

Unplanned Extubation in Neonatal Intensive Care Unit: A Systematic Review, Critical Appraisal and Evidence-Based Recommendations

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Abstract

Objective: The purpose of this study was to update the state of knowledge on unplanned extubations (UEs) in neonatal intensive care units (NICUs). This review focuses on the following topics: incidence, risk factors, reintubation after UE, outcomes, and prevention.

Material and Methods: Electronic databases were searched for relevant publications from January 1, 1950 through January 30, 2012 on the MEDLINE, EMBASE, CINAHL, Scielo, Lilacs, and Cochrane systems. Fifteen articles were selected for data abstraction. . The search strategy included the following key words: “unplanned extubation,” “accidental extubation,” “self extubation,” “unintentional extubation,” “unexpected extubation,” “inadvertent extubation,” “unintended extubation,” “spontaneous extubation,” “treatment interference,” and “airway accident.” Study quality was assessed using the Newcastle-Ottawa Scale (NOS). Grades of recommendation were assessed according to the Oxford Centre for Evidence-Based Medicine. Studies with NOS score ≥ 5 that included appropriate statistical were deemed of high methodological quality.

Results: The overall mean NOS score was 3.5. All selected studies were classified as level 4 of evidence. UE rates ranged from 0.14 to 5.3 UE/100 intubation days or 1% to 80.8%. Risk factors included restlessness/agitation (13%-89%), poor fixation of endotracheal tube (8.5%-31%), tube manipulation at the time of UE (17%-30%), and performance of a patient procedure at bedside (27.5%-50%). One study showed that every day on mechanical ventilation increased UE risk 3% (relative risk 1.03, $p < 0.01$). The association between birth weight/gestational age and UE is controversial. Reintubation rates ranged from 8.3% to 100%. There is still a gap of information about strategies addressed to reduce the incidence of UE. Best methods of endotracheal tube securement remain a controversial issue.

Conclusions: Despite numerous publications on UE, there are few studies assessing preventive strategies for adverse events and a lack of randomized clinical trials. Recommendations are proposed based on the current available literature.

KEY WORDS: accidental extubation, endotracheal tube, intubation; neonatal intensive care unit; quality improvement; unplanned extubation

1. Introduction

Mechanical ventilation through an endotracheal tube is a routine procedure in neonatal intensive care units (NICUs) and has contributed to improving critically ill neonates' survival and reducing mortality in neonatal intensive care units¹. Newborns delivered at < 28 weeks gestational age are more likely to be ventilated than their more mature counterparts². Therefore, mechanically ventilated neonates are prone to a number of adverse events such as unplanned extubation (UE)³. Of note, UE requiring reintubation is the fourth most common adverse event in NICUs in the United States³. Unplanned extubation is a potentially devastating and costly event because it may lead to a variety of complications including serious cardiovascular and respiratory events^{4, 5}. Unplanned extubation is defined as premature removal of the endotracheal tube by patients on mechanical ventilation support (deliberate UE) or by staff during nursing and medical care (accidental extubation)⁶. Greater emphasis has been placed on improving the quality of health care and patient safety in recent years and given the importance of this potentially preventable adverse event, unplanned extubation rate is monitored by many NICUs as a quality of care metric.

To reduce the UE rate in NICUs there are a variety of distinct approaches and methods that result in widely different outcomes. Therefore, standardizing procedures and goals represents an important step toward reducing outcome variability and refining quality improvement processes. A recent systematic review in critically ill children proposed a target benchmark and recommendations on UE prevention encompassing the quality of care components⁶. However, there is no consensus on strategies for the prevention of this possibly catastrophic event in neonatal care.

The aim of this review was to assess the incidence of UE, its risk factors, the incidence of reintubation after UE and the outcomes of UE. The present study will also suggest recommendations based on the available evidence to serve as a benchmark of standard care for use in quality improvement programs.

2. Methods

2.1. Search strategy

The US National Library of Medicine and National Institutes of Health (PUBMED), the Excerpta Medica database (EMBASE), the Cumulative Index to Nursing and Allied Health Literature (CINAHL), the Cochrane Library, the Scientific Electronic Library Online (SciELO) and the LILACS databases were searched for the period spanning from January 1950 to Jan 2012. The search strategy included the following key words: “unplanned extubation,” “accidental extubation,” “self extubation,” “unintentional extubation,” “unexpected extubation,” “inadvertent extubation,” “unintended extubation,” “spontaneous extubation,” “treatment interference,” and “airway accident.” In addition, the reference lists contained in the articles retrieved were checked and review articles were also included in the search to identify other potentially relevant articles..

