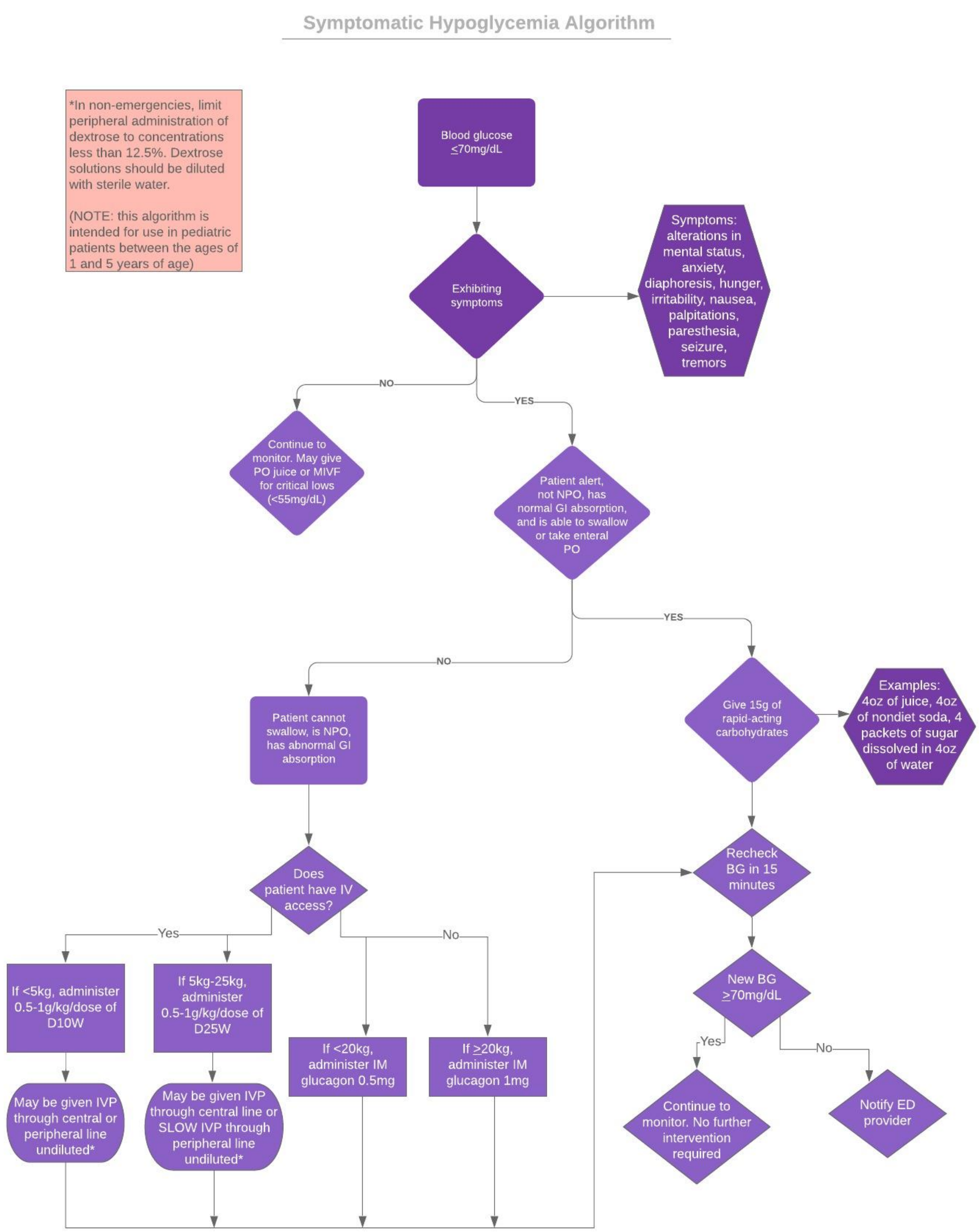
