

Reducing Unplanned Extubations in the NICU

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KEY WORDS

neonate, preterm infant, unplanned extubation

ABBREVIATION

PDSA—Plan-Do-Study-Act

Ms Merkel contributed to the data collection and analysis, helped with the development of potentially better practices, and reviewed and revised the manuscript; Ms Beers contributed to the development and implementation of potentially better practices, assisted with data collection, and reviewed and revised the manuscript; Ms Lewis contributed to the development of potentially better practices and reviewed and revised the manuscript; Ms Stauffer contributed to the development of potentially better practices, assisted with data collection, and reviewed the manuscript; Dr Majsce contributed to the data analysis and reviewed and revised the manuscript; Dr Kresch identified the need for and conceptualized the quality improvement project, contributed to the development and implementation of potentially better practices, assisted with data collection and analysis, drafted the initial manuscript, and reviewed and revised the manuscript; and all authors approved the final manuscript as submitted.

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abstract

BACKGROUND AND OBJECTIVES: Unplanned extubation can be a significant event that places the patient at risk for adverse events. Our goal was to reduce unplanned extubations to <1 unplanned extubation per 100 patient-intubated days.

METHODS: All unplanned extubations in the NICU beginning in October 2009 were audited. Data collected included time of day, patient weight, and patient care activity at the time of the event. Bundles of potentially better practices were implemented in sequential Plan-Do-Study-Act cycles. Rates of unplanned extubation (number per patient-intubated day) for each month were analyzed by using control charts, and causes of unplanned extubation were analyzed by using Pareto charts.

RESULTS: We found a significant decrease in the unplanned extubation rate after implementation of the first bundle of potentially better practices in May 2010 (2.38 to 0.41 per 100 patient-intubated days). Several more Plan-Do-Study-Act cycles were conducted to sustain this improvement. A persistent reduction in the unplanned extubation rate (0.58 per 100 patient-intubated days) began in February 2013. Causes included dislodgement during care and procedures and variation in the fixation of the endotracheal tube. The majority of events occurred in very low birth weight infants during the daytime shift.

CONCLUSIONS: Unplanned extubations in the NICU can be reduced by education of staff and by implementing standard practices of care. Sustainability of any practice change to improve quality is critically dependent on culture change within the NICU. We suggest that the benchmark for unplanned extubation should be a rate <1 per 100 patient-intubated days. *Pediatrics* 2014;133:e1367–e1372

Many infants admitted to the NICU require invasive ventilation through the use of an endotracheal tube. Unplanned extubations are one complication that can cause rapid cardiorespiratory deterioration and other adverse effects, such as airway trauma, subglottic stenosis due to repeated intubations, and ventilator-associated pneumonia.^{1–3} Unplanned extubations are relatively frequent, representing the fourth most common adverse event in North American NICUs.⁴ The incidence of unplanned extubations in the NICU ranges from 1% to 80%,^{5–8} and the rate of unplanned extubations ranges from 0.14 to 6.6 per 100 patient-intubated days.^{1,2,5,7,8} Compared with data from PICUs, unplanned extubations in neonatal patients occur 2 to 3 times more frequently.⁹ Potential reasons for this increased incidence include longer duration of intubation, shorter length of the trachea in neonates compared with older children, the use of uncuffed endotracheal tubes in neonates, and less routine use of sedation and muscle relaxation, as well as time spent out of bed while being held by parents. Factors that contribute to unplanned extubations include method of fixation of endotracheal tubes; procedures such as weighing and suctioning; and agitation of the patient, resulting in rapid movement of the head.^{2,8}

Although benchmark data exist for PICUs in terms of unplanned extubations¹¹, there are no such national data on unplanned extubations for NICUs. After noting what appeared to be a high incidence of unplanned extubations in our NICU during the last 3 months of 2009, we began the present quality improvement project with the aim of reducing unplanned extubations by developing a bundle of potentially better practices implemented in successive Plan-Do-Study-Act (PDSA) cycles. Our initial observations regarding reasons for unplanned extubations were that the

method of securing the endotracheal tubes was not consistent or standardized and that staff members were performing procedures (eg, weighing) on intubated infants without assistance. Our goal was to achieve <1 unplanned extubation per 100 patient-intubated days within the first year after the identification of the need for improvement. This rate has been identified as the benchmark for PICUs.^{10,11}

