Pediatric Unintended Extubation: Standardizing Endotracheal Tube Management

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Abstract

Introduction Unintended extubation (UE) is the most serious risk associated with endotracheal intubation. In the pediatric population, UE can lead to significant patient harm. The target rate of UE cited in the literature is <1 per 100 ventilator days (VD). The United States organization Solutions for Patient Safety (SPS) has introduced a bundle to reduce UE in their cohort and has a goal of ≤0.95 per 100 VD. On average, each UE increases length of stay by six days and costs an additional $36,000. **Methods** Rogers Diffusion of Innovation Theory was used to guide the development and implementation of an evidence-based procedure standardizing the management of endotracheal tubes. The aim of this project is to evaluate adherence of staff to the procedure and achieve rates of UE at ≤0.95 per 100 VD. The UE Bundle from SPS was the foundation of the procedure. The procedure standardizes endotracheal tube securement, anatomic depth reference point, and procedure for 'high risk' maneuvers. Plan-do-study-act cycles were utilized to direct the implementation and assessment of the procedure. Adherence to the procedure was measured through peer-to-peer audits. Rates of adherence and UE were monitored on special process control charts. **Results** Rates of UE annually for 2018-2020 present are as follows: 0.56 per 100 VD, 0.29 per 100 VD, and 0.41 per 100 VD respectively. Audit adherence was 94%. A significant correlation was noted for adherence to procedure and no UE (p=0.00). **Discussion** Audit adherence of 94% was achieved during the protocol trial period, with demonstrated improvement over time. There is a possible decrease in UE rates post procedure implementation. Rates of UE at ≤0.95 per 100 were achieved for all years of data. Practice of endotracheal tube management was standardized and processes for reporting and reviewing UE were established.

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Problem

Unintended extubation (UE) is defined as any dislodgement of an endotracheal tube (ETT) from the trachea that is not intentional (Solutions for Patient Safety [SPS], 2019). Across the world UE is used as an indicator of quality and safety in Pediatric Intensive Care Units (PICUs) (Kanthimathinathan et al., 2015; Lucas da Silva et al., 2017). Tracking of UE is not required in the United States and thus has not been tracked in this PICU (Lucas da Silva et al., 2017). Establishing the rate of UE requires the knowledge of all UE events as well as the total number of ventilator days (SPS, 2019). It is important to note the absence of tracking does not indicate there is no problem; the problem is simply unknown requiring additional data collection to understand the problem's scope.

In this PICU ETT securement and management practices related to ETT depth documentation and patient mobility were not standardized. These practices varied between providers, which increased risk for UE in our population (SPS, 2019). When UEs occurred there was neither consistent practice for reporting nor a consistent interdisciplinary root-cause analysis. This project introduced a UE bundle titled the ETT Management Procedure (MP), identified the rate of UE, and developed a tracking system and route-cause analysis plan for this PICU.

Background

UE is the most common adverse event related to use of an artificial airway and can lead to complications including: hypoxemia and hypercarbia, hemodynamic compromise and arrest, need for emergent re-intubation, and rarely death (Kanthimathinathan et al., 2015; Lucas da Silva et al., 2017). The incidence of UE varies widely across the world due to differences in practice

related to securement technique, nurse staffing, sedation, and standardization of ETT management (Censoplano et al., 2020; Lucas da Silva et al., 2017; Mehta et al., 2015). Current reported rates of UE range from 0.44 to 3.5 per 100 ventilator days (Lucas da Silva et al., 2017). The target benchmark for UE identified in the literature is <1 per 100 ventilator days, excluding tracheostomy and noninvasive ventilator days (Lucas da Silva et al., 2017; SPS, 2019).

The rate of UE requiring reintubation in children is high, and reported to be 43-65% (Kanthimathinathan et al., 2015; Lucas da Silva et al., 2018). While reintubation in children does not carry the same mortality risks as adults, children who require reintubation have longer durations of mechanical ventilation and hospital stays, increasing their risk for nosocomial infections (Gao et al., 2016; Lucas da Silva et al., 2018). On average each UE increases total hospital cost by $36,000, and increases both ICU and hospital length of stay by a total of six days (Lucas da Silva et al., 2018; Roddy et al., 2015). The causes of UE are multifactorial and require an approach that can target each of these areas. A bundle, with adequate adherence, is the most appropriate approach to reduce UE (Lavallée et al., 2017; Lucas da Silva et al., 2017). Bundles of three to five elements with 95% adherence have demonstrated improvement in expected outcomes (Lavallée et al., 2017). Each eligible patient must receive all elements of the bundle to be considered adherent (Lavallée et al., 2017; Resar et al., 2012).