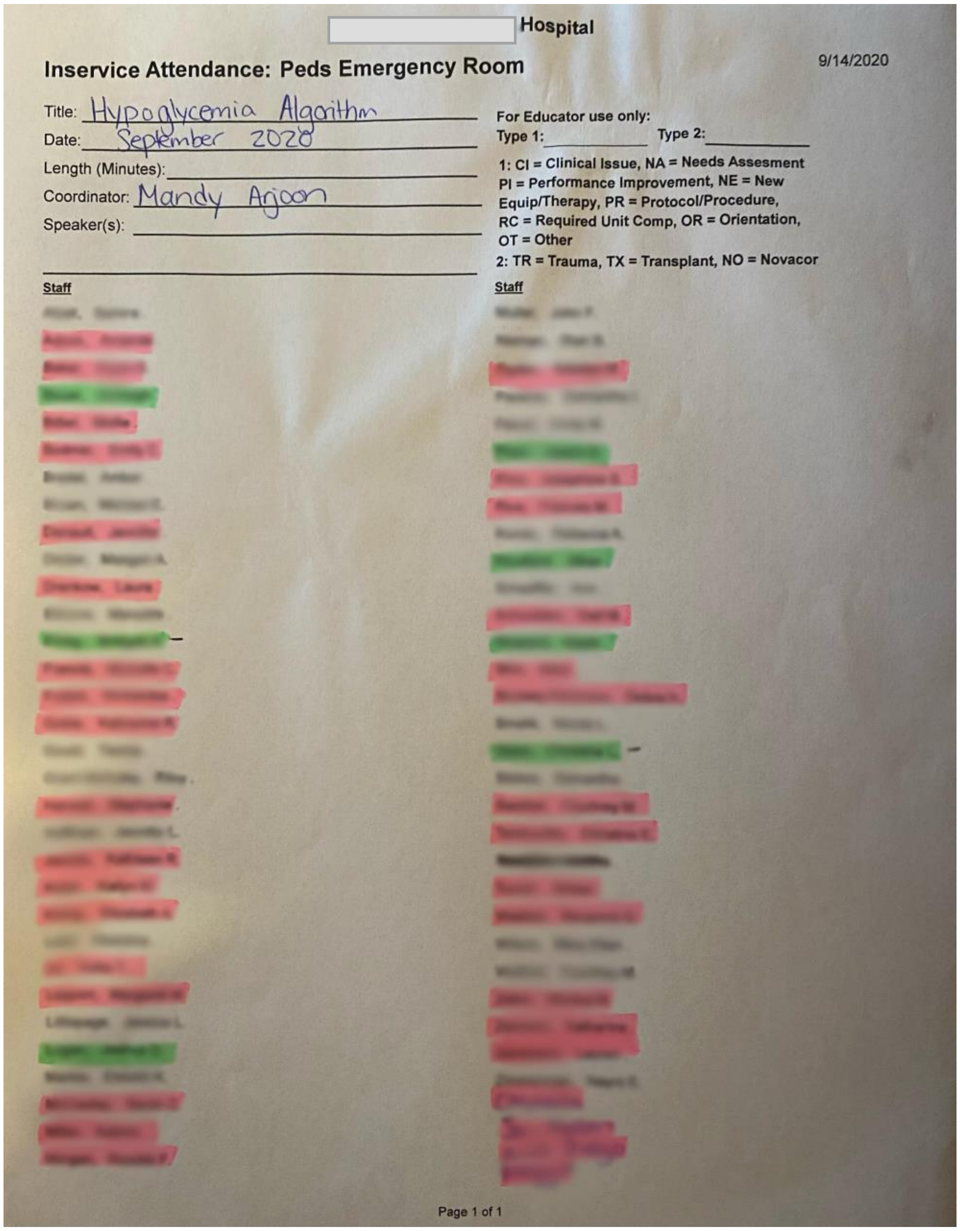


