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Development and implementation of a standardized pathway in the Pediatric Intensive Care Unit for children with severe traumatic brain injuries

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ABSTRACT

Severe traumatic brain injury (TBI) is a leading cause of morbidity and mortality in children. In 2003 and 2012, the Brain Trauma Foundation established and refined evidence-based guidelines for management of severe TBI in children. A recent multicenter study demonstrated an association between TBI guideline adherence and improved discharge survival. However, this study also showed large variation in adherence to pediatric TBI management at our level 1 pediatric trauma center, where overall adherence to fourteen pediatric intensive care unit (PICU) TBI clinical indicators was 64%. The aim of this quality improvement project was to increase TBI guideline adherence by implementing a standard care pathway for PICU management of children with severe TBI. A multi-disciplinary approach was utilized to develop the Pediatric Guideline Adherence and Outcomes (PEGASUS) care pathway, and iterative PDCA cycles were performed. Over an 18 month period following pathway implementation, overall PICU clinical guideline adherence rate increased to 80%.

PROBLEM

Harborview Medical Center (HMC) is a Level-1 adult and pediatric trauma center that serves a 5-state region with an 18 bed mixed pediatric and burn intensive care unit (PICU). The HMC PICU admits approximately 300 critically-ill pediatric trauma patients per year. There are 10 pediatric intensivists and 6 neurosurgeons who routinely staff the PICU; the model of care for all critically-ill pediatric brain injured patients is a pediatric intensivist-led primary service that works in collaboration with the neurosurgery team. In addition, HMC is a teaching hospital with pediatric and surgical residents providing 24 hour in-hospital coverage. There was large variation in the management of children with severe traumatic brain injury (TBI) at our institution despite

publication of national level severe TBI guidelines.^{1 2} Factors associated with clinician non-adherence to TBI guidelines were: 1) concern about guideline credibility and applicability to patient care, 2) lack of implementation, dissemination, and enforcement strategies, and 3) provider culture, communication style, and attitudes towards protocols.³ The global objective of this project was to reduce variability among care provided to children with severe TBI by developing and implementing a standard clinical care TBI pathway to promote adherence to the evidence-based TBI Guidelines.

BACKGROUND

Traumatic brain injury is a leading cause of morbidity and mortality in the pediatric population.⁴ While many factors related to TBI are not modifiable, a growing body of research over the past 15 years has identified several acute care interventions that can improve TBI outcomes.⁵ These “actionable” aspects of pediatric TBI care were summarized in clinical practice standards from the Brain Trauma Foundation published in 2003, and recently revised in 2012^{1 2} In 2014, the multicenter Pediatric Guidelines and Outcomes (PEGASUS) project reported a 6% improvement in discharge survival for every 1% increase in adherence to these clinical practice indicators.⁶ Specific protective PICU indicators included maintenance of all cerebral perfusion pressure (CPP) >40 mmHg, enteral nutrition within 72 hours of admission, and avoidance of hyperventilation (PaCO₂ <30 mmHg) in the absence of herniation. Previous studies have also shown the importance of avoidance of fever (temperature <38.5C) in children with TBI.^{7 8}



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Implementation of an institutional standard pathway for management of these patients may facilitate TBI guideline adherence.⁹ Recently, O'Lynnger et al reported an increase in discharges home from 36% to 69% post implementation of standard PICU TBI care.¹⁰ However, this study only evaluated protocol adherence with one indicator (use of hypertonic saline over mannitol) and had different clinical characteristics of patients before and after pathway implementation, leaving unclear the generalizability of findings and the impact of protocol implementation on outcomes.

BASELINE MEASUREMENT

Fourteen ICU clinical indicators reflecting the Brain Trauma Foundation guidelines for children with severe TBI were recorded (Supplemental Table 1) at baseline. Children were considered to have a severe TBI if 1) admission Glasgow coma scale (GCS) score was ≤ 8 , 2) head CT indicating TBI, and 3) patients required mechanical ventilation for ≥ 48 hours from admission. Children who died within 72 hours of admission were excluded from this analysis as early deaths would not allow testing of pathway adoption on guideline adherence. Data were collected from 1/1/2007-12/31/2011 and included 56 children. The baseline mean overall adherence rate for all PICU clinical indicators was 64%. Adherence with early enteral nutrition (within 72 hours of PICU admission) occurred in 51 of 56 patients (91%) and all CPP from ICU admission >40 mm Hg in 39 patients (69.6%). Only 7 (12.5%) of 56 patients had all PaCO₂ from ICU admission >30 mm Hg in the absence of cerebral herniation and 21 (37.5%) patients maintained a temperature $<38.5^{\circ}\text{C}$. The specific aim of this project was to achieve 90% adherence to all fourteen ICU clinical indicators. Our process measure aims were 100% adherence to early enteral nutrition, 90% adherence to PaCO₂ >30 mm Hg in the absence of herniation, and 80% adherence to CPP >40 mm Hg.

