Organizational Risk Factors and Clinical Impacts of Unplanned Extubation in the Neonatal Intensive Care Unit

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Objectives To assess the association between organizational factors and unplanned extubation events in the neonatal intensive care unit (NICU) and to evaluate the association between unplanned extubation event and bronchopulmonary dysplasia (BPD) among infants born at <29 weeks of gestational age.

Study design This is a retrospective cohort study of infants admitted to a tertiary care NICU between 2016 and 2019. Nursing provision ratios, daily nursing overtime hours/total nursing hours ratio, and unit occupancy were compared between days with and days without unplanned extubation events. The association between unplanned extubation events (with and without reintubation) and the risk of BPD was evaluated in infants born at <29 weeks who required mechanical ventilation using a propensity score–matched cohort. Multivariable logistic regression analysis was used to assess the association between exposures and outcomes while adjusting for confounders.

Results On 108 of 1370 days there was ≥1 unplanned extubation event for a total of 116 unplanned extubation event events. Higher median nursing overtime hours (20 hours vs 16 hours) and overtime ratios (3.3% vs 2.5%) were observed on days with an unplanned extubation event compared with days without an unplanned extubation event (P = .01). Overtime ratio was associated with higher adjusted odds of a unplanned extubation event (aOR, 1.09; 95% CI, 1.01-1.18). In the subgroup of infants born at <29 weeks, those with an unplanned extubation event who were reintubated had a longer postmatching duration of mechanical ventilation (aOR, 13.06; 95% CI, 4.88-37.69) and odds of BPD (aOR, 2.86; 95% CI, 1.01-8.58) compared with those without an unplanned extubation event.

Conclusions Nursing overtime ratio is associated with an increased number of unplanned extubation events in the NICU. In infants born at <29 weeks of gestational age, reintubation after an unplanned extubation event is associated with a longer duration of mechanical ventilation and increased risk of BPD. *(J Pediatr 2022;249:14-21)*.

Approximately 25% of infants admitted to the neonatal intensive care unit (NICU) require invasive mechanical ventilation via the placement and maintenance of an endotracheal tube (ETT).[1,2] Indications for mechanical ventilation in the NICU include respiratory failure secondary to surfactant deficiency and prematurity, complex airway malformation, congenital cardiac anomalies, and neurologic depression.[3] Some infants on mechanical ventilation may experience an unplanned extubation event during their NICU stay, which may result in clinical instability from hypoxia and bradycardia caused by loss of respiratory support.[4,5] Organizational variables, such as nurse provision ratios, have been previously identified as risk factors for unplanned extubation events in adult intensive care units but have not yet been studied in NICUs.[6] In addition, other organizational variables, such as nursing overtime ratios and unit occupancy, have been associated with medical incidents and nosocomial infections in the NICU and may contribute to unplanned extubation events.[7,8]

Clinical risk factors for unplanned extubation events include low gestational age. Preterm infants born at <29 weeks of gestational age are at elevated risk of unplanned extubation events compared with older neonates owing to anatomic factors (eg, shorter tracheas), infrequent use of sedation, and prolonged intubation times.[9-12] Possible adverse consequences of unplanned extubation event in these infants include the need for reintubation and subsequent prolongment of mechanical ventilation, which can increase the risk of bronchopulmonary dysplasia (BPD).[2,13] Although previous studies have reported an association between an unplanned extubation event and longer duration of mechanical ventilation in infants born at <29 weeks of gestational

BPD	Bronchopulmonary dysplasia
ETT	Endotracheal tube
NICU	Neonatal intensive care unit
PSM	Propensity score-matched
SNAP-II	Score for Neonatal Acute Physiology version II

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age, whether factors such as reintubation contribute to the higher risk of BPD compared with non-reintubated infants remains unclear.[4,9]

In this study, we aimed to assess the association between organizational variables (nurse provision ratio, nursing overtime ratio, and unit occupancy) and unplanned extubation events in the NICU among all infants receiving mechanical ventilation, and also to evaluate the association between unplanned extubation event (with or without reintubation) and BPD in the subgroup of infants born at <29 weeks of gestation.

Methods

This retrospective cohort study included all infants admitted to the Montreal Children's Hospital–McGill University Hospital Centre NICU between April 1, 2016, and December 31, 2019. This 52-bed level 3 NICU with single rooms and surgical or medical consultants on site averages approximately 800 admissions per year. An assistant head nurse evaluates required nurse staffing twice daily based on patient dependency categories and planned admissions. When there are increased staffing needs, administration can call on off-duty nurses, a pool of floating trained NICU nurses who can help support the demand or use of voluntary overtime as a last resort. This study was approved by the Institutional Research Ethics Board.

Organizational Variables

Data for calculating organizational variables (nurse provision ratio, overtime ratio, occupancy) were obtained from the NICU's clinical administrative database that links electronic nursing reports (patient dependency categories and number of patients on ventilation) to hospital pay systems (number of nurses and nursing overtime hours). Information on nurse provision ratio, overtime ratio, and unit occupancy and number of patients on mechanical ventilation was compiled for each individual day from midnight to 11:59 p.m. The nurse provision ratio was obtained using the number of actual nurses working divided by the number of recommended nurses per shift. The nurse provision ratio was then calculated as the average of all shifts in a day and reported as a daily percentage. The number of recommended nurses was calculated based on the number of patients physically present in the NICU along with their corresponding dependency category, using provincial guidelines: unstable (1.0 nurse), intensive care (0.7 nurse), intermediate care (0.3 nurse), or continuing care (0.25 nurse).[14] Nursing overtime was defined as the number of hours worked beyond the individually agreed-upon daily schedule, either before or after. This also included any additional work shifts when the total weekly hours of work exceeded 37.5 hours, similar to what is widely adopted throughout Canada.[15] The overtime ratio was calculated as the sum of all nursing overtime hours divided by the sum of total nursing hours.[16] Unit occupancy was defined as the number of patients in the NICU by midnight of each day divided by the number of beds. There are typically 4-5 respiratory therapists in the NICU on each shift; however, specific data on respiratory therapist hours (including overtime) per shift were not available for this study.

