Phased Quality Improvement Interventions in Reducing Unplanned Extubation in the Neonatal ICU

Vrinda Nair and Helena Smith

BACKGROUND: Unplanned extubation (UE) is a common adverse event and is an important measure of quality and patient safety in the neonatal ICU. It is well recognized that UEs occur more frequently in neonates than in any other group of ventilated patients. The objective of this study was to evaluate the effectiveness of the quality improvement interventions in reducing the rates of UE in a tertiary neonatal ICU. METHODS: A retrospective audit performed on ventilated infants showed a rate of 7.2 unplanned extubations per 100 ventilation days in a 12-month period (April 2016 to March 2017). We evaluated the common factors associated with UEs, with the primary reasons being loose fixation and providing care without assistance. We introduced sequential interventions focusing on better practices. Standardizing endotracheal tube fixation, continuous scrutiny of fixation through checks, 2-person technique for providing care, and adverse event reporting were a few of the important interventions. Rates of UE for each month were collected and analyzed. RESULTS: With interventions, UE rates reduced by 80% (from 7.2 per 100 ventilated days in the pre-implementation period to 1.4 per 100 ventilated days in the post-implementation period) in 12–18 months. CONCLUSIONS: Significant reductions in UE rates were achieved by implementing quality improvement interventions. It is important to analyze critical event rates continuously and for longer periods of time to determine the true change. *Key words: cardiopulmonary resuscitation; endotracheal tube; neonatal intensive care; quality improvement; unplanned extubation; ventilation.* [Respir Care 2020;65(10):1511–1518. © 2020 Daedalus Enterprises]

Introduction

Endotracheal intubation and mechanical ventilation are major invasive procedures in the neonatal ICU. One of the adverse events associated with intubation and mechanical ventilation is unplanned extubation (UE). UE is the fourth most common adverse event in the neonatal ICU.[1] It is an important indicator of quality care and patient safety in all patient populations.[2-5] UE is associated with temperature instability, prolonged mechanical ventilation, hypoxia, hypercarbia, hypocarbia, ventilator-associated pneumonia, longer hospital stay, and mortality.[3,6-11] Repeated intubation as a result of UE puts infants at risk of emergent intubation and risk of injury to the upper airway.[12,13] Neonates, in particular, are at higher risk for UE compared to other age groups; reasons for this include facial size, which affects the fixation technique; use of non-cuffed endotracheal tubes (ETT); shorter tracheal length; more intubation days; minimal use of sedation in the neonatal ICU; and the use of humidity in incubators.[9,13] There is no clear consensus on the benchmark UE rate that could be taken as a quality marker. In an ideal world, the rate of UE would be 0 per 100 ventilation days. However, this could be difficult to achieve in the neonatal population for reasons stated above.

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A retrospective audit performed on all ventilated infants in our neonatal ICU recorded a rate of 7.2 UEs per 100 ventilation days in the pre-implementation period from April 2016 to March 2017. The UE rate in our center was higher than in many other centers described in the literature. Sequential interventions during the implementation period of July 2017 to May 2018 were carried out by a multidisciplinary team as part of a quality improvement project to reduce UE rates by at least 50% of baseline in 12–18 months after complete implementation of phased interventions (post-implementation period was from June 2018 to December 2019). The objective of this study was to evaluate the effectiveness of the quality improvement interventions in reducing the rates of UE in a tertiary neonatal ICU in the United Kingdom.

QUICK LOOK

Current knowledge

Unplanned extubation is a common adverse event affecting ventilated neonates. Neonates are at higher risk due to their anatomy and the use of a non-cuffed tube. It is important to determine factors associated with adverse events to conceptualize interventions for improving outcomes.

What this study contributes to the current knowledge

Implementation of better practices results in successful reduction of unplanned extubation in the neonatal ICU. It is important that adverse events are analyzed for a long and continuous period of time after implementation of quality improvement interventions to ascertain the true change.

