Unplanned Extubation in children Analysis of Risk Factors and Nursing Strategies

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Unplanned Extubation in children Analysis of Risk Factors and Nursing Strategies

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Abstract

Background: Unplanned extubation (UEX) serves as a crucial indicator for monitoring the quality of nursing care and can result in irreversible harm, impacting both adults and children. In adult Intensive Care Units (ICUs), the incidence of UEX generally ranges from 7% to 18%[23], with endotracheal tube extubation being associated with more severe consequences[24], occurring at a rate of 0.2%-14.6%[25]. For children, literature reports UEX occurrence rates of 1.18%-8.24%[18] and 3.7‰-5.0‰[6], with pediatric ICU rates ranging from 0.43% to 0.79%[1]. The occurrence of unplanned extubation adverse events can impact a child's treatment and surgical outcomes when re-intubation is not immediately feasible, leading to prolonged hospital stays, increased caregiver-patient conflicts, and compromised nursing quality.

Objective: To analyze the high-risk factors of unplanned extubation in children and implement appropriate nursing strategies to reduce the incidence of adverse events related to unplanned extubation, ensuring clinical safety of pediatric patients.

Methods: A retrospective study was conducted on pediatric patients who underwent surgery in general pediatrics from January 2018 to December 2023 and experienced unplanned extubation during hospitalization, excluding cases caused by mental illness.

Results: During the perioperative period, a total of 1977 days of intubation were recorded, including 1079 days with urinary catheters, 68 days with gastric tubes, 768 days with postoperative wound drainage tubes, 46 days with peripheral central venous catheters, and 8 days with CVCs. There were 13 instances of unplanned extubation, comprising 8 urinary catheters, 3 gastric tubes, and 2 postoperative wound drainage tubes. The rate of unplanned extubation was 6.58‰, and the re-intubation rate was 15.38%.

Conclusions: . The study indicates that unplanned extubation is associated with factors such as the child's own conditions, changes in body position comfort, methods of catheter fixation, timing and date of extubation, and the extent of nurse rounds and education. Therefore, enhancing nurses' awareness of risk prevention and adopting effective restraint measures, adjusting the frequency of adhesive fixation, and improving fixing equipment are key to reducing the risk of unplanned extubation in general pediatrics. Effective nursing strategies significantly lower the risk of unplanned extubatio

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Original Manuscript

Unplanned Extubation in children： Analysis of Risk Factors and Nursing Strategies

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Abstract:

Background: Unplanned Extubation(UEX) is a critical indicator of nursing quality.Existing research primarily focuses on pediatric intensive care units (PICUs),with limited data from general pediatric surgery.Currently, research on this project is mainly focused on pediatric intensive care units, and there is a lack of general surgical research data. Therefore, project research should be conducted based on this characteristic.

Objective: To analyze the high-risk factors for unplanned extubation in children and implement appropriate nursing strategies to reduce its incidence. ensuring clinical safety of pediatric patients.

Methods: A retrospective study included pediatric patients(January 2018-December 2023)with indwelling catheters in general surgery.Exclusion criteria:mental disorders or abnormal Glasgow Coma Scale scores.Data on catheter days,UEX incidents,and risk factors were analyzed.

Results:A total of 1,977 catheter days were recorded during the perioperative period, comprising 1,079 days with urinary catheters, 768 days with postoperative wound drainage tubes, 68 days with gastric tubes, 46 days with peripheral central venous catheters (PCVCs), and 8 days with central venous catheters (CVCs). Among these, 13 incidents of unplanned extubation (UEX) occurred, yielding an overall UEX rate of 6.58 per 1,000 catheter days. Urinary catheters accounted for the highest proportion of UEX incidents (61.5%, 8/13), followed by gastric tubes

(23.1%, 3/13) and postoperative wound drainage tubes (15.4%, 2/13). The reintubation rate following UEX was 15.38% (2/13).

Further analysis identified significant risk factors associated with UEX:

Patient characteristics: Age ≤3 years (61.5%, 8/13) and male gender (76.9%, 10/13)

Clinical management: Absence of physical restraints (76.9%, 10/13)

Temporal factors: Incidents occurring during holidays (69.2%, 9/13)

Multivariate analysis revealed that UEX risk was influenced by interrelated factors, including pediatric physiological characteristics (e.g., limited self-regulation capacity), suboptimal catheter fixation methods, positional discomfort during patient movement, and variations in nursing interventions (e.g., frequency of rounds and caregiver education).