Unplanned Extubation

An unplanned extubation event was defined as the premature and/or unanticipated removal of the endotracheal tube either by the patient or by the staff. Data on unplanned extubation events were retrieved from the NICU unplanned extubation event database. Since 2016, mandatory reports of unplanned extubation events have been logged into the database; events are cross-referenced with hospital incident reports. After each event, the team members huddle and complete a standard form (**Figure 1**; available at www.jpeds.com), highlighting information surrounding the event: time, common understanding of the causes leading to the event, identified risk factors, and immediate reintubation. Infants with unplanned extubation events were identified using these records, complemented by electronic medical chart review to obtain additional information on reintubation. For unit-level analysis, days with an unplanned extubation event included any day with at least 1 unplanned extubation event (out of all unplanned extubation events within the study period). For patient-level analyses, when an infant had more than 1 unplanned extubation event, only the first event was included in the analysis of the association between unplanned extubation events (and/or reintubation) and outcomes of interest. The need for reintubation was based on the clinical context and standards of care. Only reintubation within 7 days from an unplanned extubation event was considered, because this time frame captures most reintubations related to respiratory factors.[17,18] Strategies to prevent unplanned extubation events during the study period included use of a 2-person technique when handling intubated infants, use of standardized taping techniques and protocols (eg, nontoxic hydrocolloid tape, application of Mastisol, use of a reference table for ETT insertion depth and a NeoBar [Neotech, https://www.neotechproducts.com/product/neobar/] for ETT anchoring), systematic reporting and review of each unplanned extubation event, as well as continued education and raising awareness among staff members.

Patient Characteristics and Data Merging

All infants receiving at least 1 day of mechanical ventilation over the study period were included in the unit-level analyses. Clinical data were obtained from the local Canadian Neonatal Network database that collects detailed information on all infants admitted to the NICU. Variables included gestational age, birth weight, sex, small for gestational age status (<10th percentile of weight for gestational age and sex), 5-minute Apgar score, Score for Neonatal Acute Physiology version II (SNAP-II), mode of delivery, multiple births, outborn status, use of surfactant, antenatal steroids, total duration of mechanical ventilation, length of stay, and NICU mortality.[19-21] Mechanical ventilation days were defined as calendar days on which the infant received invasive mechanical ventilation at any point.

Propensity Score–Matched Cohort and Outcomes of Infants Born at <29 Weeks of Gestational Age

To assess the association between unplanned extubation events and outcomes of infants born at <29 weeks of gestational age, we created a propensity score–matched (PSM) cohort using the following criteria: born at <29 weeks of gestational age, receiving mechanical ventilation, admitted <3 days after birth, absence of major congenital anomalies, and a reported unplanned extubation event occurring before 36 weeks corrected gestational age (to exclude infants with established BPD diagnoses prior to an unplanned extubation event). For this cohort, we used 1:1 optimal propensity score matching to allow pairing of all infants with an unplanned extubation event to infants without an unplanned extubation event, based on gestational age (±2 weeks), cumulative days of mechanical ventilation at the time of the unplanned extubation event (±5 days), and SNAP-II score >20.[21] We predefined a threshold of <0.25 for the standardized difference of patient characteristics.[22] Matching criteria were based on previous data linking gestational age, duration of mechanical ventilation, and SNAP-II score with an increased likelihood of unplanned extubation event.[4,23,24]

Among the PSM cohort of infants born at <29 weeks of gestational age, the primary outcome was BPD (ie, the need for supplemental oxygen or respiratory support at 36 weeks corrected gestational age).[1] Secondary outcomes included mortality, a composite outcome of death or BPD, postmatching duration of mechanical ventilation (in reference to the matched infants with an unplanned extubation event), total duration of mechanical ventilation, and length of stay.

Statistical Analyses

Our statistical analysis approach involved 2 levels. To identify organizational variables that may be risk factors for unplanned extubation events, characteristics (ie, nurse provision ratio, overtime ratio, and occupancy) of days without an unplanned extubation event and days with 1 or more unplanned extubation events were compared using the Wilcoxon rank-sum test. Logistic regression was used to assess the association between organizational variables and the risk of an unplanned extubation event while adjusting for all other organizational variables and the daily number of patients on mechanical ventilation. Patient acuity scores were not directly included in the model owing to collinearity with nurse provision ratios and the number of patients on mechanical ventilation.

To evaluate the association between unplanned extubation events and outcomes in the PSM cohort of <29 weeks gestational age, infants with unplanned extubation event were compared with those without using conditional logistic or cumulative ordinal regression models (as appropriate) while adjusting for sex and small for gestational age status. To further evaluate the effects of unplanned extubation events based on reintubation status, we conducted 2 subgroup analyses, 1 comparing infants with an unplanned extubation event who were reintubated with their matched controls and the other comparing infants with an unplanned extubation event who were not reintubated with their matched controls. These subgroup analyses were conducted using conditional models adjusted for sex and small for gestational age status given that the infants with an unplanned extubation event had matched controls in the PSM cohort. To evaluate potential biases, we performed sensitivity analyses among the unmatched cohort of infants born at <29 weeks of gestational age using logistic regression models adjusted for gestational age, SNAP-II score <20, sex, and small for gestational age status.

All statistical analyses were conducted using R version 3.6.1 (R Foundation for Statistical Computing). A 2-sided *P* value <.05 was considered to indicate statistical significance.

Results

Organizational Factors Associated with the Risk of an Unplanned Extubation Event Among All Intubated Infants

Among the 2775 infants admitted to the NICU during the study period, 760 (25%) received mechanical ventilation (**Figure 2**). The median duration of mechanical ventilation was 3 days (IQR, 2-9 days) among all intubated infants (**Table I**; available at www.jpeds.com). A total of 113 unplanned extubation event events were reported in 87 patients in this study (66 infants with 1 event, 17 with 2 events, 3 with 3 events, and 1 with 4 events), corresponding to 2.1 unplanned extubation events per 100 mechanical ventilation days. Most unplanned extubation events (69 of 113; 62%) were related to care (eg, loose tape or during care/interventions) (**Figure 3**; available at www.jpeds.com). Overall, there were 1262 days with no unplanned extubation events and 108 days with 1 or more unplanned extubation events. In the unadjusted comparison, days with an unplanned extubation event had a higher overtime ratio and number of infants on mechanical ventilation compared with days without an unplanned extubation event (**Table II**). The association of overtime ratio with higher odds of an unplanned extubation event remained significant in the adjusted analyses.