Methods

Context

This quality improvement project was undertaken in a tertiary-level neonatal ICU. The hospital performs approximately 5,000 deliveries annually. The neonatal ICU has 35 cots, of which 15 are intensive care/high-dependence cots. The clinical providers include 9 consultants, 6 advanced neonatal nurse practitioners, and 120 trained nurses. There are no respiratory therapists in the neonatal ICU. The tier 1 and tier 2 trainees rotate every 6 months within the regional network of neonatal ICUs. In our unit, all infants who are ventilated are intubated orally. Intubations are carried out by medical staff, and the trained bedside nurse helps with the fixation of the ETT. Ventilated infants are not routinely sedated and do not receive a routine paralytic agent. Ventilated infants are nursed one-to-one as per national recommendations. No other respiratory interventions or changes were introduced during the quality improvement implementation period.

Study Design

A retrospective audit on all ventilated infants cared for in the neonatal ICU (pre-implementation period: April 2016 to March 2017) was carried out to determine the baseline UE rates. The audit was registered with the central audit team at National Health Service (NHS) Trust. Medical records of all ventilated infants were reviewed to determine the number of UEs and the total number of ventilation days for each infant. UE was defined as any unexpected or unintended removal of the ETT and included removal of the ETT when deemed blocked or obstructed by the clinical team. The UE rate was defined as the number of UEs per 100 ventilation days. Data on the reasons associated with UE, timing of UE, method of fixation, temperature before and after UE, and requirements for cardiopulmonary resuscitation were also collected. Factors associated with UE were plotted on a Pareto chart (Fig. 1).

The Quality Improvement Team

A multidisciplinary team was formed to implement the quality improvement project and consisted of neonatal consultants and practice development nurses. The definition of UE remained the same throughout the audit and the implementation and the post-implementation periods. The project was discussed with the NHS Trust research and development team. As a quality improvement activity, this project did not require institutional ethics board review.

SMART Goal

A SMART goal is used to help guide goal setting. SMART is an acronym that stands for Specific, Measurable, Achievable, Realistic, and Timely. We set the following SMART goal: to reduce the rates of UE in our neonatal ICU by at least 50% from the baseline of 7.2 per 100 ventilation days within 12–18 months after complete implementation of the interventions. A key driver diagram was generated based on the factors associated with UE and the interventions to overcome these factors (Fig. 2). We identified the primary and secondary drivers that would help achieve the SMART goal. The interventions were introduced sequentially so as to consolidate each intervention and to ascertain the impact of each separately.

QI Interventions

The first intervention consisted of standardization of the ETT fixation technique. The retrospective audit indicated that multiple techniques were being used in the neonatal

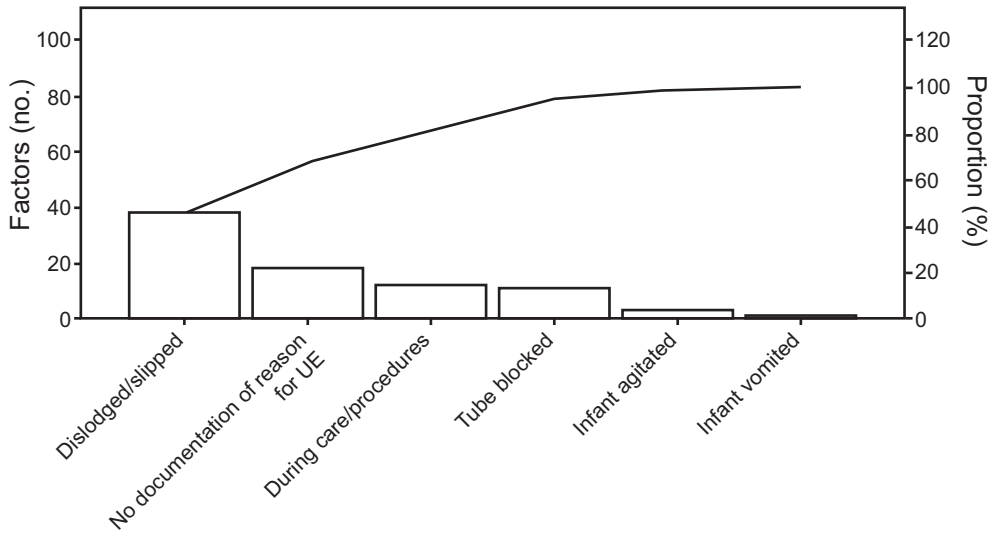

Fig. 1. Pareto chart showing most important factors associated with unplanned extubations (UEs).

