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An Interdisciplinary Initiative to Reduce Unplanned Extubations in Pediatric Critical Care Units

abstract

OBJECTIVE: Unplanned extubations in pediatric critical care units can result in increased mortality, morbidity, and length of stay. We sought to reduce the incidence of these events by reliably measuring occurrences and instituting a series of coordinated interdisciplinary interventions.

METHODS: This was an internal review board–approved quality improvement project. Data were prospectively collected from the electronic medical record, and analyzed over 24 months (January 1, 2009–December 2010), and divided into 3 periods: baseline (9 months), intervention with multiple rapid improvement cycles (8 months), and postintervention (7 months). Interventions included standardization of endotracheal tube taping practices upon admission, improved patient handoffs, systematic review of unplanned events, reexamination of sedation practices, and promotion of transparency of performance measures.

RESULTS: The PICU experienced 21 events in the 9 months before the initiative, 13 events over the 8-month intervention period, and 5 events in the 7-month postintervention period. The cardiac intensive care unit (CICU) experienced 11, 4, and 0 events, respectively. Mean event rates per 100 patient days for each interval were 0.80, 0.50, and 0.29 for the PICU and 0.74, 0.44, and 0 for the CICU. Monthly event rates for the CICU were significantly different by using the Kruskal-Wallis test ($P < .05$) but not for the PICU ($P = .36$).

CONCLUSIONS: Through accurate tracking, multiple practice changes, and promoting transparency of efforts and data, an interdisciplinary team reduced the number of unplanned extubations in both ICUs. This reduction has been sustained throughout the postintervention monitoring period. *Pediatrics* 2012;129:e1594–e1600

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KEY WORDS

intensive care units, unplanned extubation, pediatrics, quality improvement

ABBREVIATIONS

CHC—Children's Hospital Colorado
CICU—cardiac intensive care unit
CVOR—cardiovascular operating room
EMR—electronic medical record
ETT—endotracheal tube
PDSA—Plan-Do-Study-Act model

All the authors have made substantive intellectual contributions to the study and meet the following criteria: (1) substantial contributions to conception and design, acquisition of data, or analysis and interpretation of data; (2) drafting the article or revising it critically for important intellectual content; and (3) final approval of the version to be published.

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Unplanned extubations in pediatric critical illness may result in increased mortality and morbidity in already vulnerable populations.^{1,2} Severe hypoxia leading to end organ injury, aspiration, and airway trauma are among the serious adverse consequences of emergent unplanned reintubation. Within the critical care literature, there are many examples of initiatives directed at reducing this unintended occurrence.^{1–5} Patients experiencing an unplanned extubation may be at higher risk for pneumonia, prolonged ventilator requirement, and increased length of stay.^{6–9} Initiatives to reduce these events have become a mainstay of quality improvement and patient safety programs in intensive care units. Guidelines and recommendations have recently been published for reducing unplanned extubations in pediatric critical care units.¹⁰

Before 2009, Children's Hospital Colorado (CHC) did not have a formal process to systematically track unplanned extubations in our critical care units. The CHC cardiac intensive care unit (CICU) and pediatric intensive care unit (PICU) determined that unplanned extubations were an area of concern due to (1) unreliable data collection and tracking, (2) a subjective impression of an increase in these events in both units, (3) the risk of an adverse outcome, and (4) a lack of awareness of the overall incidence and importance of these events within the units.

The quality improvement and safety leadership teams of both the CICU and the PICU sought to improve clinical practice and proactively mitigate the risk for patient harm related to unplanned extubations. We report an interdisciplinary quality improvement initiative designed by using the model for improvement adapted from the Institute for Healthcare Improvement to reduce the overall incidence on unplanned extubations in both units.

METHODS

Setting

Children's Hospital Colorado on the Anschutz Medical Campus of the University of Colorado is a free-standing, pediatric academic center that serves the Rocky Mountain states and is a regional referral center for this geographic area. The 26-bed PICU has ~1500 admissions per year, and the 16-bed CICU has ~650 admissions a year. These are separate ICUs, each with its own multidisciplinary staff.

Improvement Team

The multidisciplinary team consisted of providers from the CICU and the PICU including physicians, nurses, respiratory therapists, as well as members from the hospital-wide Quality and Patient Safety Department, Epidemiology, and Clinical Informatics.