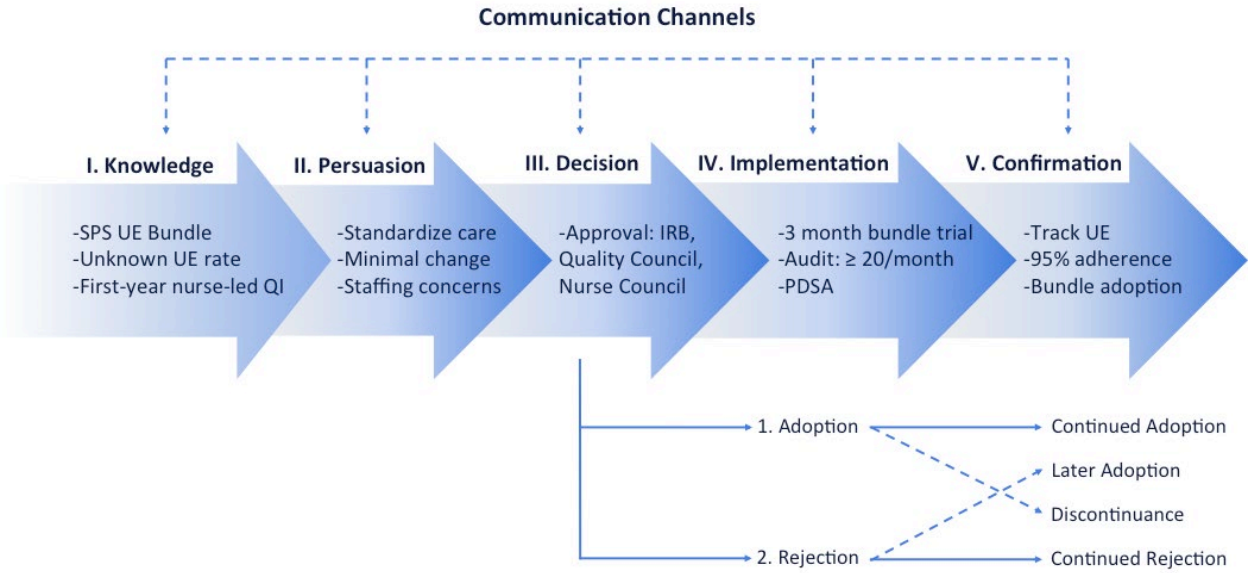
Current literature is reflective of few single-center quality improvement (QI) initiatives demonstrating improvement in UE rates with center specific bundle aims. There are commonalities in methods in the single-center initiatives, yet there is limited generalizability, which leads to inadequate identification of UE bundle elements. As a result, the organization Solutions for Patient Safety (SPS) developed a UE bundle that has been tested in their hospital cohort (SPS, 2019). SPS is a network of 140 children's hospitals in the U.S. working to eliminate

harm in children (SPS, 2020). The SPS UE goal is 0.95 per 100 ventilator days (SPS, 2020). In 2016, SPS developed a pioneer cohort to assess UE bundle elements documented in single center studies (SPS, 2019). Through their work they developed a UE bundle that includes three standard elements: standardized anatomic reference point for depth documentation, standardized ETT securement per institution, and a protocol for high risk situations (SPS, 2019). Additionally, SPS includes one recommended element in the UE bundle: a multidisciplinary apparent cause analysis for every UE (SPS, 2019).

Rationale

Figure 1

Implementation of the Endotracheal Tube Management Procedure



Note: Rogers Diffusion of Innovation theory adopted to reflect the development and implementation of the ETT MP. Adapted from "A model of five stages in the innovation-decision process" by Crowell D. M. (2016), Complexity Leadership: Nursing's role in health-care delivery, p. 117.

Roger's Diffusion of Innovation (DOI) Theory (Figure 1) was utilized to evaluate the climate related to ETT securement and management and direct the implementation of SPS UE bundle elements. Rogers DOI Theory was selected to facilitate understanding the way new practice spreads through a system and the individual's choice to adopt or reject the practice

(Crowell, 2016). It is important in practice change to examine and incorporate influence of people's past experiences and opinions related to the change (Crowell, 2016). The development and implementation of the ETT management procedure is expected to be successful through plan-do-study-act (PDSA) cycles with adequate education and knowledge sharing, support from key stakeholders, and revision of the procedure to create an ETT management procedure that can be adopted in the PICU (Institute for Healthcare Improvement [IHI], 2020).