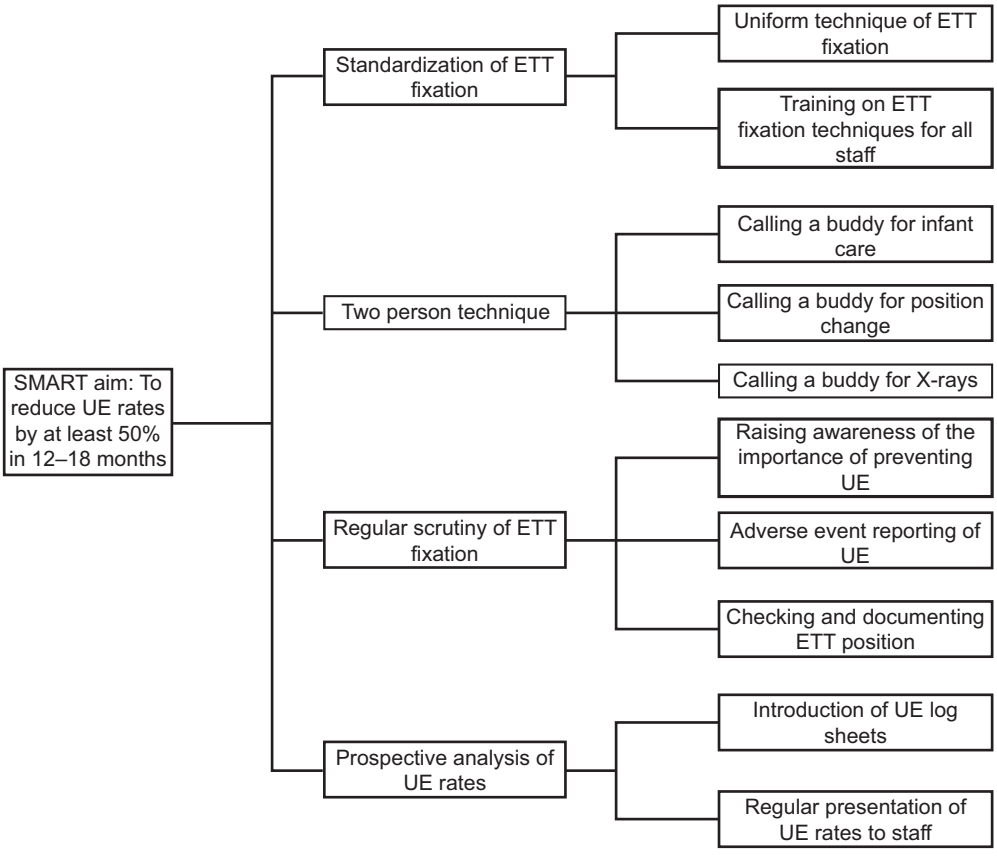

Fig. 2. Key driver diagram. ETT = endotracheal tube; UE = unplanned extubation.

ICU to fix the ETT. The various techniques included taping, stitching, and the use of commercially available devices. The fixation technique depended heavily on the team involved at the time of intubation, and there was no uniformity. The first intervention was introduced in July and August 2017. It involved standardization of ETT fixation, which was one of the most important interventions in this QI project. A commercially available device was

procured and introduced as the only device to be used for ETT fixation for ventilated infants. All of the neonatal ICU nursing and medical staff was initially given hands-on training on manikins, followed by supervised training on infants over a period of 3–6 months. Data on UE from July 2017 to Jan 2018 was collected retrospectively in January 2018.