2.2. Study selection

Two authors (PSLS and MER) independently and sequentially reviewed citations, abstracts, and full-text articles to select eligible studies. The titles or abstracts, or both, selected by either author were included in the subsequent step of the selection process. Disagreements were resolved by consensus.

The initial inclusion criteria of the potential studies for this analysis were study populations that comprised mechanically ventilated preterm and term newborns with UEs and outcomes that included UE rate, risk factors associated with UE, reintubation after UE, and strategies to prevent UE. Study designs were cohort, case-control, or cross-sectional.

Study quality was evaluated using the Newcastle-Ottawa Scale (NOS) for assessing the quality of non-randomized studies (e.g., case-control and cohort studies)⁷. Studies with NOS score ≥ 5 that included appropriate statistical analysis (e.g., risk-adjusted or multivariate) were deemed of high methodological quality. Multivariate analysis or other acceptable methods of adjusting for risk were required to reduce confounding. Two reviewers (PSLS and MER) independently rated each study, and variations in ratings were reconciled via discussion.

Grades of recommendation were assessed according to the Oxford Centre for Evidence-Based Medicine's Levels of Evidence⁸.

2.3. Statistical Analysis

We used descriptive statistics according to the variable characteristics. The medians followed by the interquartile range (25th and 75th centiles) are presented for continuous variables. Pareto charts present a summary of the data gleaned in this literature review.

3. Results

The combined computerized and bibliographic literature search yielded 34,105 potentially relevant studies, of which 192 articles were identified for more detailed review. Fifteen of these studies met the inclusion criteria^{1, 3, 5, 9-20}. Of the fifteen studies reviewed, eleven were prospective cohort studies^{3, 10-13, 15-20}, three were retrospective cohort studies^{1, 9, 14}, one was a retrospective and prospective cohort study⁵. All studies were in English.

A total of twelve studies^{3, 5, 9, 10, 12-20} were considered of low methodological quality, and three of high methodological quality^{1, 11, 18}.

3.1. Incidence

Studies conducted over the last thirty years reported UE rates ranging from 0.14⁹ to 5.3¹⁸ UE/100 intubation days (median 1.98; IQR 0.91–3.8) or 1%⁹ to 80.8%¹⁵ (median 18.2%; IQR 5.37%–45.6%). Nevertheless, this incidence has not changed over the last five years with reported rates ranging from 0.56¹⁹ to 5.3¹⁸ UE/100 intubation days (median 1.98, IQR 1.06–4.22) or from 1.28%¹⁹ to 58%¹⁸ (median 8.4%, IQR 3.7-51.6%).

3.2. Risk Factors Associated with UE

While one study showed a higher incidence of UE in infants older than 34 weeks (89%)¹⁹, two studies did not demonstrate an association between gestational age and UE^{1, 17}. With regard to association between UE and weight, the studies are also controversial. Brown¹¹ found that UE rate was higher in neonates < 1500g compared to neonates > 1500g (42% vs. 23%, $p <$

0.04) Likewise, Horimoto et al.¹⁴ found a higher UE rate in infants < 2500g (87%). On the other hand, three studies^{1, 12, 17} showed no difference in weight between UE infants and controls.

Eleven studies reported the circumstances of when UE occurred^{1, 5, 11-13, 15-20}. Seven studies^{1, 5, 11-13, 17, 19} identified that restlessness/agitation occurred between 13%⁵ and 89%¹⁹ of all patients who had UE (median 25%, IQR 16.6-57.2%) while one study reported that self-extubation (endotracheal tube cough out or pulled out) contributed to 62% of the total of UEs¹⁵. Risk factors associated with endotracheal tube are described as poor fixation (loose or wet tape) or as a tube manipulation (suctioning, retaping of endotracheal tube, and unsupported ventilator tubing). The frequency of UE associated with poor fixation ranged from 8.5%¹¹ to 31%⁵ of the total of UE (median 31%, IQR 14.9-37.5%) whereas tube manipulation at the time of UE ranged from 17%¹⁶ to 30%¹⁵ (median 26.5, IQR 21-29%) of all patients who had UE. Unplanned extubations due to a patient procedure at bedside ranged from 27.5%¹¹ to 51%¹⁷ of all UE events (median 46.1, IQR 35.4-50%). Two studies reported UE during kangaroo care (8%¹ and 21%¹⁷ of the total of UE). The use of physical restraints was assessed in two studies^{12, 13}. The percentage of patients under physical restraint at the time of UE ranged from 35%¹² to 87%¹³ of the total of UEs in these studies.