Aim

The aim of this project is to evaluate bedside care provider adherence to an evidence-based endotracheal tube management procedure in children and to achieve rates of UE at ≤0.95 per 100 ventilator days.

Methods

Context

The setting of this quality improvement project is a microsystem consisting of a 20-bed mixed medical/surgical, cardiovascular PICU in the Pacific Northwest at a tertiary medical center and level 1 trauma center. There are approximately 1,400 critical care admissions annually. The PICU multidisciplinary team consists of attending physicians in-house 24/7, fellows and advanced practice providers, Registered Nurses (RNs) and Respiratory Therapists (RTs), and the nursing leadership team.

The Model for Understanding Success in Quality framework was utilized to identify internal and external factors, historical impacts, and leadership structure to support success in the intervention (Kaplan et al., 2012). The absence of consistent reporting of UE in the U.S. limits external environmental factors that support efforts to track and limit UE. The leadership system is vertical in nature with horizontal elements within the PICU nursing culture. The PICU QI

Council is primarily physician led, with direct impacts on bedside care staff. This is the first year quality improvement initiatives were developed and led by nurses. Quality efforts in this PICU are most frequently evaluated through nursing audits; this experience with audits is of benefit to this project.

Intervention

The ETT MP was developed based on the evidence-based UE bundle from SPS (SPS, 2019). Representatives from nursing leadership, bedside RN, RT, and the physician team were included in the procedure development. The ETT MP was introduced to the primary participants upon consensus of the aforementioned multidisciplinary key stakeholder team. The primary participants in this project were bedside care staff, RN's and RT's, as they were the consistent users of the ETT MP and were responsible for reporting UEs. Secondary participants were the PICU multidisciplinary team through inclusion in the ETT SMP development and standardized reporting system. The population studied included all intubated children admitted to the PICU from January 1, 2018 to April 15, 2020.

The ETT MP elements included: standardized ETT securement and ETT depth documentation with respect to anatomy, and two licensed clinicians for 'high risk' situations (Kandil et al., 2018; SPS, 2019). 'High risk' situations include, but are not limited to, bedside imaging and procedures, parent holding, routine repositioning, and early mobility (SPS, 2019). The procedure for securing the ETT was included in written and video forms. The ETT MP also provides standardization to securement change frequency (SPS, 2019).

Upon key stakeholder agreement, the ETT MP draft was developed and disseminated to all PICU interdisciplinary staff via email. This email included a presentation with situation-background-assessment-rational communication addressing UE in the PICU and planned

intervention. Videos demonstrating correct ETT securement technique were published to the PICU RN and RT intranets. The education information was made available in the PICU education folder. Staff signatures were collected in this folder for verification of education completion. Staff education was critical to maintaining internal validity to minimize the risk of selection error and historical threats (Polit & Beck, 2017).

Study of Intervention

PDSA cycles were utilized to develop the ETT MP, complete education, evaluate the implementation of the ETT MP, and provide further direction (IHI, 2020). Bedside peer-to-peer audits were conducted by the rapid response RN once per shift for any intubated child in the PICU; no members of this team were a part of the procedure design team. Audits consisted of a chart review assessing securement and depth documentation followed by an observed encounter of a 'high-risk' situation (SPS, 2019). Statistical process control (SPC) charts were used to monitor rate of UE and adherence to the ETT MP bundle.

Measures

PDSA 1

Determination of adequate education. Stakeholders determined at least 80% of PICU staff needed ETT MP education prior to initiation of the trial. Staff self-reported completed education and understanding of the ETT MP via signature.

Determination of UE rates. Historic data reflecting UE in 2018 and 2019 were obtained through incident reports and preliminary PICU UE tracking form. Total ventilator days were obtained through the electronic medical record; non-invasive ventilation and tracheostomies were excluded from total ventilator days. A ventilator day was considered a 24-hour period from midnight to midnight.

PDSA 2

ETT MP Trial Initiation. Education saturation of 80% was achieved and ETT MP became the new standard of care on January 15, 2020. The rapid response team RN was asked to complete one audit per shift to assess adherence to the ETT MP and provide feedback. Feedback collected was utilized to edit the protocol, provide clarification, and improve education. Staff were encouraged to provide real time feedback to one another during the audit process.