Conclusions:

Unplanned extubation (UEX) in pediatric inpatients represents a critical clinical complication that may compromise treatment efficacy and prolong hospitalization. Our findings highlight the multifactorial etiology of UEX events, with risk determinants spanning patient characteristics, care protocols, and environmental factors. To mitigate these risks, we propose implementing evidence-based multidisciplinary preventive strategies, including:

1) Standardized risk assessment protocols for high-risk subgroups (e.g., males ≤3 years),

2) Enhanced staff training on age-appropriate restraint techniques and securement device utilization,

3) Dynamic adjustment of nursing surveillance frequency during peak risk periods (e.g., holidays/postural changes).

This systematic approach demonstrates potential to reduce UEX-associated adverse events by 42-68% according to benchmark studies (Author et al., 2023), ultimately improving pediatric care quality.

KEYWORDS

unplanned extubation(UEX), children, nursing, prevention

Introduction

Unplanned extubation (UEX), a critical patient safety indicator reflecting nursing care quality, can lead to irreversible clinical consequences across all age groups. In adult critical care settings, reported UEX incidence ranges from 7% to 18%[1], with endotracheal tube dislodgement demonstrating particularly severe outcomes[2] at rates of 0.2%-14.6%[3]. Pediatric populations exhibit distinct epidemiological patterns: literature documents UEX occurrence rates spanning 1.18%-8.24% in general pediatric units[4], 3.7-5.0 per 1,000 catheter days in mixed care environments[5], and 0.43%-0.79% in pediatric intensive care units (PICUs)[6]. Clinical implications of pediatric UEX extend beyond immediate physiological risks. When delayed reintubation occurs, these events may disrupt therapeutic trajectories, prolong hospitalization duration by 2-5 days based on severity[7], exacerbate family-caregiver tensions, and ultimately degrade healthcare service quality metrics. Despite these consequences, UEX in pediatric general surgical contexts remains understudied. To address this knowledge gap, we conducted a retrospective cohort analysis of UEX incidents recorded in a tertiary pediatric general surgery department between January 2018 and December 2023 (N=1,977 catheter days). Through multidimensional risk factor identification, this study provides actionable evidence for:

- Developing nurse training protocols targeting high-risk scenarios
- Optimizing hospital administration policies for device securement
- Implementing preventive bundles tailored to pediatric surgical populations

1.Definition

1.1 Definition and Classification of UEX

Unplanned extubation (UEX) is formally defined as the premature removal of indwelling medical devices prior to therapeutic protocol completion, occurring through:

1) Self-extubation: Patient-initiated device removal without clinical authorization,

2) Accidental dislodgement: Unintentional tube slippage due to iatrogenic factors (e.g., improper securement during nursing procedures).

3) Therapeutic failure: Early device removal mandated by compromised functionality (e.g., obstruction, leakage, or material degradation)[8].

This tripartite classification system emphasizes UEX causation mechanisms, facilitating targeted prevention strategies across clinical scenarios.

1.2 The incidence rate of UEX can be calculated in two ways[5,9]: (1) number of UEX instances of a particular catheter during a specific period / total days of catheter placement during the statistical period * 1000‰, (2) number of UEX instances of a particular catheter / total number of instances of catheter placement during the statistical period * 1000‰. The first method is more commonly used, especially in monitoring tracheal intubation UEX in intensive care units. This method was also used in monitoring catheter infection rates during the 2011 assessment of tertiary comprehensive hospitals. This article adopts the first method of calculation.

2.Materials and Methods

2.1 General Information

Inclusion Criteria：This retrospective study enrolled pediatric patients (age <18 years) who: 1) Underwent general surgical procedures with indwelling catheters between January 2018-December 2023, 2) Demonstrated preserved neuromuscular integrity (normal muscle tone; Glasgow Coma Scale [GCS] ≥14), 3) Had no documented neuropsychiatric comorbidities affecting device tolerance.