Other contributing factors, among the total of patients experiencing UEs, included previous UE (47%)¹², weaning stage from mechanical ventilation (44.4%)¹⁹, and day shifts (51%)¹². Also, Brown's study¹¹ found that the most significant factors predicting UE were the length of time intubated ($p < 0.0001$) and the taping method ($p < 0.02$).

Nevertheless, only two studies assessed the risk factors for UE employing multivariate analysis^{18, 20}. Carvalho et al.¹⁸ showed that assisted ventilation duration was the only independent predictor of UE. The authors analyzed gestational age, birth weight, gender, use of analgesia/sedation, intubation route, and total number of patient-days ventilated/month. Every day on mechanical ventilation increased UE risk 3% (relative risk 1.03, $p < 0.01$) and an assisted ventilation time of 10.5 days had an accuracy of 80% in identifying the occurrence of UE.

The number of studies that assessed each risk factor is presented in Figure 1.

3.3. Immediate Complication after Unplanned Extubation and Outcome

Two studies^{12, 14} reported hemodynamic complications immediately after UE. In relation to the total of patients who experienced UEs, the frequencies for bradycardia were 39%¹² and 46%¹⁴, respectively, and the percentage of neonates requiring cardiopulmonary resuscitation were 5%¹² and 13%¹⁴ in these studies.

Six studies^{1, 3, 5, 10, 15, 18} reported reintubation rates ranging from 8.3%³ to 100%⁹ in patients who had UE (median 58%; IQR 17.9–69.3%). We did not find neonatal studies describing predictors for reintubation in neonates who experienced UE.

Only one study assessed the impact of UE on outcome in NICU patients¹. Veldman et al.¹ reported an increased length of mechanical ventilation in UE neonates (345 hours vs 52 hours, p-value not significant) and longer NICU stay (51 days vs 9 days, p = 0.008) compared to controls.

3.4. Preventive Measures

Although several studies have been published over the last thirty years on UE in NICU patients, there are only a few studies assessing the use of preventive measures to reduce the incidence of this adverse event^{5, 16, 17, 19}. Three of these studies reported the use of alternative methods for securing endotracheal tubes^{16, 17, 19} while two other studies described the impact of a quality improvement program^{5, 19}.

Likewise, there is a paucity of studies evaluating the impact of specific measures such as the use of endotracheal tube securement, physical restraints, sedation, and ventilation-weaning protocols.

In Figure 2 we present the number of studies that assessed each preventive measure. Eighty three percent of the included studies appraised endotracheal tube fixation, weaning and extubation protocols, nurse-to-patient ratio suitability and attention to the infant with a previous unplanned extubation. Likewise in Figure 3 are the main interventions studied to prevent UE and their frequencies.

3.5. Endotracheal Tube Fixation

Nine studies described the method utilized for securing endotracheal tubes^{1, 5, 9-12, 15-17}. Although the techniques for stabilizing endotracheal tubes differed across studies, four of them⁹⁻¹² were based on the method described by Gregory²¹. Other techniques for securing tube included the umbilical clamp method^{5, 17}, two strips of adhesive Y-shaped tape^{1, 16}, the pectin-based skin barrier adhesive tape¹⁵ described by Lund et al.²² and the Logan Bow (nuchal arch)¹⁶. The conventional taping method involves two *Y*- or *H*-shaped adhesive tape strips.

Volsko and Chatburn¹⁶ found that the use of the Logan Bow to secure endotracheal tubes reduced the UE rate of infants weighing ≤ 1500 g when compared to the conventional method (21.3% vs 58.7%, $p < 0.0001$). Two studies employing the umbilical clamp technique for endotracheal stabilization demonstrated a reduction of UE rate by approximately 40%^{5, 17}. DeJonge and White¹⁷ described a reduction of UE rate from 3.2 to 1.8 UE/100 intubation days ($p = 0.001$) after changing the traditional *H*-shaped taping method to the umbilical clamp taping. Loughhead et al.⁵ reported an immediate decrease in UE rate, related to a change to the umbilical clamp taping method, from 4.2 to 2.5 UE/100 ventilator days. Two studies reported that nurses and respiratory therapists evaluated endotracheal tube security every 2h¹³ or 3h¹⁰.