METHODS

All infants admitted to the NICU at the Penn State Hershey Children's Hospital who required invasive mechanical ventilation were monitored as part of this quality improvement project. Prospective data were collected by an interdisciplinary team of nurses, physicians, and respiratory therapists. Data collected for each unplanned extubation included the time of day, the patient weight, patient care activity at the time of the event, and any other comments related to the event. Data for total patient ventilated/intubated days were collected from reports generated by using the electronic medical record. An unplanned extubation was defined as dislodgement or removal of the endotracheal tube from the trachea in a patient receiving invasive mechanical ventilation at a time that was not specifically intended or ordered by a physician. The Human Subjects Protection Office (institutional review board) at Penn State Hershey Medical Center granted an exemption for this project because it was conducted to implement and evaluate practices to improve the quality of patient care.

The multidisciplinary team developed several bundles of potentially better practices, including: (1) instituting the standard practice that at least 2 licensed professional staff members participate in procedures such as re-taping and securing endotracheal tubes, weighing, and transferring the patient out of bed; (2) placement of alert cards at the

bedside indicating the risk level for an unplanned extubation, the security of the endotracheal tube, and the depth of placement at the gums along with documentation of endotracheal tube position and proper security by both nursing and respiratory therapy staff during routine care; and (3) the use of a commercially available product to optimally secure the endotracheal tube. These potentially better practices or process changes were instituted sequentially in 2010 and 2011 (cycles 1–3) (Table 1).

Continuing education of staff was provided incrementally throughout 2010–2012 by staff experts (ie, “champions”). In addition, a real-time analysis form, which was completed by the staff (registered nurses, respiratory therapists, and physicians) caring for the infant at the time of the event, was created in August and September, 2012, in which many potential causes of unplanned extubations were uncovered by the clinical team. These forms were reviewed by the leadership team (neonatologist, nurse manager, and respiratory clinical specialist) to identify any root cause(s) for each unplanned extubation (cycle 4). The most recent process change included the implementation of a centrally located display of the days since last unplanned extubation (which is discussed and updated daily during a brief meeting of medical and nursing staff) and a practice change of placing mittens or socks on infants' hands for intubated patients >34 weeks' postmenstrual age (cycle 5).

The rate of unplanned extubation was calculated as the number of unplanned extubations per 100 patient-intubated days. Pareto charts were constructed to analyze potential reasons for unplanned extubations that occurred between October 2009 and December 2012. Statistical process control analyses were performed to evaluate variation in the process and to determine the effectiveness of each intervention

made. Due to the varying areas of opportunity in each subgroup (patient-intubated days per month) and discrete outcome data collected, a U chart was constructed. Means and control limits were calculated by using statistical process control methods that conformed to U chart primary assumptions¹² using Minitab statistical software version 16 (Minitab Inc, State College, PA).

RESULTS

In October through December 2009, there were 22 unplanned extubations and 926 patient-intubated days, yielding a rate of 2.4 per 100 patient-intubated days (baseline period from October 2009 through December 2009) (Table 1). The first of 5 process improvement PDSA cycles began in January 2010. This action included staff education about the frequency and significance of unplanned extubations, making security of the endotracheal tube a high priority whereby nurses and respiratory therapists regularly assessed the tape and endotracheal tube security. In addition, a guideline was developed in which we required that at least 2 licensed professional staff be involved in retaping an endotracheal tube or during any procedures, such as weighing, for any patient who had an endotracheal tube. This process resulted in all respiratory therapist and registered nurse staff members completing educational in-services and, all staff followed the guideline of having 2 licensed staff members involved in procedures. As shown in the control chart in Fig 1, the rate of unplanned extubations declined over the next 9 months compared with the baseline period in 2009. Staff members were intermittently reminded of the importance of these process improvements. Figure 1 displays 7 consecutive months (May–November 2010) during which the unplanned extubation rate was below the mean, indicating a trend for a decrease in the unplanned extubation rate