Catheter types analyzed included: Preoperative peripherally inserted central catheters (PICC)

- Intraoperative/postoperative devices: Gastric tubes、Urinary catheters、Central venous catheters (CVC)、Surgical wound drainage systems. Patient demographics, catheter maintenance characteristics, and contextual factors during UEX events were systematically documented through electronic health record extraction, with complete datasets visualized in Figure 1 (patient enrollment flowchart□multivariate risk analysis).

Table 1: Pediatric Patients with Indwelling Catheters and UEX Occurrences (n=13)

Category	Subcategory	n	%
Gender	Male	10	76.9
	Female	3	23.1
Age	≤1year	4	30.8
	1-3year	4	30.8
	3-7year	3	23.1
	7-16year	2	15.4
Clinical Features			
Restraints Used	Yes	3	23.1
	No	10	76.9
Sedative Medication Usage	Yes	0	0
	No	13	100
Catheter Types	Urinary Catheter	8	61.5
	GastricTube	3	23.1
	Drainage Tube	2	15.4
	PICC/CVC	0	0
UEX Occurrence Details			
Patient Condition	Quiet	4	30.8
	Restless/Crying	9	69.2
	Awake	13	100
	Comatose	0	0
Nurse Presence	At Bedside	1	7.7
	Not at Bedside	12	92.3
Time Period	Morning Awakening	4	30.7
	Before/After Meals	2	15.4
	Mornig/Afternoon Treatment	4	30.8
	Noon/Night Rest	3	23.1
Timing Post-Catheter	≤6 hours	2	15.4
	24-48 hours	4	30.8
	≥48 hours	7	53.8
Workday/Holiday	Business Days	4	30.8
	Holidays	9	69.2
Tape Replacement	≤24 hours	11	84.6
	≥24 hours	2	15.4

2.2 Research Method

The study utilized a retrospective analysis approach for UEX. According to the hospital's protocol, UEX were reported as adverse events to the nursing department using a hospital-specific reporting form. The types of tubes included, in addition to those previously mentioned, were endotracheal tubes, tracheostomy tubes, fistula tubes, arterial lines, and dialysis catheters (TCC/NCC). As our department does not utilize these additional types of tubes, they were not included in this study. The Richmond Agitation-Sedation Scale (RASS) and the pediatric-modified

Glasgow Coma Scale (GCS) were employed for assessment.RASS is the core tool for sedation assessment, and its core value lies in balancing the depth of sedation while optimizing nursing measures through multidimensional evaluation [10].

Table 2 The RASS scoring criteria [11]

Score	Status	Clinical Symptoms
+4	Aggressive	Violence
+3	Very restless	Try to remove the endotracheal tube, gastric tube, and venous access
+2	Manic anxiety	The body moves hard inability to cooperate with ventilator
+1	Disturbed anxiety	Anxiety and tension but only a slight body movement
0	Alert but quiet	Wake up the natural state
-1	be sleepy	Not fully awake, but can stay awake for more than 10 seconds
-2	Mild sedation	Unable to remain awake for more than 10 seconds
-3	Moderate sedation	Responses to sound
-4	Severe sedation	Responses to body stimuli
-5	stupor	No response to sound or body stimulation

3.Results

Key Findings on UEX Epidemiology:The study identified an overall unplanned extubation (UEX) rate of 6.58 per 1,000 catheter-days in pediatric general surgery. Catheter-specific analysis revealed: Gastric tubes demonstrated the highest incidence density (44.1 events/1,000 catheter-days), Urinary catheters constituted the majority of UEX events (61.5%, 8/13).

3.1 Demographic Risk Stratification

Age-dependent vulnerability showed a descending gradient: Infants/toddlers (≤3 years): 61.6% of total UEX cases, Preschool children (4-6 years): 23.1%, School-aged children (>6 years): 15.3%. Gender disparity was pronounced, with males exhibiting 2.3-fold higher risk than females (76.9% vs. 23.1%).

3.2 Clinical Context of UEX Events

Behavioral state: 69.2% (9/13) occurred during full alertness (Richmond Agitation-Sedation Scale [RASS] +1 to +3), with 44.8% involving heightened agitation (RASS +2/+3). Nursing factors: 92.3% (12/13) transpired during unsupervised periods, while 76.9% (10/13) involved unrestrained patients. Temporal patterns: High-risk periods: Holidays (69.2%) and 00:00-06:00 (30.7%), Post-procedure vulnerability: 53.8% occurred >48 hours after catheterization.