3.6. Physical Restraints

There were conflicting data regarding the influence of physical restraints and unplanned extubations. In fact, few studies^{11-13, 15} mentioned the use of restraints but only two of them provided complete information^{11, 13}. Two studies^{12, 15} found that the use of limb restraints did not differ between in infants who did and did not extubate. In contrast, two other studies showed the role of restraints for UE prevention. Little et al.¹³ showed that the lack of two points or more of restraint contributed for UE in 58% of all patients who had UE while Brown¹¹ reported that head restraint may benefit infants who are more agitated. However, methodological flaws hamper the interpretation of these results.

3.7. Sedation

There are no studies in NICU patients properly assessing the use of sedatives to prevent UE. Two studies^{12, 15} reported that the use of sedatives was not associated with an increased incidence of UE. On the other hand, two authors^{1, 13} showed a high UE occurrence in patients who had not previously received sedative agents. Furthermore, Carvalho et al.¹⁸ found that UE rates were higher in newborns without sedation/analgesia; however, this variable was not associated with UE ($p = 0.858$), probably due to the limited number of patients without sedation (12% of the total ventilated patients). Only one study¹ mentioned the sedative/analgesic agents (morphine, benzodiazepines, or phenobarbital) administered in the NICU. Again, the serious methodological flaws of these studies do not allow for any consistent conclusion.

3.8. Nurse-to-patient Ratio

Three studies^{1, 12, 15} did not find a correlation between UE and nursing workload. Kleiber and Hummel¹² found that a professional was at the bedside during 75% of the events, while Franck et al.¹⁵ showed no association with nurse-to-patient ratio. In addition, Veldman et al.¹ reported that nursing staff experience and workload of nurses were not a reason for UE. On the other hand, a study by Lamy Filho et al.²⁰ demonstrated that the larger the number of newborns classified by care demand (NCCD = number of newborns present during each shift by the number of professionals in each category) per nurse and nursing technician, the more likely the occurrence of intermediate adverse events linked to mechanical ventilation. A number of NCCD > 22 per nurse (relative risk 2.86) and > 4.8 per nursing technician (relative risk 3.41) was associated with a higher prevalence of intermediate adverse events.

3.9. Quality Improvement Programs

Continuous quality improvement programs involved multiple interventions and focused mainly on data collection tool elements, identification of risk factors leading to UE events, standardization of procedures, and care practices related to the method of securing tube, staff education, and early extubation with nasal CPAP support. We identified three studies reporting the impact of a quality improvement program on UE occurrence^{5, 18, 19}. Loughhead et al.⁵ showed

that the primary reason for the improvement in the UE rate was a process improvement project which also included a change of the method of endotracheal tube stabilization. The improvement project quality comprised three different phases. Consistent with Plan-Do-Check-Act quality improvement cycles during the first period (Baseline) the authors performed data collection and review and the inconsistency in taping methods was identified as the cause for most UEs. In the second period (Intervention 1) the authors changed to a single, consistent, conventional taping methodology (bilateral Y-shaped tape strips). Throughout this period, the UE rate improved but still remained steadily above the target rate. In the third period (Intervention 2) the authors instituted the cord clam method for endotracheal tube fixation. The authors then were able to demonstrate a significant and sustained overall reduction in UE from 4.8 UEs to 0.9 UE/100 ventilator days. This improvement was found in all weight groups. Nevertheless, the smaller birth weight group the greater degree of improvement in the incidence of UE. Thus, infants with birth weight > 2500g experienced a 53% reduction in UE rate while the groups weighting between 1000g-2500g and < 1000g had a 77% and 86% reduction in UE rate, respectively. Ligi I et al.¹⁹ observed that the UE rate increased from 0.56 UE/100/intubation days at the baseline period to 1.55 UE/100 intubation days after implementation of a quality improvement program ($p = 0.03$). However, according to the authors, no conclusion should be drawn from this finding because of the negative effect of major changes during the study such as the banishment of tincture of benzoin, a reduction in the use of bilateral Y-shaped tape strips in tube fixation, and a high turnover of caregivers.