Figure 2

Competency Checklist for Staff



Hospital

Inservice Attendance: Peds Emergency Room

9/14/2020

Title: Hypoglycemia Algorithm

Date: September 2020

Length (Minutes):

Coordinator: Mandy Arjoon

Speaker(s):

For Educator use only:

Type 1: Type 2:

1: CI = Clinical Issue, NA = Needs Assesment
PI = Performance Improvement, NE = New
Equip/Therapy, PR = Protocol/Procedure,
RC = Required Unit Comp, OR = Orientation,
OT = Other

2: TR = Trauma, TX = Transplant, NO = Novacor

Staff

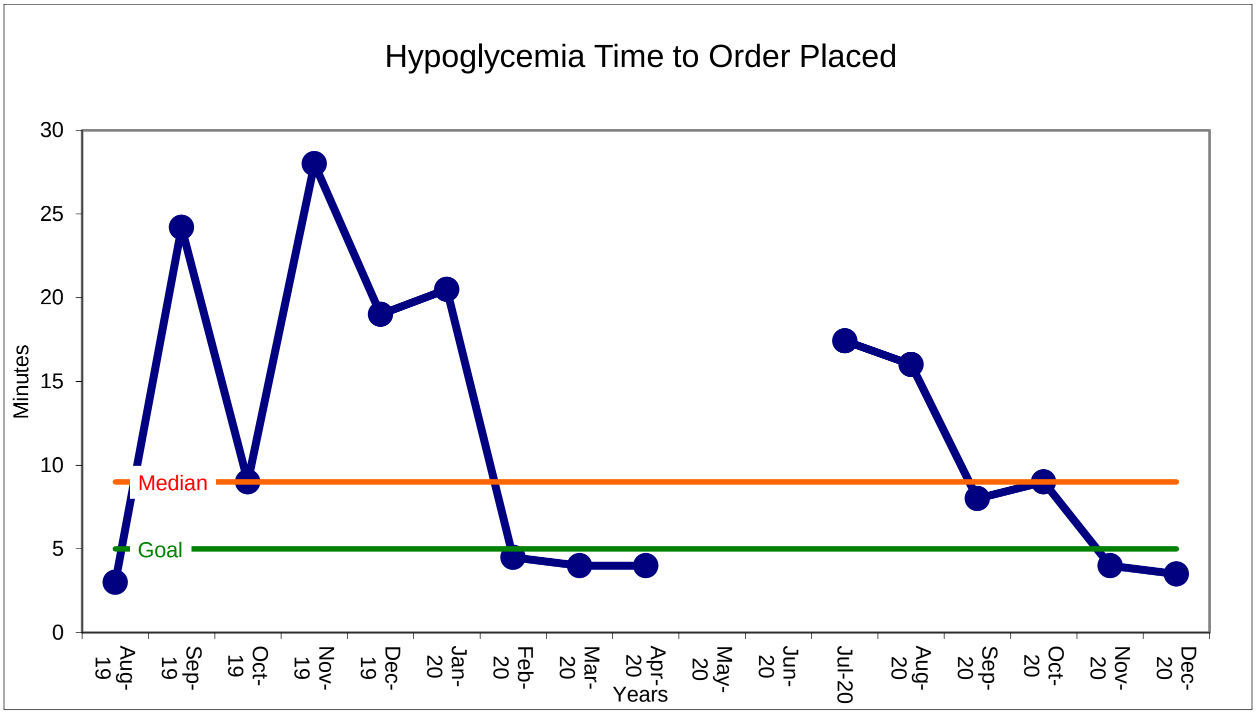
Staff

Page 1 of 1

Note. After completing the educational session, participation is captured on a competency checklist. The names of the participants and the institution were intentionally obscured to protect identities.

Figure 3

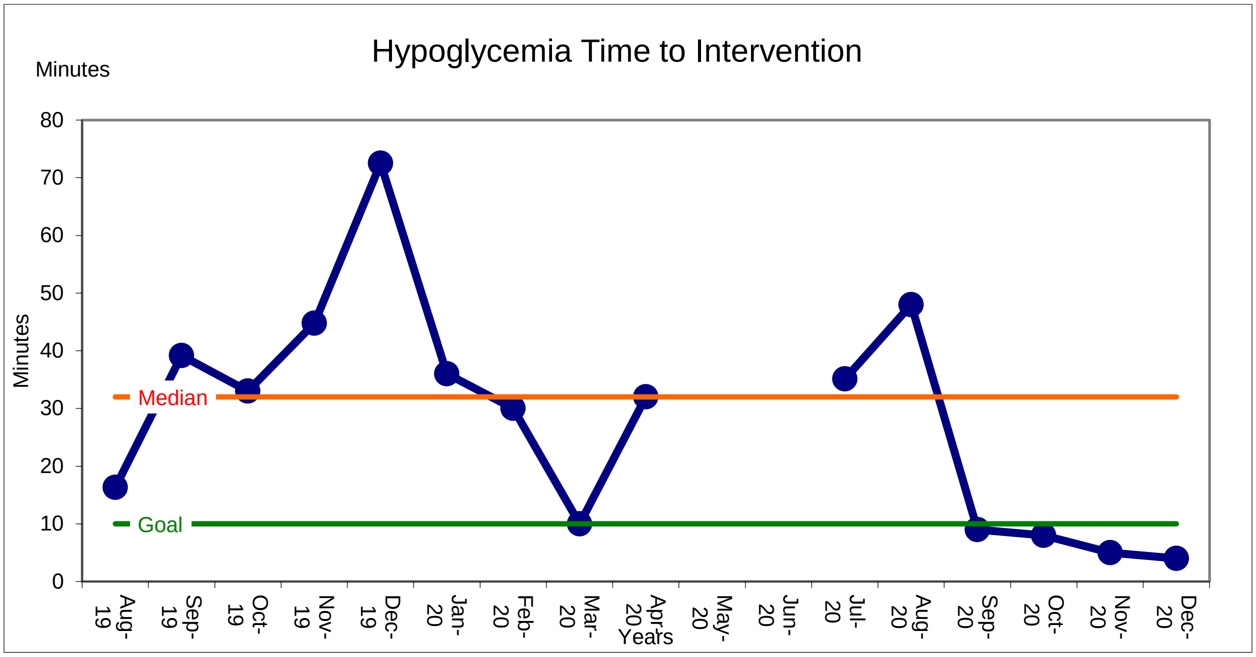
Time from Identification of Symptomatic Hypoglycemia to Time an Order was Placed