Study Background

This was an institutional review board–approved quality improvement study for which consent was waived. For a 24-month period, January 2009 through December 2010, all unplanned extubations were documented by respiratory therapists and bedside nurses via the electronic medical record (EMR). In addition, total ventilator days for both units were also recorded by obtaining ventilator-use data from the EMR. For the first 9-month baseline period (January–September 2009), there was no formal change in practice within the ICUs. Data collected included time of day, patient age, patient diagnosis, and disposition: reintubated or remained extubated. From the data, it was possible to construct a report on the incidence and characteristics of the events.

Interventions

During the 8-month intervention period (October 2009–May 2010), in addition to documentation in the EMR, a series of clinical practice improvements were

put into practice. First, all patients admitted to either ICU from the operating room or an outside facility, including emergency departments, underwent retaping of the endotracheal tubes in a uniform manner. Second, in the CICU, handoffs from the cardiovascular operating room (CVOR) were standardized and included discussing the endotracheal tube position by the anesthesiologist and visibly recording it at the bedside. Third, all unplanned extubations were reviewed by a short root cause analysis that specifically addressed the casual and contributing factors surrounding the event to identify improvement opportunities. Data collected in the root cause analysis included time of day of the event, level of sedation of the patient, and acuity of nursing and respiratory therapist assignments at the time of the event. Fourth, the level of sedation was specifically addressed during daily rounds as it related to extubation readiness. Fifth, both units began publically displaying a large whiteboard that recorded “days since the last adverse event.”

Statistical Analysis

Monthly unplanned extubation rates for each unit were calculated by dividing the number of unplanned extubation events by the number of patient ventilator days. Average rates for each of the 3 periods (baseline, intervention, and postintervention) were calculated by dividing the sum of all unplanned extubation events by the total patient ventilator days. Differences in rates across all 3 intervals were examined by using the nonparametric Kruskal-Wallis 1-way analysis of variance. Differences in rates between the preintervention and postintervention intervals were examined by using the nonparametric Mann-Whitney-Wilcoxon rank-sum test. All statistical analyses were performed by using IBM SPSS Version 18 (IBM Corporation, Somers, NY). Statistical

process control charts were created by using ChartRunner Version 3.6 (PQ Systems, Dayton, OH).

RESULTS

Patient characteristics for both the CICU and the PICU during the study time are displayed in Table 1. The differences between the patient populations of each unit is demonstrated; the PICU has more admissions per year, more total ventilator days per year, and a longer average ventilator time per ventilated patient. Although the rate of decline in unplanned, extubation events in the PICU did not achieve statistical significance, there is a clear decrement in the total number of events as well as the mean event rate per month per study period.

Figures 1 and 2 demonstrate the monthly rate of unplanned extubations per 100 patient-days in each unit, plotted as run charts.¹¹ Included in Fig 1 is the timing of each quality improvement change during the intervention interval. Means are calculated separately for the baseline, intervention, and postintervention periods. Figure 1 shows that the overall mean monthly event rate decreased from the baseline to intervention to postintervention periods. The rate of unplanned extubations in the CICU remained zero for the final 9 months of the study, which indicates a sustained change in the unplanned extubation rate during the postintervention period. Audits were performed on compliance with the cardiovascular operating room

to CICU handoff protocol: over a 3-week period, 25 handoffs were silently observed by a nurse observer, and in 24 of the handoffs, the protocol was used (96%).

Using monthly rates from all 3 periods, the *P* values were .017 for the CICU and .315 for the PICU. Removing the monthly rates observed during the intervention period and by using the Mann-Whitney-Wilcoxon rank-sum test for the preintervention and postintervention, monthly rates did not change the results: CICU *P* = .008; PICU *P* = .21.

In the CICU, 3 of the 15 patients experiencing an unplanned event were nasally intubated, and 12 were orally intubated. In the PICU, all but 1 of the unplanned events occurred in a patient who was orally intubated (Table 1). Of note, the average length of stay in the PICU during the study period was calculated as shorter than the median ventilator time. There are 2 explanations for this: (1) there were many more nonventilated patients than ventilated patients during the study. (2) Part of the study occurred during the H1N1 influenza outbreak, and a number of the ventilated patients in fact had a prolonged course of mechanical ventilation.