Outcomes of Intubated Infants Born at <29 Weeks of Gestation

In the 190 intubated infants born at <29 weeks of gestation who met our inclusion criteria, the median duration of mechanical ventilation was 13 days (IQR, 3-29 days) (**Table I**). Among these infants, 59 (29%) had at least 1 unplanned extubation event (for a total of 82 events), and the median age at the time of their first unplanned extubation event was 15 days (IQR, 7-25 days) (**Table III**).

Outcomes of Unplanned Extubation Events Among PSM Infants Born at <29 Weeks of Gestation

Propensity score calculation allowed for 1:1 matching of the 59 infants with an unplanned extubation event with 59 infants without an unplanned extubation event. Infant characteristics were balanced between the infants with an unplanned extubation event and their matched controls (all standardized differences <0.25) (**Table IV**; available at

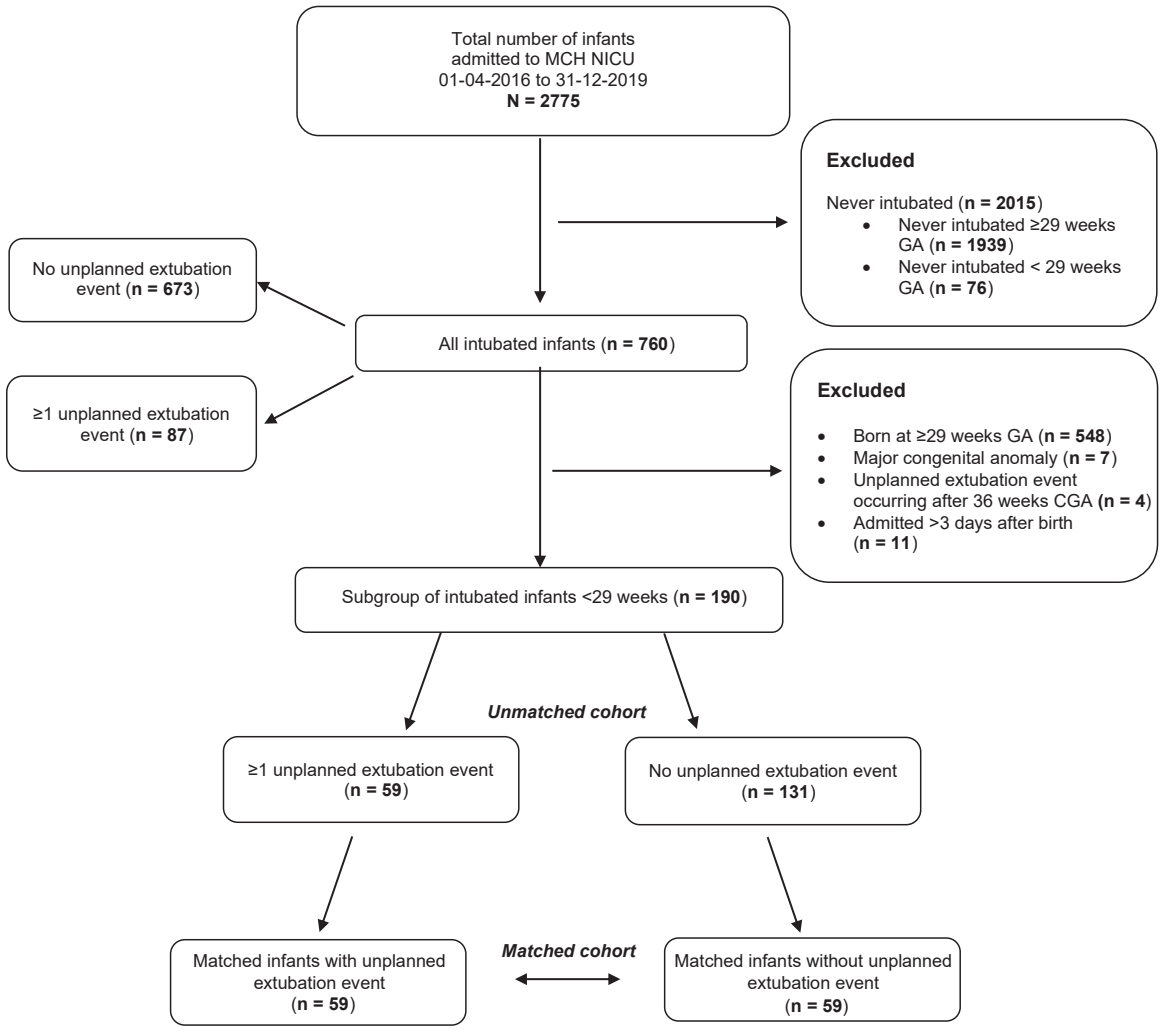

Figure 2. Flowchart describing exclusion and inclusion criteria for the study sample. *CGA*, corrected gestational age; *GA*, gestational age; *MCH*, Montreal Children's Hospital.

www.jpeds.com). Compared with infants without an unplanned extubation event, those with an unplanned extubation event had longer total duration of mechanical ventilation and longer postmatching duration of mechanical ventilation, but no significant difference in the risk of BPD (**Table V**; available at www.jpeds.com).