Evidence of practice change. All bundle elements on the ETT MP audit form had to 'be met' to be considered adherent, no partial adherence was accepted. All intubated children were eligible for audit. Reliability of audits was maintained by collecting at least 20 per month (SPS, 2019). Audits did not collect any patient identifiers. Peer to peer audits had an adherence goal of ≥95% to support internal validity (Polit & Beck, 2017).

Impact on unintended extubation. The patient chart for every UE in 2018 and 2019 was reviewed looking for differences from new bundle elements. Any UEs that occurred during the ETT MP trial phase underwent a chart review assessing for adherence to bundle.

PDSA 3

Formal adoption of the ETT MP. The ETT MP was updated with audit feedback and conversations with staff. The ETT MP was submitted to the protocol management system at our institution to be published as a protocol.

Adherence to bundle. Barriers to full adherence to the bundle were explored through conversations with staff and key stakeholders. Language in the ETT MP was changed to reflect the needs of our population.

Analysis

Data were processed in Microsoft Excel, version 14.7.7, and SPSS software, version 25. A SPC P chart was utilized to assess audit adherence. Rates of UE were tracked on two SPC U-charts; UE rates per month starting in January 2108 and UE rates per week pre and post introduction of the ETT MP. All SPC charts were assessed for special and random variation (Perla et al., 2011). The means and control limits were calculated using SPC methods that conform to U and P chart assumptions. Charts were examined for stability and improvement using common and special cause variation (Perla et al., 2011; Portela et al., 2015). Special cause variation was defined as two points in a row or two out of any three consecutive points beyond the second standard deviation line, four points in a row or four out of any five consecutive points beyond the first standard deviation line, and eight consecutive points on the same side of the centerline.

UE were tracked with respect to date of event, age, gender, weight, route of intubation, ETT size, securement type, primary diagnosis, pre or post ETT MP, and ETT MP adherence when applicable. Each UE patient was paired with a patient who experienced a planned extubation based on age, gender, and primary diagnosis as possible for a total of 15 UE patients and 18 planned extubation patients. All data was retrieved from the electronic medical record. Pearson's r, pointbiserial, and phi coefficient correlations were completed for variables recorded including: gender, age, intubation route, ETT size, securement type, and diagnosis. Correlations with a p value <0.05 were considered significant.

Ethical Considerations

This project was submitted to the Oregon Health and Science University Institutional Review Board for waiver and was determined not to be human subject research, IRB

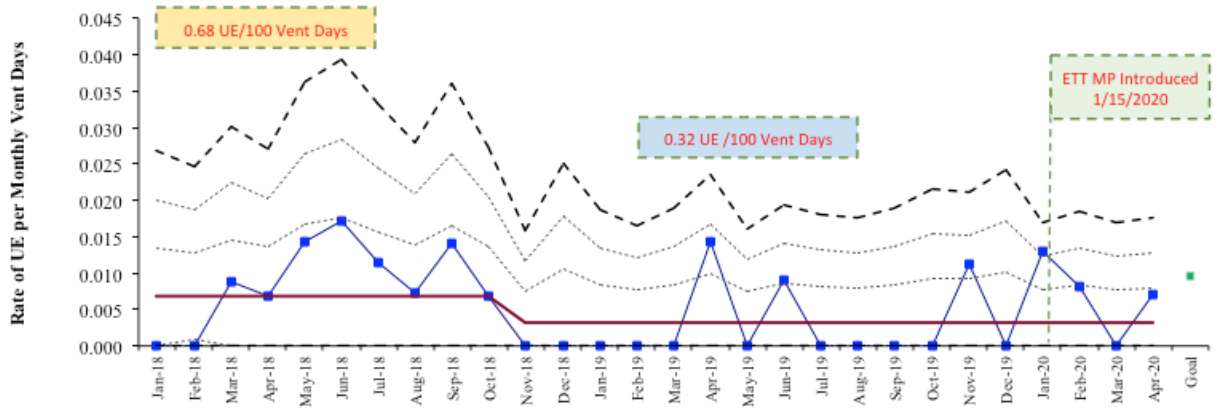
STUDY00020584. There was no randomization of interventions, compared subjects, or therapies. No personal health information was shared outside of the organization. This analysis occurs in the PICU and thus involves children, who are a vulnerable population. The author has no conflicts of interest requiring disclosure.