The second QI intervention was the implementation of a 2-person requirement for providing care to neonatal patients. The audit had revealed that infant care, position changes, and other procedures were carried out singlehandedly by the bedside nurse. The second intervention was introduced in February 2018. One member of the staff is responsible for the integrity of the ETT while the other member performs the necessary procedure. Data on UE after the second QI intervention was collected in March 2018.

The third intervention was introduced in April 2018 and involved continuous scrutiny of the ETT and fixation during ward rounds and while any members provided care to the patients. The ETT fixation length was documented on neonatal ICU daily care charts with each check. If the ETT fixation length had changed from previous check, the medical team undertook corrective measures. We also introduced reporting of any UE in the neonatal ICU on the NHS Trust adverse event reporting system. This step was intended to raise the awareness that UE is a critical event and that it is important to capture adverse events to help prevent them in the future.

The fourth intervention, implemented in June 2018, included the introduction of UE log sheets for real-time UE reporting and for prospective collection of details around each UE. The neonatal team caring for the infant at the time of UE collected the ETT in a sealed bag after UE for the QI team to inspect. The log sheet collected details about the timing of UE, events around the UE, the number of staff involved in care or performing a procedure, temperature before and after UE, need for re-intubation, and whether cardiopulmonary resuscitation was required. The log sheets helped in prospective collection of data. The UE data were presented to the team on a monthly basis.

Regular education sessions were incorporated in the nurses' and trainees' teaching program. The sessions included training on the fixation device, raising the awareness on regular checks, and emphasizing the importance of UE reporting.

Statistical Analysis

We used statistical process controls to understand the special cause variations and trends. Factors associated with UE prior to implementation of interventions were plotted on a Pareto chart. The outcome data of UEs were constructed on a control chart with means and control limits calculated using the process control methods in SPSS 26 (IBM, Armonk, New York). We used Montgomery rules to analyze the stability of the process before and after implementation of interventions.

Results

Figure 1 is a Pareto chart showing the distribution of various factors associated with UEs before the implementation of QI interventions. The predominant reason stated for UEs was slipping of the ETT due to loose fixation. Different fixation techniques were mentioned in the documentation, including tape, stitches, and commercially available devices. There was no discernible reason stated for some of the UEs. Because this was a retrospective audit, we were unable to determine the reasons for these events. The other reasons documented in the medical notes included agitated infant, vomiting, blocked tube, and dislodgement during provision of care. With the available reasons stated from the retrospective audit, sequential interventions were introduced to overcome causes (Table 1).

Table 2 presents the characteristics in the pre-implementation, implementation, and post-implementation periods. The majority of infants who had UEs were < 32 weeks gestational age during the studied period. Intubation and ventilation for respiratory conditions are more common in preterm infants. The difference in the total number of ventilation days during the different phases is attributed to the difference in the length of the study periods. The perinatal service was expanded starting with the delivery of twins exclusively in our center followed by an expansion of neonatal cots in September 2018. The latter was the result of centralization of services with infants < 30 weeks gestational age being cared for in our center. This could explain the higher number of ventilation days in the post-implementation period.

The retrospective audit on ventilated infants cared for in our unit (April 2016 to March 2017) revealed a baseline rate of 7.2 per 100 ventilation days. Around 10% of infants who experienced UE underwent cardiopulmonary resuscitation following UE, and 34.7% developed hypothermia.

The first QI intervention was introduced in July 2017. We standardized the ETT fixation in our neonatal ICU by using a commercially available fixation device for all ventilated infants. The QI team undertook training sessions for neonatal ICU staff regarding the standardized technique of ETT fixation over a period of 3–6 months, including both simulation and real-time sessions. We retrospectively analyzed the UE rates from July 2017 to January 2018 using the Badgernet (ie, an electric patient record system used for neonates in UK) and medical records. With the completion of the first Plan-Do-Study-Act cycle, there was a reduction in UE rates to 5 UEs per 100 ventilation days, although this reduction was $< 50\%$ as stated in the SMART goal.