Carvalho et al.¹⁸ reported an intervention program to reduce the occurrence of UE that included staff education, tube fixation and suctioning standardization of care, as well as the use of analgesia and sedation. According to the authors, the mean UE rate reduced from 6.5 to 4.4 UE/100 intubation days.

4. Discussion

Unplanned extubation is a common event in the NICU that may be associated with serious conditions such as bronchospasm, aspiration pneumonia, hypotension, arrhythmias, cardiorespiratory arrest, and even death⁴. Moreover, UE often leads to emergent endotracheal reintubation in a less controlled scenario⁵. Repeated intubations, especially those performed emergently, increase the risk of laryngeal or tracheal injury and scarring, pulmonary injury from excessive ventilation, intraventricular hemorrhage⁵ and physiologic changes such as hypoxemia, hypercarbia, increased arterial pressure and increased intracranial pressure⁵.

Our literature review showed that there are few studies assessing unplanned extubation in neonatal intensive care units. It also revealed that high-quality studies are scarce, and only few of them assess the effectiveness of strategies to reduce the incidence of UE. Furthermore, the vast majority of the available studies simply report the incidence and risk factors associated with UE, and present methodological flaws and lack proper statistical analysis. In addition, the search yielded no case-control studies, relevant systematic reviews, or controlled, randomized clinical trials.

The incidence of UEs is expressed as a percentage (number of UEs divided by the number of ventilated patients) or as the number of UEs per 100 intubation days. The latter measure incorporates the concept of days as an exposure factor for event occurrence, thus it is more suitable as it allows comparison among different NICUs. The overall incidence of UE in NICU infants was higher than that reported for the pediatric (0.11 to 2.7 UE/100 intubation days)⁶ and adult (0.10 to 3.62 UE/100 intubation days)^{23, 24} populations. There is evident room for improvement of these NICU results and this is a particularly timely topic in light of the growing accreditation and regulatory standards aimed at improving patient safety in acute and critical care settings.

We used Pareto chart as a basic quality tool to summarize the main findings of this study. Pareto charts are useful for focusing on the areas of a process that will have the greatest impact in achieving the desired results. Figures 1 and 2 detail risk factors and preventive measures reported

in the literature review. It was clear that agitation, endotracheal tube fixation, patient procedure at bedside, loose/wet taping and prolonged time on mechanical ventilation comprised the few important risk factors for UE forming 70% of all reported reasons (Figure 1).

On the one hand agitation was one of the most assessed risk factors (20% of the studies) sedation, as a method to minimize agitation, was not as studied. On the other hand, there is evidence that the use of a defined sedation/analgesia protocol results in significant reduction in the incidence of UE in both pediatric²⁵ and adult²⁶ patients.

Still in the context of the main risk factors we also found that endotracheal tube manipulation and loose or wet taping comprised one third of the studies and likewise securing endotracheal tube techniques like umbilical clamp and Logan Bow methods included 64% of the most studied interventions (Figure 3).

Of note, the finding that a large proportion of infants successfully tolerated UE suggests that many patients are kept on mechanical ventilation longer than necessary. Hence, early extubation intended to reduce the duration of mechanical ventilation, especially once weaning process have commenced, should be taken into account as another strategy to reduce UE¹⁸.

Unplanned extubation is a quality measure involving multi-factorial causes. Thus, it is plausible to assume that interventions on quality factors may be important in reducing unplanned extubations. One third of the included studies addressed the use of quality improvement studies in order to reduce UE because the development of appropriate data tracking tools, data collection, real-time reporting to all caregivers, peer champions' education, and reinforcement of best practices are key components of clinical process improvement⁵. Thus, we suggest some recommendations for preventing UEs based on what is available in the literature (Table 1).

In summary, we reported a review of the literature assessing the main topics involved in UE and proposed a set of recommendations for UE prevention based on the available studies. The limitations in suggesting recommendations on major care activities such as the ideal method for securing endotracheal tubes, sedation/analgesia protocols, and weaning protocols are due to the

studies' methodological flaws and the limited available evidence. The small number of publications assessing the use of preventive measures, in addition to the lack of randomized clinical trials, underscores the need for future studies aiming to prevent UE events. These recommendations provide a first step forward to improve the science behind the prevention of UEs.

5. Conflict of Interest

None

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