DESIGN

A multi-disciplinary approach was utilized to engage multiple stakeholders in the development of a standard pediatric severe TBI pathway, named the PEGASUS pathway. Representative stakeholders involved in pathway development included neurosurgeons, pediatric intensivists, trauma surgeons, emergency department physicians, anesthesiologists, nurses, nursing leadership, respiratory therapists, pharmacists, nutritionists, and social workers. The 2012 Brain Trauma Foundation Guidelines² were used as a framework for the pathway. Where the guidelines rely on local expert opinion, consensus was reached among participating stakeholders. These aspects included initial sedation medications, intracranial pressure (ICP) goals at various ages, initial vasopressor choice to treat systemic and cerebral hypotension, as well as first and second line treatments of elevated ICP. Next, value stream mapping was used to

analyze the current state of TBI care and develop the PEGASUS pathway. An electronic PICU severe TBI admission orderset was revised to encompass the pathway and a bound paper booklet with daily goals was created for use by nursing staff. For example, a cooling blanket order was preselected in the orderset with instructions on placing the blanket on the bed prior to the patient's arrival in the PICU with goal temperature $<38^{\circ}\text{C}$. The PEGASUS pathway booklet was designed for use from PICU admission through transfer to the ward.

The core working group met weekly to discuss pathway components and implementation strategies. Research findings on factors associated with clinician non-adherence to TBI guidelines were reviewed and one champion from each specialty group met one-on-one with their colleagues to solicit feedback on reducing barriers to pathway implementation. A consistently identified barrier was the number of rotating providers who would need just-in-time education about the PEGASUS pathway if initiation relied on trainees. This challenge resulted in a nursing-led initiation of the PEGASUS pathway. Nursing staff initiated the pathway upon arrival of the patient to the PICU and queried the PICU and neurosurgery teams to ensure each step in the pathway was complete. The pathway empowered nursing staff when encountering physicians who have different levels of training and expertise on the management of pediatric severe TBI.

Prior to PEGASUS pathway implementation, the working group engaged the hospital's interdisciplinary trauma council and pediatrics council to approve the pathway. A plan was made for iterative PDCA cycles to be performed with quarterly meetings to hospital leadership and the above committees on pathway adoption, challenges to implementation, and provider engagement.

STRATEGY

The first PDCA cycle of the pathway was performed in the PICU with one patient using a paper copy of the PEGASUS pathway. Initial feedback about the consensus of medical management in the pathway was positive; however the nurse found the pathway form confusing to complete and required too much time away from direct patient care. It was also unclear to the nurse which patients should be started on the pathway.

The second PDCA cycle simplified the documentation process and involved implementing the pathway throughout the PICU for any child admitted with concerns for severe TBI. The team decided to simplify the eligibility criteria for the nurses by establishing the following criteria for pathway initiation: patient <18 years with suspected TBI requiring mechanical ventilation. During the implementation period, the PICU section team continued weekly meetings to discuss feedback from the pathway. Additional changes to the pathway included adding sections on interdisciplinary

communication as well as early consultation of rehabilitation medicine physicians.

The third PDCA cycle involved disseminating the pathway throughout the hospital by developing additional phases for the operating room and emergency department. The largest barrier was the implementation of the pathway in a busy level one adult and pediatric trauma center. Several interventions were made including easier access to pathway materials, dissemination of results at faculty meetings, and identifying pathway champions within nursing leadership. Also, pathway process measures were added to the hospital's online quality metrics dashboard. The electronic dashboard can be viewed by any hospital provider to visualize pre-pathway data and target adherence rates for specific PICU clinical indicators such as CPP and early enteral nutrition. Pathway information was shared via many forums including division meetings, grand rounds and just-in-time training.