Table 1. Implementation Phases of Quality Improvement

	Time Period	Interventions
Pre-implementation period	April 2016 to March 2017	Retrospective audit on all ventilated infants admitted between April 2016 and March 2017
Intervention 1	July 2017	Introduction of standard and uniform endotracheal tube fixation device Staff education
Intervention 2	February 2018	Two-person technique for cares and procedures Intervention 1 continued
Intervention 3	April 2018	Continuous scrutiny and documentation of endotracheal tube length on care charts Reporting unplanned extubation on adverse event reporting system Intervention 1 & 2 continued
Intervention 4	June 2018	Introduction of unplanned extubation log sheets Real-time collection of unplanned extubation data on unplanned extubation log sheets Intervention 1, 2 & 3 continued
Post-implementation period	June 2018 to December 2019	Prospective analysis of unplanned extubation rates on monthly basis

Table 2. Subject Characteristics During Different Periods of Quality Improvement

	Pre-implementation Period (April 2016 to March 2017)	Implementation Period (July 2017 to May 2018)	Post-implementation Period (June 2018 to December 2019)
Gestational age, weeks, median (IQR)	28 (25–30)	26 (25–32)	26.5 (25–30.75)
Birth weight, g, median (IQR)	1,020 (852.5–1515)	1,000 (695–1875)	890 (702.5–1447.5)
UEs in infants < 32 weeks gestational age; *n* (%)	43 (87.7)	36 (81.8)	17 (69.6)
UEs in infants > 32 weeks gestational age; *n* (%)	6 (12.2)	8 (18.1)	7 (30.4)
Total days on ventilation, *n*	678	923	1,660
UEs, *n*	49	44	24
UE per 100 ventilation days, *n*	7.2	4.7	1.4
UEs per infant, *n*	2	1.5	1
CPR following UE, %	10.2	6.9	0
Hypothermia following UE, %	34.7	45	39

IQR = interquartile range
UE = unplanned extubation
CPR = cardiopulmonary resuscitation

The second intervention, which was the requirement for care to be delivered by 2 staff members, was introduced in February 2018. This requirement applied to all care, including position changes and any procedures on the infant. While one person carried out the procedure or position change, the assistant ensured the security of the ETT. There was further reduction in the UE rate, although it still did not satisfy the SMART goal (ie, a reduction to 4.8 UEs per 100 ventilation days).

The third intervention to be introduced was continuous checks and documentation of the ETT length. Regular checks were carried out, and ETT position was documented on the neonatal ICU observation chart. If the check showed that the ETT position was as desired, the fixation was reinforced. We also introduced reporting of UE on the adverse event reporting system.

The last intervention, introduced in June 2018, was real-time capture of the events on UE log sheets. The data collected included timing, event around UE, type of fixation used, the number of staff involved with care, temperature before and after the event, need for cardiopulmonary resuscitation, and respiratory support after UE. The removed ETT with the fixation device was collected and analyzed by the QI team to ascertain the cause. The UE data were thus collected prospectively. There was no difference in the timing of UE in relation to day time or night time.

Figure 3 presents the UEs rates per 100 ventilation days on a monthly basis in the pre- and post-implementation