TABLE 1 Summary of Process Changes in PDSA Cycles

| PDSA Cycle | Date | Process Change | UE (n) | Mean UE Rate |
|------------|--------------------|--|--------|--------------|
| Baseline | Oct 2009–Dec 2009 | Data collection; develop potentially better practices | 22 | 2.4 |
| Cycle 1 | Jan 2010–Nov 20-10 | Two qualified people involved in procedures (eg, retaping, weighing); staff education | 15 | 0.8 |
| Cycle 2 | Dec 2010–Aug 2011 | Airway alert cards at bedside; documentation of ETT position and security | 27 | 1.4 |
| Cycle 3 | Sep 2011–July 2012 | Use of commercially available ETT-securing product | 25 | 1.8 |
| Cycle 4 | Aug 2012–Jan 2013 | Real-time analysis of each event, leadership RCA review | 13 | 1.1 |
| Cycle 5 | Feb 2013–present | Display “days since last UE” and daily review; use of mittens for infants >34 weeks’ postmenstrual age | 13 | 0.6 |

ETT, endotracheal tube; RCA, root cause analysis; UE, unplanned extubation.

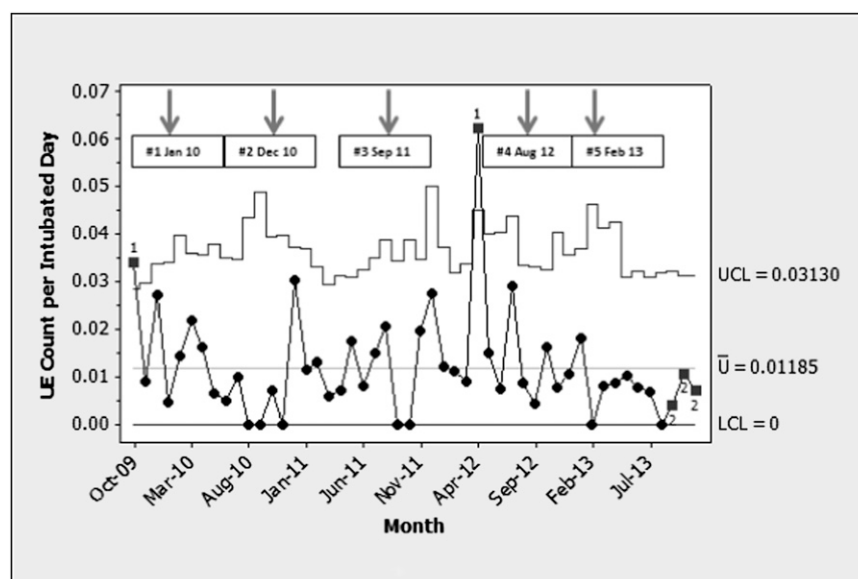


FIGURE 1

Control chart (U chart) for unplanned extubations (UEs) from October 2009 to November 2013. Solid line depicts the mean UE rate (number of UEs per patient-intubated day) for the entire period. Gray line represents the upper control limit (UCL; 3 σ above the mean). Tests were performed with unequal sample sizes. LCL, lower control limit.

after the first process change was implemented in January 2010.

The second process change, which was implemented in April and May 2011, included the placement of airway alert cards at the bedside of each infant who was intubated and mechanically ventilated. Yellow cards signified a general risk for unplanned extubation; red cards signified a very high risk for unplanned extubation, based on weight <1000 g, previous repair of tracheoesophageal fistula, history of previous unplanned

extubation or difficult intubation, anomalies of the face or airways, and patients receiving extracorporeal membrane oxygenation. During this process change, we also implemented a standardized method of taping endotracheal tubes and created a place to document artificial airway placement and security in the electronic medical record. Random audits of these process changes demonstrated that all infants had the airway alert cards at the bedside and respiratory therapist staff had documented

the endotracheal tube position and security in the electronic medical record. Despite these changes, there was no significant change in the rate of unplanned extubations, which remained at a median value of 1.03 per 100 patient-intubated days through the end of 2011 (Fig 1).