Table II. Comparison of unit organizational variables on days without unplanned extubation events to days with unplanned extubation events among all infants with mechanical ventilation in the unit

Variables	Days without an unplanned extubation event (N = 1262), median (IQR)	Days with ≥1 unplanned extubation event (N = 108), median (IQR)	*P* value*	Crude OR (95% CI)	aOR (95% CI)†
Descriptive characteristics					
Total nursing hours, h	195 (187-203)	197 (187-205)	.32	NA	NA
Nursing overtime hours, h	16 (4-28)	20 (8-32)	**.01**	NA	NA
Organizational variables					
Nursing provision ratio, %	97 (91-105)	98 (92-102)	.55	0.99 (0.97-1.01)	1.00 (0.98-1.02)
Nursing overtime rate, %	2.5 (0.7-4.2)	3.3 (1.4-4.9)	**.01**	**1.09 (1.01-1.18)**	**1.09 (1.01-1.18)**
Unit occupancy rate, %	90 (85-93)	89 (86-92)	.36	0.99 (0.95-1.02)	0.97 (0.93-1.01)
Number of patients on mechanical ventilation, n	4 (3-5)	5 (3-6)	**<.01**	**1.17 (1.07-1.28)**	**1.17 (1.06-1.29)**

NA, nonapplicable to descriptive variables.
Significant values are in bold type.
*Obtained using the Wilcoxon rank-sum test.
†The aORs were calculated using all three organizational variables (nursing provision ratio, nursing overtime and unit occupancy rate) simultaneously, and the number of mechanically ventilated patients.

Table III. Characteristics of the PSM infants born at <29 weeks with an unplanned extubation event with reintubation and those without reintubation compared with their respective matched controls

Characteristics	Infants with an unplanned extubation event, reintubated (N = 35)	Matched controls without an unplanned extubation event (N = 35)	P value*	Infants with an unplanned extubation event, not reintubated (N = 24)	Matched controls without an unplanned extubation event (N = 24)	P value†
Gestational age at birth, wk, median (IQR)	25 (24-26)	25 (24-26)	.92	26 (24-26)	25 (24-26)	.45
Gestational age group, n (%)			1.00			.56
<26 wk	25 (71)	26 (74)		11 (46)	14 (58)	
≥26 wk	10 (29)	9 (26)		13 (54)	10 (42)	
Birth weight, g, median (IQR)	695 (600-785)	740 (640-888)	.14	772 (658-872)	790 (610-850)	.91
Male sex, n (%)	19 (54)	15 (43)	.47	8 (33)	11 (46)	.55
Small for gestational age, n (%)	5 (14)	1 (3)	.20	2 (8)	2 (8)	1.00
SNAP-II score >20, n (%)	13 (37)	18 (51)	.34	8 (33)	10 (42)	.77
Apgar score at 5 min <7, n (%)	24 (69)	21 (60)	.62	16 (67)	18 (75)	.75
Multiple births, n (%)	5 (14)	8 (23)	.54	8 (33)	5 (21)	.52
Cesarean birth, n (%)	24 (69)	24 (69)	1.00	14 (58)	16 (67)	.77
Outborn, n (%)	2 (6)	5 (14)	.43	4 (17)	3 (12)	1.00
Surfactant, n (%)	30 (86)	30 (86)	1.00	19 (79)	21 (88)	.70
Antenatal steroids, n (%)	34 (97)	32 (91)	.61	21 (88)	22 (92)	1.00
Corrected gestational age at time of first unplanned extubation event, wk, median (IQR)	26 (26-28)	NA	NA	28 (27-29)	NA	NA

NA, not applicable to infants without an unplanned extubation event.
*Comparison between patients with unplanned extubation events who were reintubated and matched controls with non-unplanned extubation events. Obtained using the Wilcoxon rank-sum test for continuous variables and the χ^2 test for categorical variables.
†Comparison between patients with unplanned extubation event who were not reintubated and matched controls with non-unplanned extubation events. Obtained using the Wilcoxon rank-sum test for continuous variables and the χ^2 test for categorical variables.

Reintubation Outcomes in PSM Infants Born at <29 Weeks of Gestation

Among these infants with an unplanned extubation event, 35 (59%) were reintubated, and 17 (49%) had 2 or more unplanned extubation events (with or without subsequent reintubation). Unplanned extubation events occurred earlier in the reintubated infants (median corrected gestational age, 26 weeks; IQR, 26-28 weeks) compared with those who were not reintubated (median corrected gestational age, 28 weeks; IQR, 12-29 weeks). Among the 49 reintubations, 35 (71%) occurred within 1 hour of an unplanned extubation event, 13 (27%) occurred between 1 and 24 hours after an unplanned extubation event, and 1 (2%) occurred between 1 and 7 days after an unplanned extubation event. The most frequently reported reason for reintubation was desaturation (63%) (**Table VI**; available at www.jpeds.com).

Characteristics of the 35 reintubated infants with an unplanned extubation event were similar to those of their matched controls without an unplanned extubation event (**Table III**). The characteristics of the 24 nonreintubated infants with an unplanned extubation event were also similar to those of their matched controls without an unplanned extubation event. Compared with matched controls without an unplanned extubation event, infants with an unplanned extubation event who were reintubated had significantly longer adjusted total duration of mechanical ventilation and postmatching duration of mechanical ventilation and a higher risk of BPD (**Table VII**). However, infants with an unplanned extubation event who were not reintubated did not have significantly different outcomes than those without an unplanned extubation event.

Sensitivity Analyses

Sensitivity analyses using nonconditional logistic regression models in the complete cohort of infants born at <29 weeks of gestational age (n = 190) showed similar results: higher odds of BPD in infants with an unplanned extubation event who were reintubated compared with infants without an unplanned extubation event, but no association between BPD rate and unplanned extubation events in nonreintubated infants with an unplanned extubation event compared with patients without an unplanned extubation event (**Tables VIII** and **IX**; available at www.jpeds.com).