DISCUSSION

In phase 1 of a 3-staged prospective approach, we were able to identify areas for potential improvement to reduce unplanned extubations. In the second phase, we were able to test interventions to address these weaknesses. In the final stage, we demonstrated that continuing practice changes previously initiated resulted in a statistically significant decrease in unplanned extubations in the CICU and a consistent decrement in the PICU. The success of this quality improvement initiative to reduce the incidence of unplanned extubations in 2 distinct critical care units was predicated on identifying unit specific and discipline specific champions. These members of the team were

TABLE 1 Patient Characteristics and Key Outcome Variables

	Baseline 1/2009–9/2009 9 mo	Intervention 10/2009–5/201 8 mo	Postintervention 6/2010–12/2010 7 mo	Study period 1/2009–12/2010 24 mo
CICU				
Admissions	515	377	405	1297
Ventilator days	1492	913	1113	3518
Ventilated patients	406	262	297	965
Nonventilated patients	109	115	108	332
No. of events	11	4	0	15
Unplanned events orally intubated				12
Unplanned events nasally intubated				3
Mean event rates, per mo	1.2	0.5	0	0.63
Average length of stay, d	4.9	5.1	5.2	5.1
Average length of vent time, d	2.4 (57.9 h)	1.9 (44.3 h)	1.6 (37.1 h)	2 d (48.2 h)
Reintubation for unplanned events	1	2	0	3 (15) (20%)
CPR for unplanned events	1	0	0	1 (15) (6.7%)
PICU				
Admissions	1191	1142	993	3326
Ventilator days	2611	2620	1719	6951
Ventilated patients	495	499	384	1378
Nonventilated patients	696	643	609	1948
No. of events	21	13	5	39
Unplanned events orally intubated				38
Unplanned events nasally intubated				1
Mean event rates, per mo	2.3	1.6	0.7	1.6
Average length of stay, d	3.9	4.2	3.5	3.9
Average vent time all patients, d	4.6 (111 h)	4.9 (117 h)	3.4 (82 h)	4.3 d (103 h)
Reintubation for unplanned events	15	5	3	23 (39) (59%)
CPR for unplanned events	0	0	1	1 (39) (2.6%)

CPR, cardiopulmonary resuscitation.