In the fourth quarter of 2011, the third process change introduced the use of a commercially available device for securing the endotracheal tube (NeoBar; Neotech, Valencia, CA). Before this PDSA cycle, all endotracheal tubes were secured with the use of tape; after institution of the use of the device, >90% of patients had their endotracheal tubes secured with the device. Unplanned extubations remained unchanged in the first quarter of 2012 compared with the fourth quarter of 2011, but there was a significant increase in unplanned extubations in April 2012; the rate of unplanned extubation was above the upper control limit, signaling a special event had occurred (Fig 1). There were several potential causes that led to the increase in unplanned extubations in April 2012, including endotracheal tube dislodgement during care and procedures (suctioning, weighing, retaping, and repositioning the infant), lack of familiarity with a newly introduced commercially available device to secure the endotracheal tube (reflecting the learning curve of this change in practice), and variability in practice of assessing and reinforcing loosely secured endotracheal tubes (Fig 2). Other causes associated with unplanned extubations included lack of sedation of infants who were active and agitated (3 events), registered nurses being distracted in a busy shift (2 events), an infant coughing out the endotracheal tube (1 event), and transfer of the infant from a transport isolette to the radiant warmer (1 event).

A fourth process change was then implemented, which included real-time analysis of any unplanned extubation, as well as a root cause analysis of un-

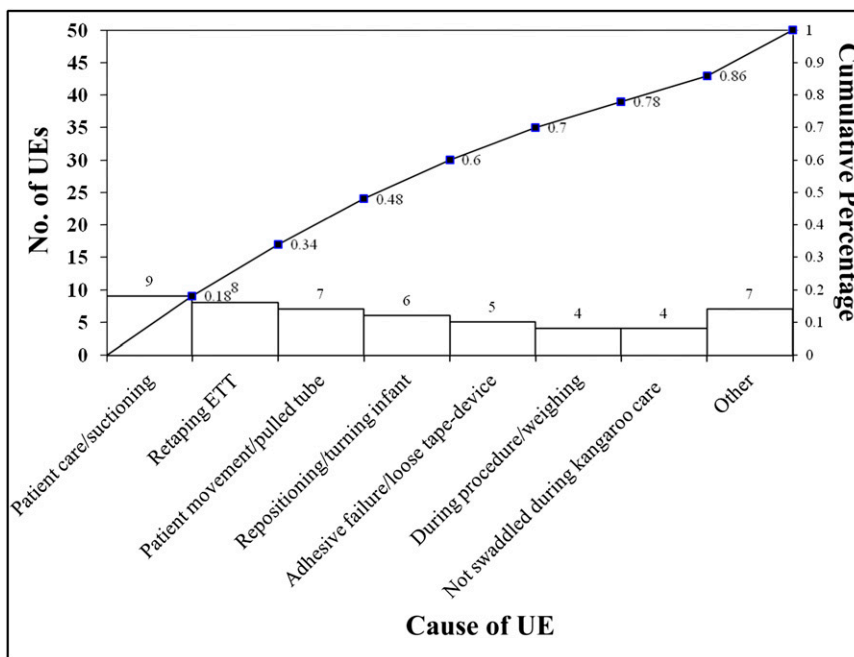


FIGURE 2

Pareto chart for causes of unplanned extubations (UEs) that occurred from October 2009 through December 2012. Number of UEs is shown on the left vertical axis, and cumulative percentage for each cause is depicted on the right vertical axis. Patient care/procedures (suctioning, repositioning, weighing, and retaping), patient movement, and loose tape/adhesive failure represented 70% to 80% of the causes of UEs.

planned extubations that was performed by a multidisciplinary team including a respiratory therapist, NICU nurse, and neonatologist. Staff reinforcement of the importance of preventing unplanned extubations continued to be a priority during this period. All unplanned extubation events during this PDSA cycle had a real-time analysis and review performed. In the next several months, the unplanned extubation rate decreased to levels seen before the increase in April 2012 (Fig 1). The most recent process change (cycle 5) (Table 1) resulted in a significant decrease in the unplanned extubation rate, as depicted by the signal of 10 months (February–November 2013) below the mean. During this most recent cycle, the display of days since last unplanned extubation and the daily review occurred each day, and restraining mittens were used for most infants >34 weeks' postmenstrual age. The unplanned extubation rate did not correlate with NICU average daily census

or with level of acuity as determined by number of ventilators in the unit during any month over this 3-year period of time. A large number of unplanned extubations occurred in infants who weighed between 750 and 1500 g, which reflects the fact that most intubated patients on mechanical ventilation are very low birth weight infants. Unplanned extubations occurred more frequently during the day shift (7:00 AM–7:00 PM) than during the night shift (7:00 PM–7:00 AM).