Discussion

In this 2.5-year retrospective study of unplanned extubation events occurring in the NICU, we report an association between nursing overtime and increased risk of an unplanned extubation event. In the PSM cohort of infants born at <29 weeks of gestational age, we showed that an unplanned extubation event followed by reintubation was associated with a longer duration of mechanical ventilation and a greater risk of BPD compared with the absence of an unplanned extubation event. In contrast, an unplanned extubation event without reintubation was associated only with longer duration of mechanical ventilation and was not

Table VII. Outcomes of the PSM infants born at <29 weeks of gestation with an unplanned extubation event with reintubation and those without reintubation compared with their respective matched controls

Outcomes	Infants with an unplanned extubation event, reintubated (N = 35)	Matched controls without an unplanned extubation event (N = 35)	aOR (95% CI)*	Infants with an unplanned extubation event, not reintubated (N = 24)	Matched controls without an unplanned extubation event (N = 24)	aOR (95% CI)†
Total duration of mechanical ventilation, d, median (IQR)	33 (24-46)	15 (6-29)	**6.34 (2.58-16.25)**	19 (10-33)	20 (11-33)	0.66 (0.24-1.82)
Postmatching duration of mechanical ventilation, d, median (IQR)	18 (13-33)	4 (2-8)	**13.06 (4.88-37.69)**	1 (1-1)	4 (−1 to 6)	0.58 (0.20-1.65)
Length of stay, d, median (IQR)	115 (96-154)	98 (86-125)	**3.05 (1.31-7.31)**	96 (80-112)	110 (100 to 140)	**0.28 (0.09-0.80)**
BPD, n (%)	24 (69)	16 (46)	**2.86 (1.01-8.58)**	9 (38)	13 (54)	0.50 (0.14-1.72)
Mortality, n (%)	5 (14)	6 (17)	0.59 (0.13-2.34)	2 (8)	3 (12)	0.49 (0.04-4.05)
Death or BPD, n (%)	27 (77)	22 (63)	1.85 (0.61-5.90)	10 (42)	16 (67)	0.32 (0.09-1.09)

Significant values are in bold type.
*aOR for comparison between patients with an unplanned extubation event who were reintubated and matched controls without an unplanned extubation event calculated using conditional logistic regression adjusted for small for gestational age status and sex.
†aOR for comparison between patients with an unplanned extubation event who were not reintubated and matched controls without an unplanned extubation event calculated using conditional logistic regression adjusted for small for gestational age status and sex.

associated with other outcomes compared with no unplanned extubation event.

The association between overtime ratio and unplanned extubation events is consistent with previous studies linking higher nursing overtime ratios with adverse events in the NICU, such as health care–associated infections.[7] In adult patient studies, higher nursing overtime also has been associated with greater fatigue, increased burnout, and reduced hand hygiene compliance.[7,25-27] Given that the most common causes of unplanned extubation events are related to care, nursing overtime may contribute to an increased risks of unplanned extubation events through reduced focus during handling of infants. In addition, nursing overtime may be correlated with other unmeasured variables of unit strain, such as reduced availability of respiratory therapists. Interestingly, nurse provision ratio and unit occupancy were not associated with unplanned extubation events. In fact, previous studies evaluating the association of nurse provision ratio with patient outcomes have shown mixed results, with some reporting that lower nurse provision ratio is associated with increased odds of mortality/morbidity in the NICU but others not reporting any such association.[8,28,29]

There are several possible explanations for this lack of association in the present study. First, the median nurse provision ratio was of 97% with a narrow IQR (91%-105%), which suggests that overall, adequate nurse provision ratios were maintained compared with the fluctuations seen in other studies.[30] For instance, a US group evaluating the association of nurse provision ratio with outcomes reported that >31% of shifts were understaffed.[31] Second, it is possible that despite variation in the overall nurse provision ratio, attempts were made to maintain adequate staffing for sicker infants (typically those requiring mechanical ventilation).

In the PSM cohort of infants born at <29 weeks of gestational age, we found an increase in postmatching duration of mechanical ventilation among infants with an unplanned extubation event compared with those without an unplanned extubation event but no association with BPD. When factoring in reintubation status, we found that infants with an unplanned extubation event followed by reintubation had higher odds of BPD compared with infants without an unplanned extubation event, suggesting that the association between unplanned extubation events and adverse outcomes is driven primarily by the reintubated group. Because the majority of reintubations occurred within 1 hour of an unplanned extubation event, reintubation most likely serves as a marker of lung disease severity. This is in line with the fact that reintubated infants had a lower birth weight than nonreintubated infants, although the difference was not statistically significant. Nevertheless, reintubation also may uniquely contribute to morbidity owing to the intrinsic risks of the intubation process, such as transient hypoxia, increased inflammation response, tracheal injury, and scarring.[5,10,32] This is consistent with studies showing that recurrent unplanned extubation events increase the odds of longer-term morbidities, such as BPD, subglottic stenosis, and the need for tracheostomy (although we did not include

data on subglottic stenosis and tracheostomy in our cohort).[33] In a recent study of very low birth weight infants, 88% of unplanned extubation events were followed by reintubation, and unplanned extubation events were associated with increased costs and duration of respiratory support.[4] The association of unplanned extubation events followed by reintubation with BPD is similar to studies reporting that failed early extubation in very low birth weight infants was associated with higher odds of BPD.[34] Even without an unplanned extubation event, reintubation has been associated with increased BPD and mortality.[35] The absence of association between unplanned extubation events and mortality in our study may be related to the relatively low event rate and survival bias, given that the median timing of the first unplanned extubation event was 15 days and the majority of deaths occur earlier (70%-80% of deaths occur in the first 14 days after birth).[36,37] As for the absence of differential outcomes between the unplanned extubation event, nonreintubated group and the no unplanned extubation event group, it is likely that the former infants were ready for extubation but were kept on ventilatory support. This further highlights the need for better evaluation of extubation readiness and the potential impact on reducing unplanned extubation events.