Results

From January 15, 2020 to April 30, 2020, there were 493 ventilator days in this PICU and two UEs, resulting in a rate of 0.41 UE per 100 ventilator days. This is comparable to the identified annual rates for 2018 and 2019 identified. In 2018 there were a total of 8 UE and 1418 ventilator days resulting in 0.56 UE per 100 ventilator days and in 2019 there were a total of 4 UE and 1372 ventilator days resulting in 0.29 UE per 100 ventilator days respectively. The rates of UE per month starting January 1, 2018 were tracked on an SPC U chart (Figure 2). A shift in means occurred in November 2018 as a result of special causes and removes further special causes. This SPC chart is in statistical control and it is capable of predicting change.

Figure 2

Frequency of UE per Month, January 2018 to Present



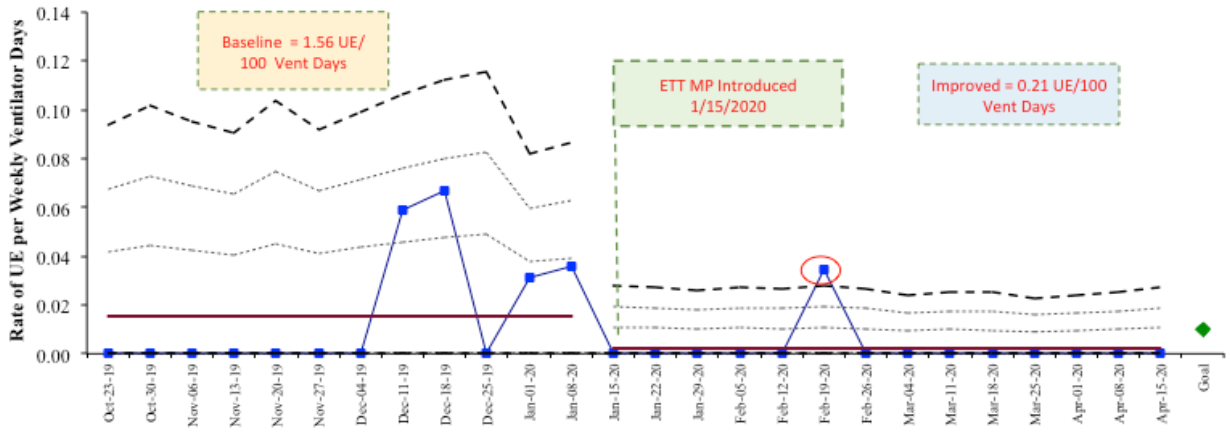
Note: SPC U chart reporting rate of UE starting January 1, 2018. The solid red line reflects the mean. The dashed black lines reflect first and second standard deviations. The bolder black dashed line reflects the upper control limit. A UE rate of < 0 is unattainable, eliminating the display of a lower control limit. Numerator: the count of UEs per month. Denominator: number of ventilator days per month. A month

starts January 1, 2018 and includes all days per month. A shift in means in November 2018 removes special cause variation.

The rate of UE was closer examined with equal weeks pre and post ETT MP introduction to reflect potential shifts in UE (Figure 3). The rate of UE in the 12 weeks pre ETT MP is 1.56 per 100 ventilator days and post 14 weeks is 0.21 per 100 ventilator days. There is one special cause of variation noted the week of February 19, 2020; the low rate of UE post bundle implementation results in any UE appearing as special cause.

Figure 3

Frequency of UE per Week Pre and Post ETT MP Implementation



Note: SPC U chart reflecting UE per week 13 weeks pre and 14 weeks post ETT MP bundle implementation. The solid red line reflects the mean. The dashed black lines reflect first and second standard deviations. The bolder black dashed line reflects the upper control limit. A UE rate of < 0 is unattainable, eliminating the display of a lower control limit. Numerator: the count of UEs per week. Denominator: number of ventilator days per week. A week is Wednesday-Tuesday starting October 23, 2019. A shift in means of UE pre and post ETT MP implementation removes special cause variation. One incidence of special cause variation noted February 19, 2020; the low rate results in any single UE appearing as special cause.

Development of the intervention, staff education, bundle implementation, and bundle audit criteria are listed in Table 1, based on PDSA cycle. The PDSA cycle 1 focused on development of the ETT MP and staff education. Key interventions included developing the interdisciplinary team, identifying evidence, drafting the ETT MP, and dissemination for staff education.