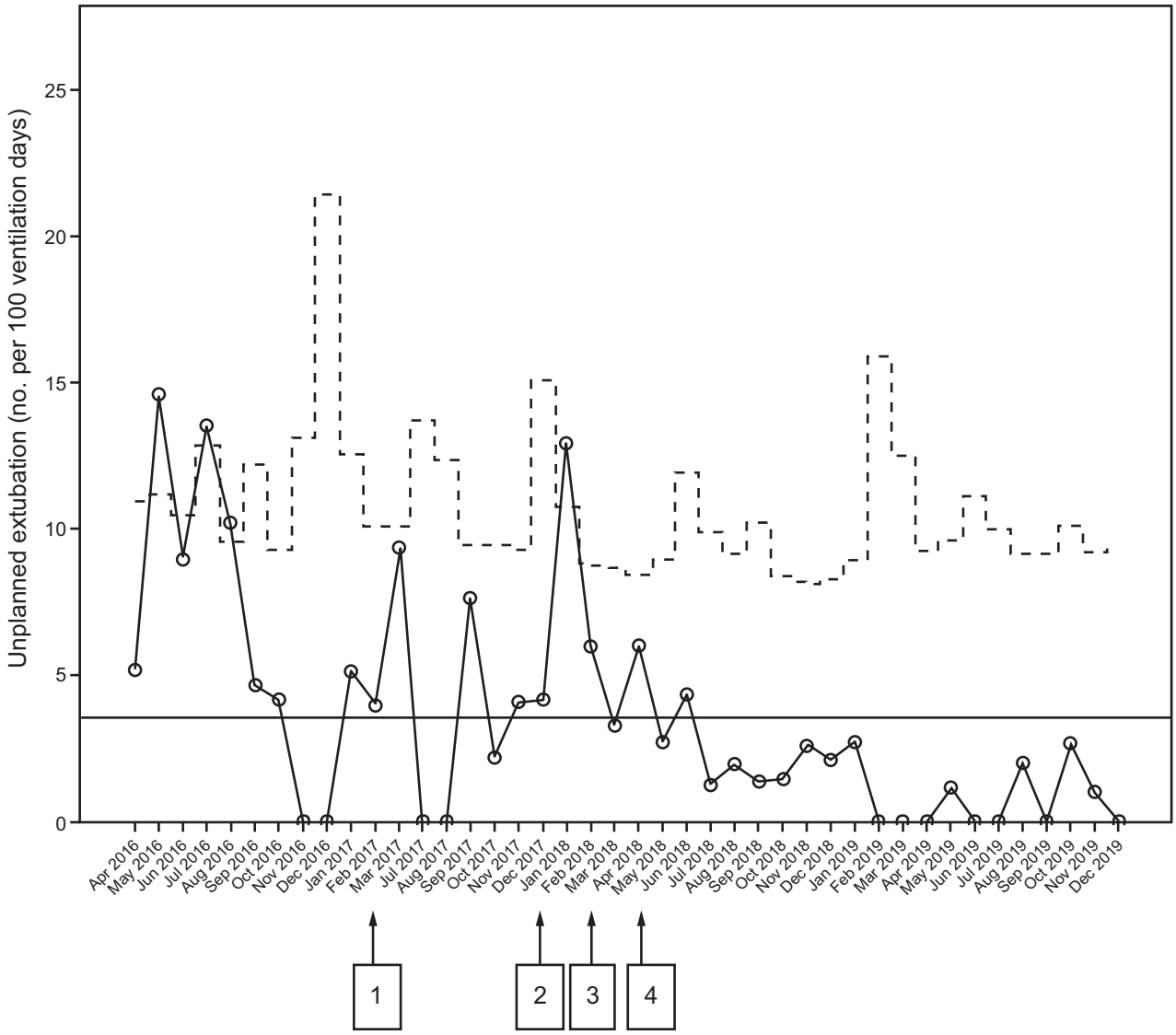

Fig. 3. Control chart of monthly unplanned extubations per 100 ventilation days. Numbers denote interventions. 1: Standardized fixation technique. 2: Two-person care/procedure. 3: Continuous scrutiny of endotracheal tube length and adverse event reporting. 4: Unplanned extubation log sheet. The dashed line represents upper confidence limit and the horizontal line represents mean.

periods as the sequential interventions (1, 2, 3, and 4) were introduced. The control chart depicts the changes in UE rates through the different periods. We achieved a rate of zero UEs for 3 consecutive months in the post-implementation period. Additionally, for > 8 months the UE rate was below the mean, which depicts the special cause variation.

Discussion

In this study we observed a significant reduction in the UE rates of approximately 80% in the neonatal ICU after implementation of QI interventions. In the retrospective audit of the pre-implementation period, the most common reason stated for UEs was slipping of the tube through loose fixation. A Cochrane review on methods of ETT fixation in newborns included 5 randomized controlled trials. The most common outcome measured was UE rate. A meta-analysis could not be carried out because of heterogeneity and poor methodological quality.[14] For our first QI intervention, we considered available fixation devices and took into account the effectiveness, ease of fixation, and cost. The fixation method was standardized, and training was provided to all staff members on a regular basis by the QI team. We saw a reduction in UEs with this single intervention, but it did not reach the SMART goal of at least 50%. The less significant change may have been related to the learning phase and unfamiliarity with the new device.