Note. There were no patients meeting inclusion criteria during May and June 2020.

Figure 4

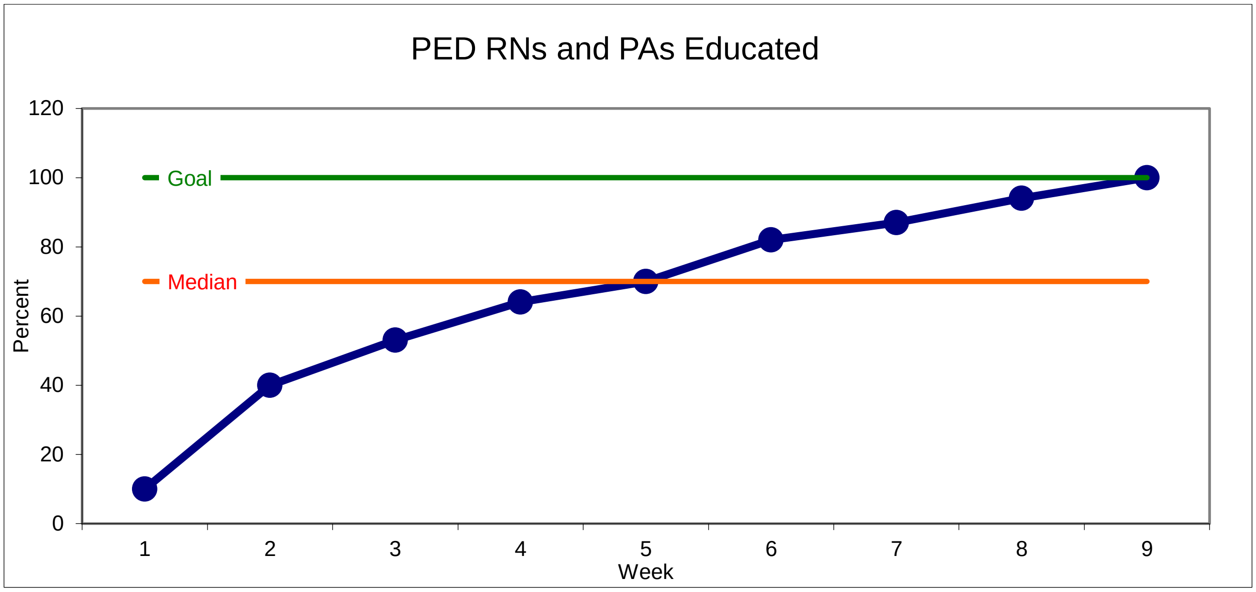
Time from Identification of Symptomatic Hypoglycemia to Time of Intervention



Note. There were no patients meeting inclusion criteria during May and June 2020.

Figure 5

Percentage of Staff who Received Education on Use of Symptomatic Hypoglycemia Algorithm



Appendix A

Educational Lesson Plan

Learning Objectives	**Content Outline**	**Method of Instruction**	**Time Spent**	**Method of Evaluation**
Nurses and providers in the PED will be able to verbalize significance of the problem	-Overview of symptomatic hypoglycemia -Evidence from literature review -Consequences of delays in treatment -Reported unit-specific barriers -Internal evidence of the problem	In-person in-service	10 minutes	Assess for verbal understanding, pre/post knowledge survey
Nurses and providers will demonstrate increase knowledge in caring for patients with symptomatic hypoglycemia through higher test scores	-Administer knowledge of evidence-based care for symptomatic hypoglycemic patients pre-survey -Administer knowledge of evidence-based care for symptomatic hypoglycemic patients post-survey -Review step-by-step algorithm -Allow opportunity to ask questions -Review where policy and algorithm can be found -Review where rapid-acting carbohydrates can be found (and examples of these)	In-person in-service	30 minutes	Knowledge of evidence-based care for symptomatic hypoglycemic patients pre/post-survey, demonstrated use of the algorithm and policy, demonstrate or verbalize ability to access symptomatic hypoglycemia resources