Almost one-third of the mechanically ventilated infants born at <29 weeks of gestational age in our cohort had 1 or more unplanned extubation events, a rate similar to previous reports.[38] Although the incidence of unplanned extubation events in this population is similar to the incidences of other major morbidities, such as nosocomial infections, unplanned extubation events are not systematically reported in most neonatal databases.[7] This highlights the need for standardized reporting, national benchmarking, and new trials looking at interventions aimed at reducing the rate of avoidable unplanned extubation events specifically in infants born at <29 weeks of gestational age. Multiple quality improvement studies have successfully implemented bundles to reduce the rate of unplanned extubation events in the NICU, but few have focused on the subgroup of infants born at <29 weeks of gestational age or evaluated BPD specifically.[11,12,38-40] Common strategies include using a standardized method for ETT securement through anatomic reference points, having 2 staff members involved in care/interventions requiring moving of the intubated infant, and continuous training and routine reminders of prevention methods.[11,38,40] Of note, most previous studies have focused on reporting rates of unplanned extubation events per 100 mechanical ventilation days among all infants regardless of the proportion of higher-risk patients. In our study, although we found 2.1 unplanned extubation events per 100 mechanical ventilation days (similar to other reports in the literature of 1.98 events per 100 mechanical ventilation days), the incidence among infants born at <29 weeks of gestational age was higher, at 2.3 events per 100 mechanical ventilation days.[4,9] This underscores the importance of separately reporting unplanned extubation events, identifying risk factors and outcomes among high-risk and younger populations, who often require longer invasive mechanical ventilation (which is now done at our site).

Overall, our findings demonstrate the importance of developing and adopting optimal ETT maintenance practices to reduce the rate of unplanned extubation events, particularly within high-risk groups of infants born at <29 weeks of gestational age.

This study was subject to limitations. As with all single-center studies, it is inherently difficult to predict how representative our reported outcomes reported are of other sites. Specifically, our site follows a standard reporting protocol for unplanned extubations, which does not preclude previously reported biases for unplanned extubation event identification. In addition, our organizational variables were analyzed using the NICU as the unit of analyses, and we cannot confirm whether individual patients were exposed to a nurse working overtime. Nonetheless, our data suggest that periods of higher nursing overtime represent a unique at-risk period for patients. Although we acknowledge that units may experience fluctuations in strain throughout a single day, our organizational data structure only allowed for day-by-day comparisons. Another consideration is that of the role of respiratory therapists in the care of intubated infants. These professionals participate actively in multiple responsibilities, such as taping of the ETT, kangaroo care, and supporting nurses in their care. Additional data on respiratory therapists' hours and ratios would have helped better quantify their role in preventing unplanned extubation events. The observational nature of the study also limits our ability to infer causation and account for unknown confounders. However, we used propensity score matching to help mitigate confounders, and sensitivity analyses using standard logistic regression models showed similar results. We also leveraged the use of a large population sample. With nearly 800 intubated patients, we were able to investigate multiple outcomes within different patient populations. Most importantly, we assessed organizational variables such as nurse provision ratio, overtime ratio, and unit occupancy in relation to unplanned extubation events. Similarly, this study is one of the very few to specifically distinguish the effects of reintubation within unplanned extubation event groups. Our results highlight the need to standardize reporting and monitoring of nurse provision ratio, overtime ratio, and unit occupancy to prompt administrators and NICU managers on when to optimize care strategies.

This study highlights that nursing overtime was associated with increased odds of unplanned extubation events in the NICU. Furthermore, reintubation after an unplanned extubation event was associated with worse outcomes for infants born at <29 weeks of gestational age. These findings highlight the need to implement standard reporting and to identify optimal strategies that reduce the risk of unplanned extubation events, particularly among more premature infants. ■

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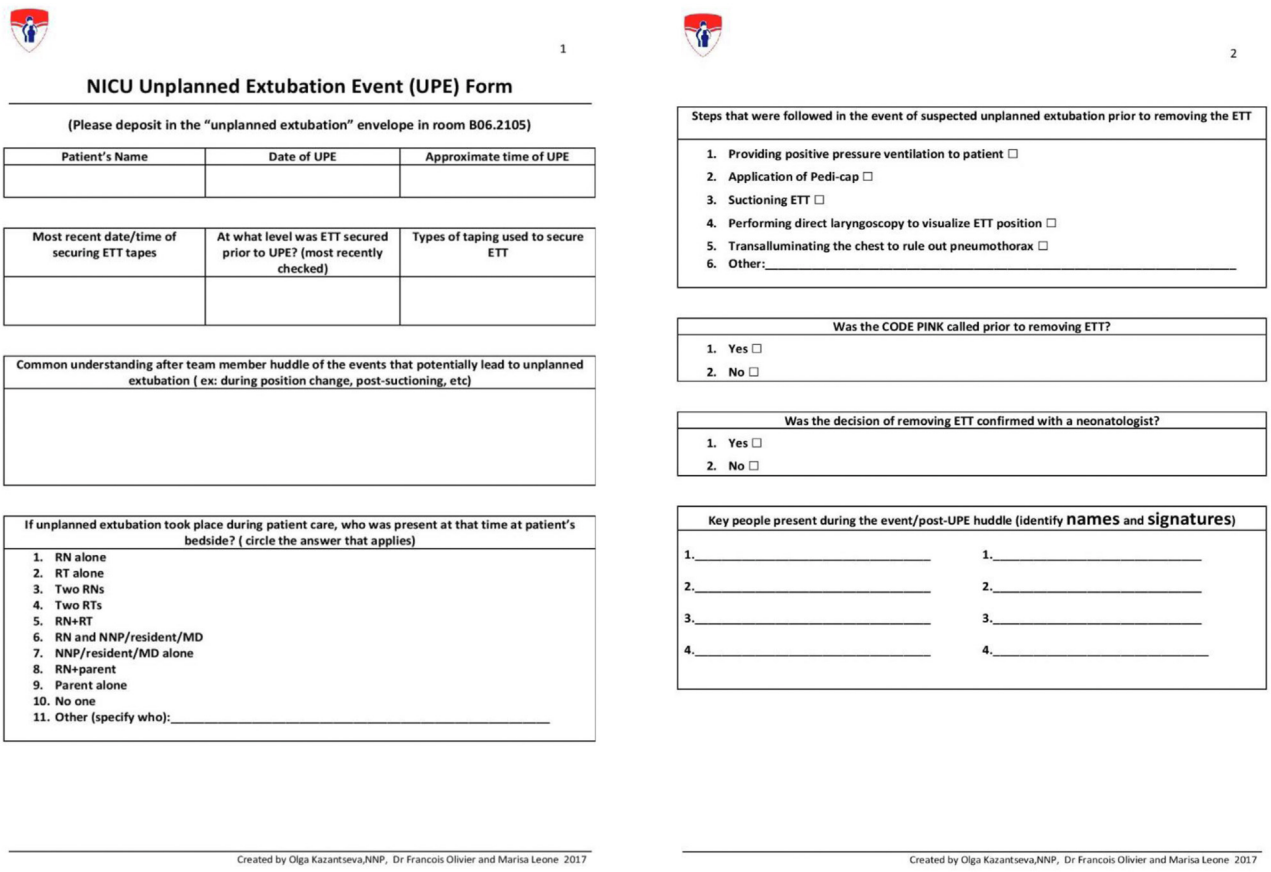