Table 1

PDSA Cycle Specific to Improvement and Intervention

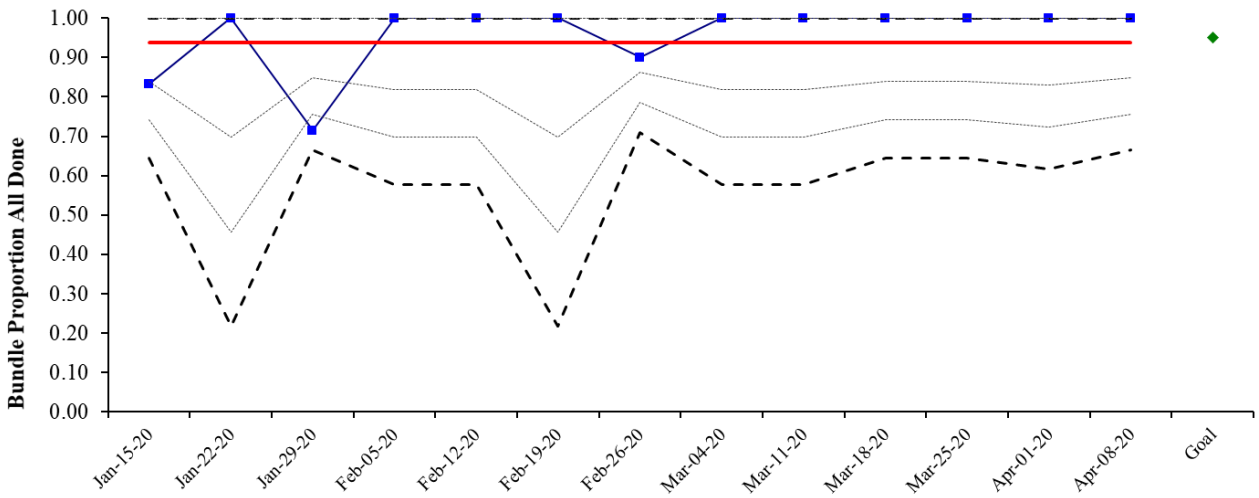
PDSA Cycle	Improvement Step	Improvement Group
PDSA 1	1. Determination of UE definition 2. Determination of UE rates 3. Determination of adequate education.	Interdisciplinary key stakeholders, PICU registered nurses and respiratory therapists
PDSA 2	1. ETT MP (bundle) trial initiation 2. Evidence of practice change 3. Impact on UE	PICU registered nurses and respiratory therapists
PDSA 3	1. Formal adoption 2. Adherence to the bundle	Institutional policy adoption committee, interdisciplinary key stakeholders, PICU registered nurses and respiratory therapists

Note: Evolution of PDSA cycle interventions.

In PDSA cycle 2, the ETT MP was incorporated into practice and staff audits were completed as a process measure. The adherence of staff to the ETT MP was tracked through audits and reflected on a SPC P chart (Figure 4). There are no incidences of special cause variation. The average adherence to the bundle reflected in audit was 94%. A total of 65 audits were collected from January 15 - April 15, 2020, meeting the goal of 20 audits per month. Of the audits, 7.7% did not adhere to the bundle: 1.5% incorrect securement, 3.1% inaccurate anatomic reference point documentation, and 3.1% missed high-risk situations (Table 2).

Figure 4

Adherence to the ETT MP Bundle



Note: SPC P chart demonstrating adherence to the ETT MP bundle. The solid red line reflects the mean. The grey lines reflect first and second standard deviations. The bolder black dashed line reflects the lower control limit. Adherence >100% is not attainable, eliminating the display of an upper control limit. Numerator: count of audits with all 'met' elements in a week. Denominator: number of audits completed in a week. A week is Wednesday- Tuesday, starting with January 15-January 21. Average adherence was 94%. No special cause variation noted.

Table 2

Incidence of N*onadherence to ETT MP* B*undle*

	Completed Audits	Securement	Anatomic Reference Point	High Risk Situation
January 15- 31	10	0	1	0
February	20	0	0	2
March	23	1	1	0
April 1-15	12	0	0	0
Total	65	1.54%	3.08%	3.08%

Note: Adherence to the ETT MP improved over the trial period. An adherence rate of 94% was achieved.

In PDSA cycle 3, the ETT MP was edited to reflect a recommendation, rather than requirement, of two licensed clinicians completing routine repositioning. This decision was based on key stakeholder input and assessment of UE rates below literature benchmark.

Correlations (Table 3) between variables in planned extubation and UE were completed using Pearson, pointbiserial, and phi correlation methods; p values did not change when

adjusting for non-parametric, non-linear distributions, or completing log-transformation. The following correlations were statistically significant: gender and ETT size 0.42 (p = 0.02), gender and weight 0.43 (p = 0.01), gender and age 0.37 (p = 0.03), weight and ETT size 0.97 (p = 0.00), ETT size and age 0.94 (p = 0.00), ETT size and ETT securement 0.58 (p = 0.00), and ETT out and ETT Protocol 0.94 (p = 0.00), weight and age 0.98 (p = 0.00), and weight and ETT securement 0.59 (p = 0.00).