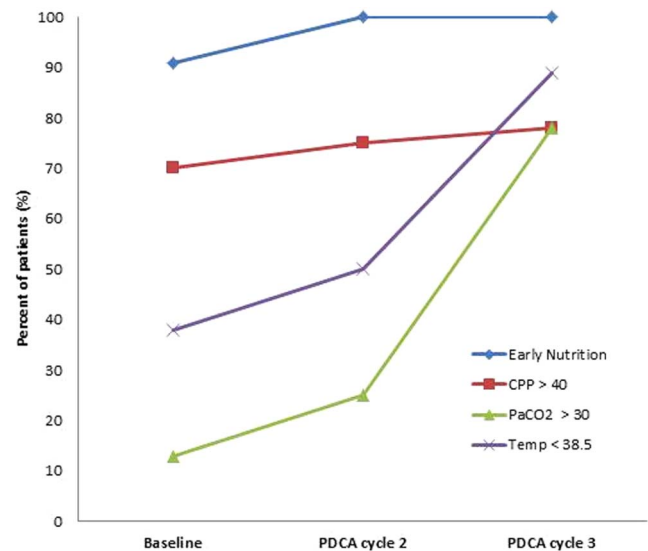
RESULTS

Patients were screened daily by PICU nurses for PEGASUS pathway eligibility and the pathway was initiated if applicable. A data analyst also reviewed all PICU admissions for children receiving mechanical ventilation with a diagnosis of traumatic brain injury. We identified three process measures (early initiation of enteral nutrition, all cerebral perfusion pressure >40 mm Hg, and all PaCO₂ >30 mm Hg) to evaluate monthly during pathway implementation. The remainder of the eleven PICU clinical indicators were obtained retrospectively through chart review. Sixty children meeting eligibility criteria were admitted to the PICU during the implementation period from 5/2014-12/2015. Twelve patients were admitted during the second PDCA cycle and forty-seven during the third PDCA cycle. Four patients missed having the pathway started; these patients were all admitted during the second PDCA cycle. The number of patients included and excluded during each PDCA cycle is shown in Table 2.

Fourteen patients met initial study inclusion criteria (GCS ≤8, mechanically ventilated ≥48 hours, and survived ≥72 hours). Pathway adoption among eligible patients was 93%. Post PEGASUS pathway adoption, the mean overall guideline adherence rate to all PICU clinical indicators was 80%. All fourteen patients received early enteral nutrition. Adherence to PaCO₂ >30 mmHg, maintenance of temperature <38.5°C, and all CPP >40 mm Hg improved with each PDCA cycle. Adherence rates to these specific indicators are compared in Figure 1 (See Supplemental Content Table 2).

LESSONS AND LIMITATIONS

Introducing the PEGASUS pathway for children with severe TBI was challenging, but was overall received with enthusiasm by multiple stakeholder groups. Several lessons were learned during this project. First, the initial



pathway was conceived as a paper booklet in order to allow for iterative changes over time. However, both nursing documentation and physician-order entry are electronic at HMC and this created challenges for the nursing staff to remember to complete all sections of the booklet. In addition, patients often transfer locations requiring the staff to remember to transfer the pathway booklet with the patient. A future goal of this project will be to transition the pathway to an electronic form which will also allow for more complete monitoring of all steps in the pathway. Second, during pathway implementation, several new nursing and respiratory therapy staff were hired to work in the PICU in addition to the rotating residents. For the pathway to continue to be successful, continuing nursing and physician education needs to be implemented for all involved in the pathway. Additionally, with the integration of the PEGASUS pathway into clinical practice, increased compliance with process measures may reflect a Hawthorne effect. The team is continuing to monitor adherence to the process measures and overall adherence to ICU clinical guidelines. Finally, an important limitation is the small number of eligible patients. As we accrue larger patient numbers, we will continue to analyze the data and monitor adherence to the pathway. We hope to examine the effect of the PEGASUS pathway on discharge outcomes in the future as we currently are not powered at this time. We expect this pathway to be generalizable to other large tertiary care level one pediatric trauma centers caring for children with severe TBI. In addition, the process of combining national guidelines with a multidisciplinary nursing-led pathway to improve adherence rates may also cross disciplines.

CONCLUSION

Implementation of the PEGASUS pathway in the PICU for management of children with severe TBI was successful in our institution due to a multi-disciplinary

approach that utilized quality improvement principles to overcome barriers to pathway development and adoption. Implementation of the pathway was associated with high levels of pathway adoption (93%) and an increase in adherence to evidence-based guidelines indicators, from 64% pre-pathway to 80% post-pathway implementation. Our study is the first to examine implementation of a standard pediatric TBI management pathway on adherence to specific ICU clinical indicators that have been associated with improved discharge outcomes in children with severe TBI. These results follow studies by Pineda and O'Lynnnger which showed improvement in discharge outcomes with implementation of standard pediatric TBI pathways.^{9 10} Pathway initiation by nursing has been critical to the implementation and success of the PEGASUS pathway at our institution.

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Declaration of interests Nothing to declare.

Ethical approval This project was considered a quality improvement project and thus local policy dictated that IRB approval was not necessary.

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