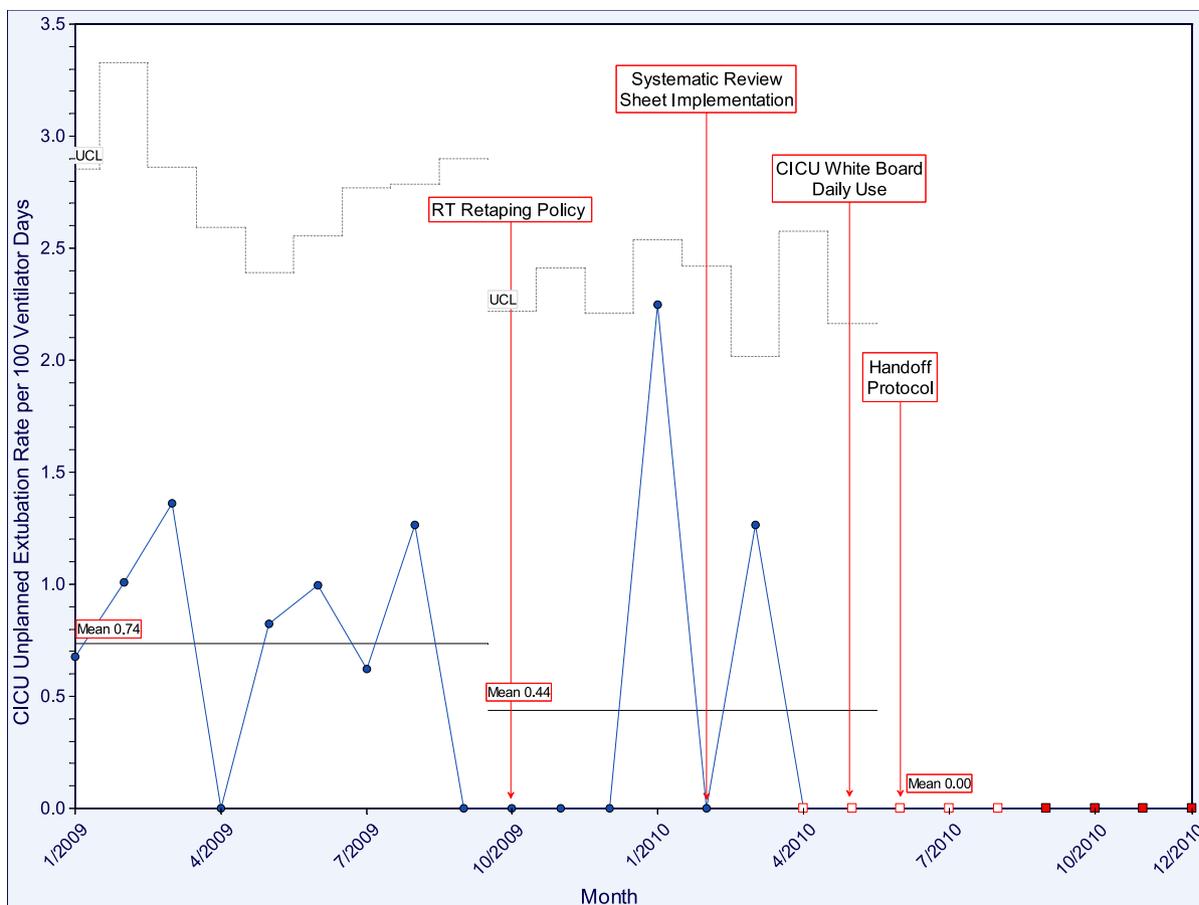


FIGURE 1

Statistical process control (SPC) u chart of CICU monthly unplanned extubation rate per 100 ventilator days. Average rates are calculated separately for baseline, intervention, and postintervention periods. UCL, upper control limit.

the key drivers of accurate data collection and were responsible for introducing interventions. We were committed to fostering a sense of interdisciplinary interaction within the team, which we understood to mean a collaborative blending of practices of each discipline (nurse, physician, respiratory therapist, patient safety) involved.¹²

There are many previously described interventions effective in reducing unplanned extubation events. These include instituting a standardized sedation algorithm, limiting nursing workload and nurse per patient acuity, endotracheal tube fixation, the use of restraints, and improvements in interdisciplinary team communication.^{1–3,13–15} We designed our program strategy by using the Institute of Health Care Improvement's

Plan-Do-Study-Act model (PDSA) as our formal quality improvement methodology.^{16,17} In the Planning stage of the first PDSA cycle, we first needed to identify baseline incidences of unplanned extubations. Root cause analysis methods were applied to each unplanned extubation event and provided the analytic framework for identifying what may have contributed to or shaped the event. It also provided the opportunity for process improvement. Both units consistently reported events associated with contributing to unplanned events as (of decreasing frequency) loose endotracheal tube (ETT) taping, patient's sedation status, and oral and airways secretions. Infrequently, tonguing or coughing out the ETT was noted as a cause of an unplanned event.

In postevent reviews overall daily nursing and respiratory therapy assignment, and unit acuity were particularly examined.

Key drivers of quality improvement were accurate data collection and tracking; standardization of taping and securing of the ETT on arrival to the units; consistency of event reviews of instances unplanned extubations; in the CICU, handoff protocols for operating room to ICU patient transfer; and a commitment to transparency and improved visibility of our efforts and results. Both critical care units determined that transparency of our efforts was desirable, whether the results were favorable or not.

After the first cycle and the institution of standardized retaping practice, both units experienced an impressive absolute