Another common factor associated with UEs in our audit was events around care, procedures, and position changes. The bedside nurse carried out all the care for the particular infant. We implemented a culture change by introducing the requirement for 2 people to provide care or change an infant's position. This reduced the UE rates further. Other authors have reported similar reductions in UE rates with a 2-person technique.[9]

Another important culture change that was introduced as part of QI was the continuous bedside attention to the ETT and its fixation. The bedside nurse, along with other observations, documented the ETT fixation length and the integrity of the fixation device. If there was any concern that the ETT had moved or if the integrity of the fixation device was questioned, this was reviewed by the medical team and necessary actions were taken. This, along with the adverse event reporting system, raised the awareness among the staff that any UE should be considered as an adverse event. The UE data were presented to the team on a monthly basis. This helped the team recognize areas of improvement and maintained positivity despite a significant culture change.

UE log sheets were used to capture the UE events in real time and to analyze the factors responsible for the event prospectively. The neonatal team caring for the infant at the time of UE collected the ETT and its fixation device in a sealed bag for the QI team to inspect. This helped in determining the cause of UE. If the cause was determined to be preventable, feedback was given in a constructive manner and training was emphasized.

Education played a crucial role in all phases of implementation. In our QI project we implemented education rollouts to all members of the staff on a monthly basis. The study was conducted in a tertiary neonatal ICU in the United Kingdom. There are no respiratory therapists in neonatal ICUs in the United Kingdom. Ventilated infants are cared for by registered and trained senior nurses on a one-to-one basis. Robust interventions are the most important factors in successful implementation of QI projects. The trained bedside caregivers play an extremely important role in QI projects. We carried out training for our trained bedside nurses regarding the interventions before the implementation.

UEs are associated with neonatal morbidities like temperature instability, prolonged hospital stay, airway trauma, subglottic stenosis, and ventilator-associated pneumonia.[6,8,9,11,15] We have observed that UE rates can be reduced to significantly lower rates by adopting better practices, which may indirectly affect these morbidities. Although we saw a significant reduction in UE rates with the QI process, the rates of hypothermia during the audit and the QI phase remained around 40%. We are in the process of implementing another QI to help with better thermoregulation during these events.

The greatest strength of our study is the long period of observation that allowed us to see a consistent improvement in outcomes. Continuous and longer observation is crucial to demonstrate the true change. UE rates were analyzed through the implementation period and the post-implementation period, which has helped in determining the impact of each measure. We had baseline audit data that identified the burden of UE in our neonatal ICU and formed the basis of developing this QI project. Analyzing the removed ETT following any UE allowed the QI team to assess the exact reason for UE and to provide real-time feedback, which is essential in any QI project.

Our study has some limitations to note. There is a clear lack of benchmarking of ideal UE rates, which may be due to underreporting of these adverse events. Hence, we opted for an arbitrary 50% cutoff to assess a clinically important change. Our baseline data indicated that, in many instances of UE, there was no explanation of the factors around the UE. We may not have captured other reasons associated with UEs in the neonatal ICU. However, with the reasons identified in the audit, we were able to implement interventions and successfully reduce the rates of UE. With the prospective collection of data in the post-implementation period, we have not identified any additional reasons beyond those identified in the initial audit.

Conclusions

UE, a common adverse event in the neonatal ICU, is an important marker of quality care and patient safety. UE rates can be successfully reduced by implementation of QI bundles. Adopting better evidence-based practices could improve patient safety and improve outcomes in the neonatal ICU. There is no consensus definition for the ideal UE rate in the neonatal literature; however, we should strive to achieve the lowest UE rates possible. Practices based on the needs of individual units should be adopted. It is also important that any QI outcome is analyzed continuously for a long period of time to ascertain the true change. Future studies should also examine the short-term and long-term outcomes of infants who have experienced UE in the neonatal ICU.

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