Table 3

Correlations Between Planned and Unintended Extubations

Variables	1	2	3	4	5	6	7	8	9
1. Gender	-								
2. UE	0.13 (0.45)	-							
3. ETT Size	0.42 (0.02)*	0.10 (0.58)	-						
4. Weight (KG)	0.43 (0.01)*	0.07 (0.72)	0.97 (0.00)*	-					
5. Route[a]	-0.32 (0.07)	-0.28 (0.12)	-0.12 (0.53)	-0.13 (0.48)	-				
6. Diagnosis[b]	-0.14 (0.45)	0.10 (0.58)	-0.28 (0.11)	-0.31 (0.08)	-0.23 (0.19)	-			
7. Age in Years	0.37 (0.03)*	0.04 (0.81)	0.94 (0.00)*	0.98 (0.00)*	-0.10 (0.58)	-0.30 (0.09)	-		
8. Securement[c]	0.17 (0.35)	0.01 (0.96)	0.58 (0.00)*	0.59 (0.00)*	0.33 (0.06)	-0.33 (0.06)	0.554 (0.00)*	-	
9. ETT Procedure	0.19 (0.30)	0.94 (0.00)*	0.10 (0.58)	0.06 (0.74)	-0.30 (0.10)	0.17 (0.35)	0.04 (0.85)	0.02 (0.91)	-

Note. Reported as Pearson correlation. Significance level is 2 tailed. *p* reported in parenthesis after each correlation.

[a] Nasal or Oral

[b] Respiratory or Other

[c] AnchorFast or Tape

* $p < 0.05$. – same variables could not be compared.

As all historical UE data were collected from incident report, it must be acknowledged these rates may be under-reported. The total number of children requiring intubation each month was not obtained.

Discussion

Summary

The fourteen-week trial of the ETT MP bundle demonstrated 94% adherence to the ETT MP bundle with possible decreased rate of UE in this PICU. Adherence to the bundle improved over time, with 100% adherence for April 1-15, 2020 demonstrating continued adoption from early adopters and later adoption from previous change rejecters according to DOI. UE rates per 100 ventilator days for all years of data were well below the SPS goal of ≤0.95 per 100 ventilator days; achieving the aim of this project. High levels of adherence support continued low UE rates in this PICU (Lavallée et al., 2017). This combination of low UE rate and high ETT MP adherence makes UE less likely, which decreases the cost and length of stay as well as possibility of life threatening sequelae of UE (Lucas da Silva et al., 2017; Roddy et al., 2015).

Interpretation

Implementation of the evidence based ETT MP standardized care and reliably demonstrated almost 95% staff adherence to the bundle. Rates of UE continued to be well below benchmark and goals, supporting bundle practice changes maintaining the already low UE rates. The use of a bundle with three elements minimized actual change, increasing the likelihood of continued adherence beyond the audit period. Educational opportunities and staff adoption improved adherence to the bundle, demonstrating a commitment to safety and quality by staff.

The primary strength of this project is the high adherence to the ETT MP with a demonstrated improvement in adherence over time. High adherence to simple bundles has the potential to standardize processes, improve care, and prevent unwanted outcomes and the impact to cost of care and health (Lavallée et al., 2017; Resar et al., 2012). Although it can be argued the

historically low rates of UE dissuade the efforts to standardize practice, adherence to this change can continue to further decrease UE rates.

The ETT MP standardized the practice of RNs and RTs, using evidence to decrease variation in practice (Resar et al., 2012). This project developed a reporting and tracking system for UEs in this PICU, which allows for future tracking and understanding of UE in this center . While it is not standard to report rates of UE in the U.S., tracking rates of this critical patient safety event improves the dedication to quality and safety in this institution and may be of benefit in the future if reporting becomes required.

As previously mentioned RNs in this PICU are very familiar with collecting audits; this is both of benefit, due to familiarity with the process, and a potential hindrance due to audit burnout limiting completed audits. The goal of 20 audits/month was achieved to maintain reliability; the reported non-adherent categories may be inflated due to low sample size (Table 2). Periodic audits will likely be needed due to shifts in attention decreasing adherence to the bundle to maintain adherence.