1

NICU Unplanned Extubation Event (UPE) Form

(Please deposit in the "unplanned extubation" envelope in room B06.2105)

Patient's Name	Date of UPE	Approximate time of UPE

Most recent date/time of securing ETT tapes	At what level was ETT secured prior to UPE? (most recently checked)	Types of taping used to secure ETT

Common understanding after team member huddle of the events that potentially lead to unplanned extubation (ex: during position change, post-suctioning, etc)

If unplanned extubation took place during patient care, who was present at that time at patient's bedside? (circle the answer that applies)

1. RN alone
2. RT alone
3. Two RNs
4. Two RTs
5. RN+RT
6. RN and NNP/resident/MD
7. NNP/resident/MD alone
8. RN+parent
9. Parent alone
10. No one
11. Other (specify who):_____

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2

Steps that were followed in the event of suspected unplanned extubation prior to removing the ETT

1. Providing positive pressure ventilation to patient ☐
2. Application of Pedi-cap ☐
3. Suctioning ETT ☐
4. Performing direct laryngoscopy to visualize ETT position ☐
5. Transalluminating the chest to rule out pneumothorax ☐
6. Other:_____

Was the CODE PINK called prior to removing ETT?

1. Yes ☐
2. No ☐

Was the decision of removing ETT confirmed with a neonatologist?

1. Yes ☐
2. No ☐

Key people present during the event/post-UPE huddle (identify **names** and **signatures**)

1._____ 1._____

2._____ 2._____

3._____ 3._____

4._____ 4._____

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Figure 1. Unplanned extubation event form used to report incidences in our hospital. This database form is completed by the health care team on the occurrence of an unplanned extubation event. *RT*, respiratory therapist; *UPE*, unplanned extubation event.

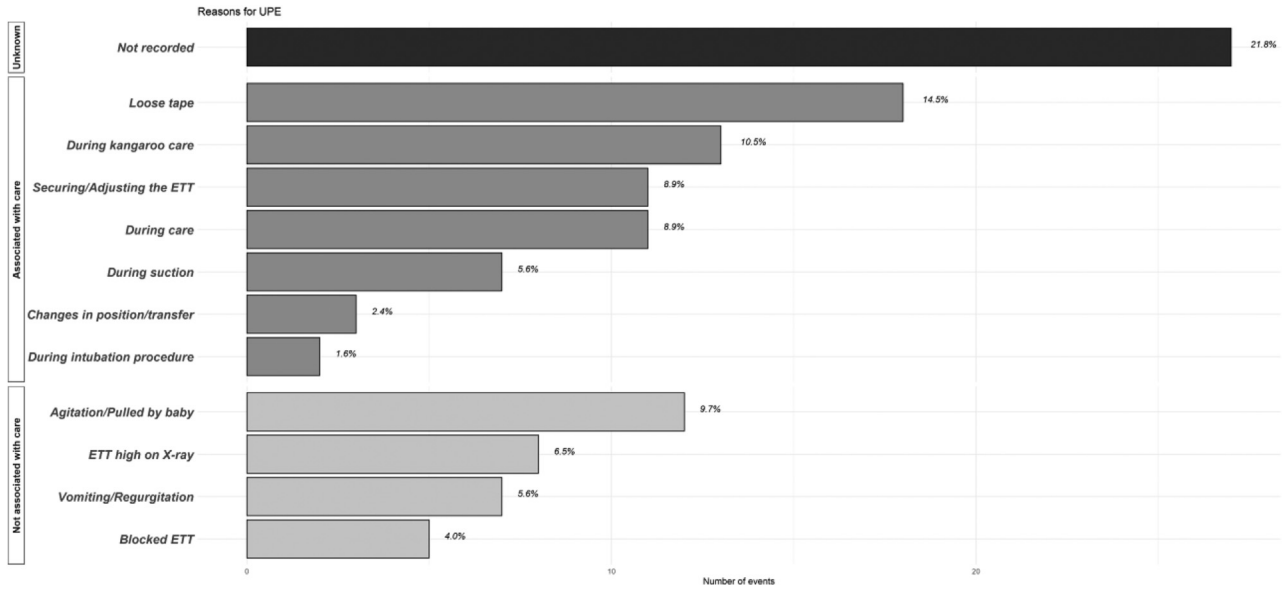

Figure 3. Bar graph comparing reasons for unplanned extubation events subclassified by association to care vs not among all unplanned extubation events (n = 113). Percentages do not add up to 100, given that one event can have multiple causes recorded, and the denominator is the number of unplanned extubation events.