DISCUSSION

We have shown that unplanned extubation rates can be diminished by heightened staff awareness of the problem and adopting standardized methods of endotracheal tube security. In addition, having 2 licensed professionals involved in any procedures of patients who are intubated seems to have been effective in reducing unplanned extubations. The use of a commercially available device did not initially seem to have a significant

impact on the numbers of unplanned extubations, but this outcome may be related to the learning curve of staff members developing familiarity with placement and securing of endotracheal tubes with this device. Multiple in-service educational sessions and identifying staff members familiar with the device (nurse and respiratory therapist “champions”) to provide support for the staff were used to address the learning curve.

The use of a real-time analysis tool may have affected the rate of unplanned extubations in several possible ways. First, it has helped to identify future potentially better practices and explore gaps in compliance with process improvements. In addition, having staff members review the event in real time has increased awareness among clinical staff and has fostered a change in the unit’s culture to be one of continuous improvement.

The PDSA cycle that has demonstrated the most significant reduction in unplanned extubation was the implementation of 2 new process changes: a publicly visible progress display and the use of mittens or socks on the hands of infants >34 weeks’ postmenstrual age. The display of the days since last unplanned extubation is discussed each morning with the medical, nursing, and allied health professional staff. We suspect that the display and daily discussion of this quality indicator have changed the culture of safety in the NICU. The mittens prevent the patients from tugging on their endotracheal tube and provide the added benefit of a continued visual reminder of the risk of extubation for staff and family, and it also prompts discussion and education with the family. These ongoing dialogues reinforce the culture of safety, which plays a critical role in any quality improvement initiative.

We consider unplanned extubations to be preventable and should be a “never event” in a NICU. There are many acute and long-term adverse effects of

unplanned extubation. Short-term sequelae include acute cardiorespiratory deterioration, as well as trauma and swelling of the supraglottic tissues, the glottis, and subglottic tissues. There is also the potential for increased risk of intraventricular hemorrhage in the first few days of life in the preterm infant. Long-term complications include subglottic stenosis, increased risk of ventilator-associated pneumonia, and increased number of ventilator days, leading to an increased risk of chronic lung disease.^{1–3} Our data show that quality improvement efforts require constant vigilance, as a sustainable effect on improvement in any practice is difficult to achieve. The most important factor appears to be changing the culture within the NICU so that all staff members recognize unplanned extubation as a potentially avoidable and preventable event. Because we have achieved 10 consecutive months of lower unplanned extubation rates, we speculate that we will be able to generate a decreased mean and upper control limit if the effect is sustained for a total of 12 months. In addition to constant vigilance of the artificial airway security, it has been shown by others that the method of securing the endotracheal tube also affects the occurrence of unplanned extubations.^{2,7} Each unit needs to develop a method for securing endotracheal tubes that is consistent and standardized.

We found that lack of sedation of infants may contribute to unplanned extubations, which has been shown in PICU studies¹³ as well as in other NICUs. Although sedation is a very important factor in PICUs, it is not without its own adverse effects. Children hospitalized in PICUs have much shorter duration of mechanical ventilation and are exposed to a much shorter duration of sedation. Infants in NICUs are often on ventilators for weeks, and sedating them for a long period of time include the risks of

negatively affecting the short-term pulmonary outcome, length of hospital stay, and neurodevelopment later in infancy.^{14–16} Nevertheless, it is important that clinicians be aware that if a patient is agitated because of the mechanical ventilation process, sedation should be considered and used. However, agitation is one symptom of hypoxemia, and clinicians must first determine the cause of any agitation in a NICU patient and address that cause.

CONCLUSIONS

Although we have identified unplanned extubation as an area of improvement, the sustainability of maintaining unplanned extubations at a very low rate continues to be an important aspect of success. There are no benchmark data for NICUs, but it has been suggested that 2 unplanned extubations per 100 patient-intubated days would be the upper limit of acceptable rate of unplanned extubations in the NICU (Vermont Oxford Network iNICQ Intensive 2012: Controversies in Respiratory Care). We suggest that a stricter upper limit of 1 unplanned extubation per 100 patient-intubated days be the stretch goal for all NICUs in agreement with a recent recommendation.⁸ This rate has been identified as the benchmark for PICUs in which children are intubated for shorter durations and are often intubated with cuffed endotracheal tubes, which are more likely to stay in place.

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