Appendix B

Table B1

Knowledge of Evidence-Based Care for Symptomatic Hypoglycemic Patients Pre-Survey for Providers and Nurses

Question: Please indicate your level of agreement with each of the following statements	Likert Scale				
	Strongly Disagree 1	Disagree 2	Undecided 3	Agree 4	Strongly Agree 5
1. All blood glucose levels below 60mg/dL require intervention					
2. Dextrose 50% can be given undiluted through peripheral intravenous line					
3. A 2-pack of prepackaged graham crackers is an excellent source of 15g rapid-acting carbohydrates					
4. A new glucose should be assessed 30 minutes after intervention					
5. Delays in treatment of symptomatic hypoglycemia can lead to devastating long-term effects on a child's neurological development					
6. Dextrose 10% should be administered via peripheral intravenous line to patients between 5kg-25kg					
7. If the patient has alterations in level of consciousness, it is appropriate to trial enteral intervention first					

Table B2

Knowledge of Evidence-Based Care for Symptomatic Hypoglycemic Patients Post-Survey for Providers and Nurses

Question: Please indicate your level of agreement with each of the following statements	Likert Scale				
	Strongly Disagree 1	Disagree 2	Undecided 3	Agree 4	Strongly Agree 5
1. All blood glucose levels below 60mg/dL require intervention					
2. Dextrose 50% can be given undiluted through peripheral intravenous line					
3. A 2-pack of prepackaged graham crackers is an excellent source of 15g rapid-acting carbohydrates					
4. A new glucose should be assessed 30 minutes after intervention					
5. Delays in treatment of symptomatic hypoglycemia can lead to devastating long-term effects on a child's neurological development					
6. Dextrose 10% should be administered via peripheral intravenous line to patients between 5kg-25kg					
7. If the patient has alterations in level of consciousness, it is appropriate to trial enteral intervention first					

8. Where will the hypoglycemia policy and algorithm be located?
   a. Both medication rooms in the PED
   b. The charge nurse binder
   c. Hopkins Policy and Document Library (HPO)
   d. A & C
9. Where can I access 15g of rapid-acting carbohydrates?
   a. The PED nutrition room
   b. The PED nutrition galley
   c. The PED equipment pyxis
   d. Any medication pyxis in the PED

Appendix C

Symptomatic Hypoglycemia Algorithm Survey

1. What is your role in the PED?
    a. PEM attending
    b. PEM fellow
    c. Resident
    d. PEM physician assistant
    e. Registered Nurse

2. Have you received training on the symptomatic hypoglycemia algorithm?
    a. Yes
    b. No

3. Have you used the algorithm on a patient?
    a. Yes
    b. No

4. If you have not used the algorithm yet, do you feel confident that you would know the appropriate interventions to treat symptomatic hypoglycemia based on the algorithm?
    a. Yes
    b. No
    c. N/A (I have used the algorithm on a patient)

5. Have you taken care of a patient who met inclusion criteria for the algorithm, but chosen not to use the intervention recommended by the algorithm?
    a. Yes
    b. No

6. What barriers have you encountered with utilizing the algorithm?

7. Do you have any suggestions for improvement?

Appendix D

Symptomatic Hypoglycemia Audit Tool for the Pediatric Emergency Department

De-Identified Patient ID	Age (years)	Glucose Level (mg/dL)	Experiencing Symptoms (Y/N) If Yes, 1-10	Intervention	Use of Algorithm (Y/N)	Intervention Consistent with Algorithm (Y/N)	Route of Administration of Intervention

Dextrose Concentration	Time to Order Placed (minutes)	Time to Intervention (minutes)	New Glucose Concentration after Intervention (mg/dL)

Symptoms of Hypoglycemia Legend

Numerical Code	Symptom
1	Alterations in mental status
2	Anxiety
3	Diaphoresis
4	Hunger
5	Irritability
6	Nausea
7	Palpitations
8	Paresthesia
9	Seizure
10	Tremors