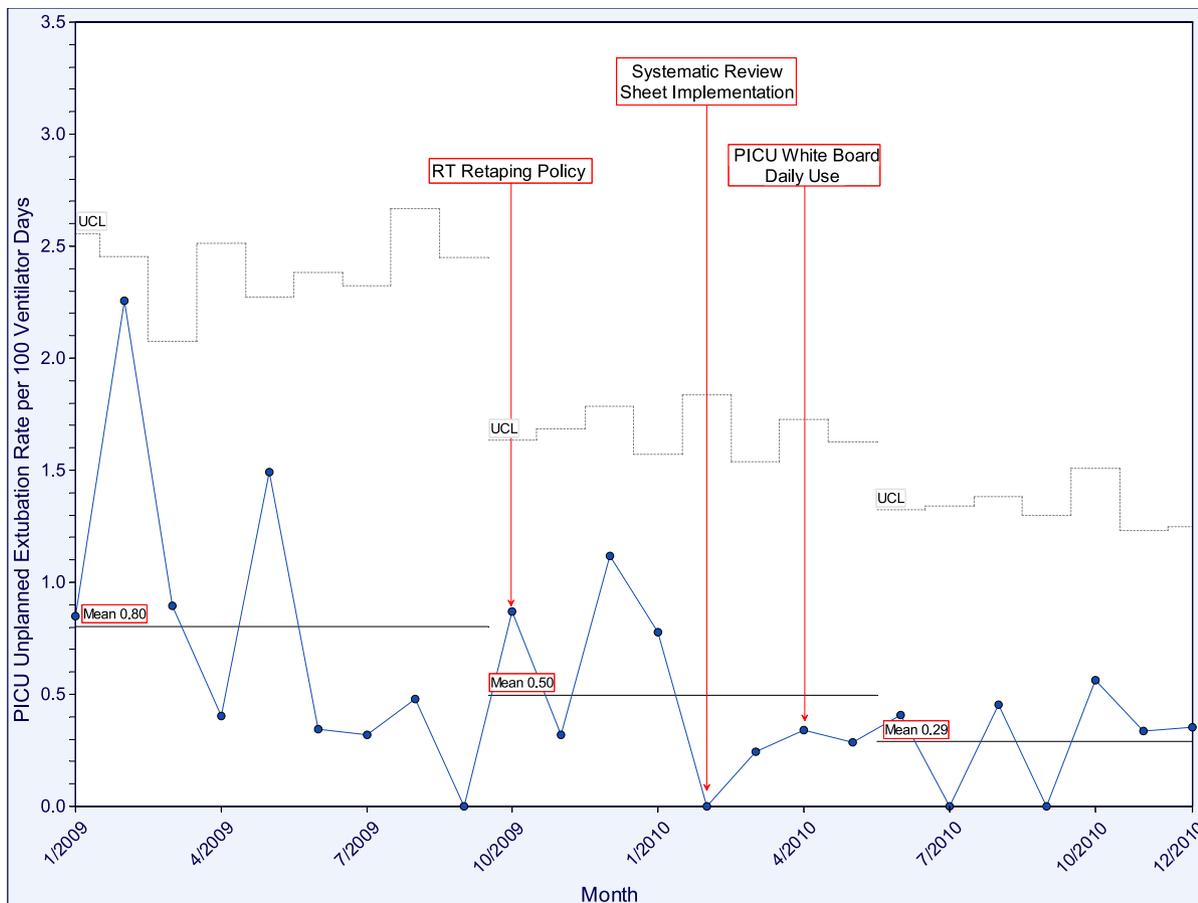


FIGURE 2 Statistical process control (SPC) u chart of PICU monthly unplanned extubation rate per 100 ventilator days. Average rates are calculated separately for baseline, intervention, and postintervention periods. UCL, upper control limit.

reduction of unplanned events. The CICU in particular, experienced an additional dramatic event reduction, to zero. This occurred in the third cycle, coincident with adoption of a cardiovascular operating room to CICU handoff protocol. This handoff protocol included attention to the ETT position before exiting the OR, 1 person speaking at a time while giving a report to the team in the CICU, verbal description of airway anatomy, tube placement, tube location, respiratory status during the case, and rapid and consistent ordering of a postoperative flat plate chest radiograph to check, among other things, ETT placement before retaping.

The first planning phase of this initiative addressed reliable event reporting and consistent data collection. This phase

also identified the first obstacle to address in this multidisciplinary initiative: ensuring reliable methods of data collection. Until we were able to identify consistently the number of unplanned extubation occurrences in both critical care units, any steps aimed at reducing the absolute numbers were not possible. Successful tracking of events depended on bedside nurses and respiratory therapists reliably indicating events on the EMR. Clinical Informatics extracted this information and constructed monthly reports. These reports were distributed to unit leaders and discussed at quality improvement meetings in the ICUs as well as hospital-wide. We anticipated that the EMR documentation tools will improve the ability to capture and track patient safety and outcomes data.

Subsequent PDSA cycles identified the lack of standardization of ETT taping practice as an area of specific concern. We found that our lack of a standardized ETT taping practice for intubated patients transferred into the critical care units and differential positioning placed the patient at a higher risk for self-extubation. A review of our practice also revealed that the ETT taping did not occur in a timely manner when the patient was deemed likely to be extubated quickly. In reality, extubation plans change and are frequently delayed, and there often was no revision of securing of the ETT after a decision to delay extubation had been made. These clinical practices became obvious targets for process change. Along with a consistent method and timing of taping the ETT, we also

instituted nursing documentation of tube placement in the electronic flow sheets.