Table I. Characteristics of all intubated infants and intubated infants born at <29 weeks of gestational age in this study

Characteristics	All intubated infants (N = 760)	Intubated infants born at <29 wk of gestational age (N = 190)
Gestational age at birth, wk, median (IQR)	35 (28-38)	26 (24-27)
Birth weight, g, median (IQR)	2290 (1068-3148)	810 (660-998)
Male sex, n (%)	425 (56)	92 (48)
Small for gestational age, n (%)	115 (15)	14 (7)
SNAP-II score >20, n (%)	180 (24)	70 (37)
Apgar score at 5 min <7, n (%)	381 (51)	116 (61)
Multiple births, n (%)	105 (14)	52 (27)
Cesarean birth, n (%)	423 (56)	133 (70)
Outborn, n (%)	387 (51)	29 (15)
Surfactant, n (%)	316 (42)	162 (85)
Antenatal steroids, n (%)	335 (44)	168 (88)
Duration of mechanical ventilation, d, median (IQR)	3 (2-9)	13 (3-29)
Length of stay, d, median (IQR)	22 (8-78)	98 (73-124)
BPD, n (%)	115 (16)	81 (43)
Mortality, n (%)	84 (11)	26 (14)
Death or BPD, n (%)	194 (26)	104 (55)

Table IV. Standardized difference of characteristics of infants with and those without an unplanned extubation event in the PSM cohort

Characteristics	Infants with an unplanned extubation event (N = 59)	Matched controls without an unplanned extubation event (N = 59)	Standardized difference
Gestational age at birth, wk, median (IQR)	25 (24-26)	25 (24-26)	.090
Gestational age group, n (%)			.142
<26 wk	36 (61)	40 (69)	
≥26 wk	23 (39)	19 (31)	
Birth weight, g, median (IQR)	710 (610-820)	765 (615-860)	.188
Male sex, n (%)	27 (46)	26 (44)	.034
Small for gestational age, n (%)	7 (12)	3 (5)	.245
SNAP-II score >20, n (%)	21 (36)	28 (47)	.243
Apgar score at 5 min <7, n (%)	40 (68)	39 (66)	.036
Multiple births, n (%)	13 (22)	13 (22)	<.001
Cesarean birth, n (%)	38 (64)	40 (68)	.072
Outborn, n (%)	6 (10)	8 (14)	.105
Surfactant, n (%)	49 (83)	51 (86)	.094
Antenatal steroids, n (%)	55 (93)	54 (92)	.064

Matched for gestational age (+/−2 weeks), mechanical ventilation days at time of unplanned extubation event (+/−5 days), and SNAP-II >20.

Table V. Clinical outcomes of PSM cohort infants born at <29 weeks of gestation with an unplanned extubation event and those without an unplanned extubation event (n = 59 pairs)

Outcomes	Infants with an unplanned extubation event (N = 59)	Matched controls without an unplanned extubation event (N = 59)	Median difference within pairs (IQR)	aOR (95% CI)*
Duration of mechanical ventilation, d, median (IQR)	28 (18-42)	17 (8-31)	**7 (−3 to 20)**	**2.54 (1.34-4.86)**
Post-matching duration of mechanical ventilation, d, median (IQR)	13 (1-22)	4 (1-7)	**7 (−3 to 20)**	**2.66 (1.37-5.23)**
Length of stay, d, median (IQR)	105 (88-134)	104 (90-128)	5 (−19 to 43)	1.22 (0.65-2.28)
BPD, n (%)	33 (56)	29 (49)		1.26 (0.59-2.69)
Mortality, n (%)	7 (12)	9 (15)		0.65 (0.20-1.93)
Death or BPD, n (%)	37 (63)	38 (64)		0.81 (0.37-1.79)

Significant values are in bold type.
*Adjusted for small for gestational age status and sex using conditional logistic regression.

Table VI. Reasons for reintubation in all infants with an unplanned extubation event necessitating reintubation (N = 49)

Reason for reintubation	Reintubation events, n (%)
Baseline condition	1 (2)
Respiratory distress	11 (22)
Desaturation	28 (57)
Desaturation plus another reason	3 (6)
Increased work of breathing	3 (6)
Apneas and bradycardias	3 (6)

Table VIII. Clinical outcomes of all infants born at <29 weeks of gestation receiving mechanical ventilation (N = 190)

Outcomes	Infants with an unplanned extubation event (N = 59)	Infants without an unplanned extubation event (N = 131)	aOR (95% CI)*
Length of mechanical ventilation, d, median (IQR)	28 (18-42)	7 (3-22)	**4.13 (2.30-7.50)**
Length of stay, d, median (IQR)	105 (88-134)	94 (63-117)	1.33 (0.76-2.31)
BPD, n (%)	33 (56)	48 (37)	1.65 (0.85-3.22)
Mortality, n (%)	7 (12)	19 (15)	0.65 (0.23-1.66)
Death or BPD, n (%)	37 (63)	67 (51)	1.07 (0.53-2.14)

Significant values are in bold type.
*Adjusted for gestational age, SNAP-II >20, small for gestational age status, and sex using logistic regression models.

Table IX. Outcomes of all infants born at <29 weeks of gestation with an unplanned extubation event with reintubation and those without reintubation compared to infants without an unplanned extubation event (n = 190)

Outcomes	Infants with an unplanned extubation event, reintubated (N = 35)	Infants with an unplanned extubation event, not reintubated (N = 24)	Infants without an unplanned extubation event (N = 131)	aOR (95% CI)*	aOR (95% CI)†
Total length of mechanical ventilation, d	33 (24-46)	19 (10-33)	7 (3-22)	**6.68 (3.19-14.32)**	**2.27 (1.06-4.88)**
Length of stay, d	115 (96-154)	96 (80-112)	94 (63-117)	**2.06 (1.02-4.21)**	0.82 (0.40-1.70)
BPD	24 (69)	9 (38)	48 (37)	**2.72 (1.17-6.60)**	0.82 (0.30-2.12)
Mortality	5 (14)	2 (8)	19 (15)	0.73 (0.22-2.13)	0.52 (0.08-2.02)
Death or BPD	27 (77)	10 (42)	67 (51)	1.96 (0.79-5.25)	0.49 (0.18-1.27)

Significant values are in bold type.
*aOR for comparison between patients with an unplanned extubation event who were reintubated and infants without an unplanned extubation event, calculated using logistic regression adjusted for gestational age, SNAP-II >20, small for gestational age status, and sex.
†aOR for comparison between patients with an unplanned extubation event who were not reintubated and infants without an unplanned extubation event, calculated using logistic regression adjusted for gestational age, SNAP-II >20, small for gestational age status, and sex.