Barriers to adherence were primarily cultural in nature, reflecting staff resistance to change, reinforced, by historical and perceived low rates of UE. Replication of this process may pose a challenge in differing environments due to inadequate staff, absence of buy-in from hospital and key committee members. Opportunity costs, such as adherence to central line associated blood stream audits and delirium audits were not assessed; however, it is of distinct possibility the focused attention to the ETT MP detracted from these other areas. An important note is this project was extremely low cost to implement; products utilized for securement of ETT were not changed.

The rates of UE as demonstrated in Figure 2 demonstrate a change in means and stability pre and post ETT MP intervention. Historical data suggests a change in means in November of 2018 occurred due to special cause variation. It is possible to attribute this special cause to the introduction of a commercial securement device for larger ETT and increased attention to ETT securement. UE rates in 2019 are lower than 2018 and 2020 to date, without significant variation in the number of ventilator days. The reason for this change in rate is unclear and could be attributed to a variety of upstream and downstream factors. Upstream factors include total number of children intubated, changes in sedation practice, or changes in staffing. Downstream factors potentially impacting the rates include: underreporting of UE and individual practices of ETT management. Further data collection is needed to understand this process more completely.

Limitations

This quality improvement effort was located in a single center mixed cardiovascular medical-surgical PICU; the size and nature of a mixed ICU limits the generalizability to other institutions. Additionally, it must be noted the nursing staff in this PICU is new to being primary leaders and participants in quality improvement efforts. We did not have true measurement of balancing measures including staffing, skin integrity, duration of mechanical ventilation, or cost of ICU stay. Although formal definitions were established, self-report remains the primary way to communicate a UE to providers and nursing leadership allowing for the possibility of underreporting of UEs. External validity and generalizability is compromised due to lack of mandatory tracking of UE in the U.S. (Lucas da Silva et al., 2017).

The ETT MP bundle intervention data was collected over fourteen weeks, while there are two years of historical data related to UEs collected. Historical UEs were reported exclusively through incident report; it remains possible the incidence of historical UEs is under reported in

this PICU. The correlations (Table 3) were completed comparing present performance to historical controls; we were unable to adjust for differences in time or unmeasured confounders. The sample size of this initiative is limited, which greatly limits statistical testing due to violations and non-normal distributions. The organizational culture in this PICU does not have a history of support for implementation of changes. This project was generally adopted with some 'continued rejection' as is expected with the DOI theory in Figure 1, contributing to inadequate ETT MP adherence and limited audit collection (Crowell, 2016). Understanding of this culture and tilt towards rejection could have been addressed through formal exploration of RN and RT perceptions of the bundle.

The ETT MP bundle did not address sedation, which is a critical element of preventing UE. A sedation protocol is followed in this PICU, with a shift in primary agents from fentanyl and versed to fentanyl and dexmedetomidine in June 2018. We did not collect information related to number of children intubated during the study period or their length of ventilator days. The reporting process continues to impact internal validity as self-report has the potential bias towards early adopters. The audit process was not connected to patient identifiers, while this limited chart review of audited patients it does limit the selection bias and increased opportunity for all ventilated patients to be audited.

Conclusions

To date, there is limited information about UE in the PICU environment. While there may be fewer challenges in PICUs compared to neonatal ICUs, due to anatomy and size, UE remain a key indicator of quality and safety in the ICU environment. Minimizing UE has high potential to limit morbidity and improve the cost of care (Lucas da Silva et al., 2018; Roddy et al., 2015). To my knowledge this is the first analysis examining adherence to an UE bundle in a

PICU, using the bundle approach to improving care (Resar et al., 2012). These findings have implications suggesting the use of a bundle to decrease UE events is feasible and cost effective. The use of a simple evidence based bundle is necessary to address current costs of healthcare and global goal to decrease ICU stay times (Resar et al., 2012; Roddy et al., 2015). The SPS UE Bundle (2019) is well suited to be adopted in different institutions as it allows for institutional specific standards within the key bundle practice areas, is low cost, and sustainable.

Further study must be centered on implementation of UE bundles and impact on length of stay in ICU and in the hospital, total ventilator days, and costs of care. Additionally, there remains no best practice recommendations for ETT securement in children or adults with respect to oral and skin integrity, frequency of ETT migration, and UE rate (Lucas da Silva et al., 2018). Exploration of barriers related to UE bundle adherence, specifically the impact of RN and RT staffing on adherence to the high-risk situation protocol is necessary for patient safety and economic impact.

This protocol will be submitted for formal adoption within the institution and included in annual RN and RT competencies. A checklist will be devised for new hire education to demonstrate competency of ETT securement per unit standards.

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