As has been previously described in the literature,^{5,15} we also found that the level of sedation contributed to the occurrence of unplanned extubations. We renewed emphasis on addressing the level of sedation and clarifying a daily sedation care plan for each patient. Rounds in both units include discussion of sedation level, sedations goals, and sedation weaning plans on all ventilated patients. Rounding discussions include characterizing opioid and benzodiazepine withdrawal scores, and use of the previously described Withdrawal Assessment Tool.¹⁸

Finally, a public display of the initiative via a dry erase white board in each unit and the real-time status updates raised awareness of the effort among the staff. The display also increased awareness with parents and families of patients. These results are displayed with other internal measures of quality improvement and safety. In promoting transparency of these unit-based efforts, positive results are a cause for celebration, such as when the number of days since the last event is high, as well as scrutiny when the number of days since the last event is low. In either case, the initiatives are difficult to ignore because of the heightened visibility.

We sought to achieve sustainability of these efforts with ongoing reassessment, reinforcement, and reeducation around the initiative. Long stretches of “no events” are recognized by the hospital administration and within the specific unit. Collaboration among the critical care units is fostered by a multiunit critical care practice council in which initiatives such as this one are presented. The work has also been extended to the NICU.

Although our interventions resulted in a demonstrable decrease in the mean unplanned extubation rates in both the

CICU and the PICU, only the CICU reached statistical significance. We hypothesize this may be because of unit-specific characteristics. The CICU has a higher percentage of neonatal admissions (~20% of all admits), and it is standard of practice to nasally intubate many of the neonates and infants. Children in the PICU are rarely nasally intubated, in part because of age, as well as the number of patients with confirmed or suspected cranial or facial trauma, in whom this would be contraindicated. The PICU also has a more variable patient population in terms of diagnoses and conditions that require intubation, specifically upper and lower airway disease and brain-injured patients, all of whom may be more susceptible to an unplanned extubation event because of copious oral secretions or inability to handle these secretions. However, when we analyzed the data by projecting the preintervention mean across the intervention and postintervention periods, both the CICU and PICU triggered an “under the mean” run rule during the last 9 and 12 months, respectively. The CICU statistical process control chart shows 9 consecutive months of zero events.

It was not possible to determine whether rates of compliance with interventions within each unit also contributed to the difference in rates of events. The data on this were limited, although compliance with the cardiovascular operation room–CICU handoff protocol was high. Perhaps, as important as compliance with the handoff protocol, this intervention (or practice) was not in place in the PICU during the study period. It is also true that the PICU experiences transfer of care and handoff of critically ill children from many more sources than the CICU: multiple operating rooms and anesthesiologists compared with 2 CVORs a limited number of pediatric cardiac anesthesiologists, and a catheterization laboratory. Finally,

the PICU has more beds and a higher yearly census and necessarily more providers: including nurses, physicians, and respiratory therapists. Despite a standardization of taping endotracheal tubes, there may be less uniformity of practice overall within the PICU.

Although the successful reduction of events is no doubt in part related to the specifics of the units at CHC, we believe the basic tenets of the project are capable of being reproduced in other institutions. The success of this effort rests on objective scrutiny of practice using high-quality, reliable measures; review of all potential contributing practices; and creating awareness. For example, it was not until we identified the incidences over the first 10-month period that we realized there was significant variability in ETT taping practices. We believe that without the principle of interdisciplinarity that allowed the multidisciplinary teams to interact efficiently, these outcomes would not have been possible.

There are limitations to this quality improvement project. This is a single-center study, although it was performed in 2 separate and autonomous units within the same institution. This initiative details events over a 24-month period. We undertook limited auditing of unit-specific compliance with the practice interventions; more robust audits of compliance could have helped to identify specific drivers of improvement. Finally, other pediatric critical care environments will likely present challenges entirely different from those found in our study. Interventions we found to be effective will likely require adaptation to meet specific institutional characteristics.

CONCLUSIONS

Through collaboration and multiple practice improvements and interventions,

an interdisciplinary team was able to reduce the number of unplanned extubations in the both the CICU and the PICU. Future challenges remain, such as how to “lock in” the

sustainability of this effort, as well as identify particular high-risk patients who remain vulnerable to experiencing an unplanned extubation event.

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