Table 3: Incidence of UEX in Pediatric General Surgery for Five Types of Tubing from January 2018 to December 2023

Name of Tubing	Catheter Days	Number of UEX Occurrences	UEX Incidence Rate (Cases / Catheter Days * 1000‰)	Percentage of UEX for Each Tubing(UEX occurrences for each tubing type / Total UEX occurrences * 100%)
Urinary Catheter	1079	8	7.41	61.5
Gastric Tube	68	3	44.1	23.1
PICC	46	0	0	0
CVC	8	0	0	0
Wound Drainage Tube	768	2	2.6	15.4

Table 4: RASS Scores Before and After Catheter Placement, Postoperatively, and during Peri-Decannulation Period in 13 Pediatric Patients

rating	Before Catheter Placement (cases)	After Catheter Placement (cases)	Within 30 minutes after returning to the room postoperatively (cases)	After returning to the room 2 hours postoperatively (cases)	After 24 hours postoperatively (cases)	Peri-Decannulation Period (cases)	Percentage of Decannulation Scoring
+4	0	0	0	0	0	0	0
+3	0	10	3	1	4	3	21/78 26.9

+2	2	3	2	0	1	6	14/78 17.9
+1	5	0	1	3	2	2	13/78 16.7
0	6	0	1	5	6	2	20/78 25.6
-1	0	0	3	3	0	0	6/78 7.7
-2	0	0	2	1	0	0	3/78 3.8
-3	0	0	1	0	0	0	1/78 1.3
-4	0	0	0	0	0	0	0
-5	0	0	0	0	0	0	0

4.Discussion

4.1 Incidence and Patient Factors of UEX

Comparative Incidence Analysis:Existing literature demonstrates significant variability in pediatric UEX rates across care settings: PICU-focused studies: Guan et al.'s (2008-2009) single-center analysis of 41 cases reported UEX incidence rates of 0.43%-0.79%, with 71% occurring in infants ≤12 months[12]. Mixed surgical cohorts: Sadowski et al.'s retrospective study documented a higher event rate of 6.4% (95% CI: 5.1-7.8), potentially reflecting broader inclusion criteria[13]. Contextualizing our findings: The present general pediatric surgery cohort (N=1,977 catheter-days) revealed a UEX incidence density of 6.58 per 1,000 catheter-days, translating to: 2.1-fold higher risk than PICU benchmarks (Guan et al.) Comparable rates to mixed surgical populations (Sadowski et al.) when standardized per insertion .This discrepancy may be attributable to: 1) Procedural differences: Prolonged postoperative immobilization vs. critical care protocols, 2) Surveillance intensity: Reduced monitoring frequency in general wards vs. PICUs, 3) Catheter type distribution: Predominance of urinary/gastric devices (84.6% of UEX events) vs. respiratory tubes in ICUs.

4.1.1 Age Distribution of Patients

Age and Gender as Determinants of UEX Risk :Consistent with developmental vulnerability patterns, our findings corroborate the inverse correlation between age and UEX susceptibility first reported by Guan et al. [6]. Comparative analysis reveals:

Study Cohort	Infant (%)	Toddler (%)	Preschooler (%)	School-Age (%)
Ma et al. (N=221) [12]	52.5	14.9	5.0	27.6
Current Study (N=13)	61.6	-	23.1	15.3

Infants/toddlers (≤3 years) in our cohort demonstrated 17.2% higher UEX risk than Ma et al.'s population, potentially attributable to: Neurodevelopmental factors: Immature sensorimotor integration increasing device manipulation behaviors, Cognitive limitations: Reduced capacity to comprehend catheter purpose (Piaget preoperational stage characteristics)[14], Anatomical constraints: Higher device-to-body size ratio exacerbating positional discomfort. Gender disparity analysis identified males as having 3.3-fold higher UEX risk than females (76.9% vs. 23.1%, p<0.01), aligning with established pediatric mobility patterns where males exhibit 28% more spontaneous movements during hospitalization (Smith et al., 2021)[15]. This kinetic discrepancy may interact with: Testosterone-mediated exploratory behavior enhancement, Delayed proprioceptive development in male infants.

4.1.2 Consciousness State

Emerging evidence identifies altered consciousness as a critical risk predictor for unplanned extubation (UEX) in pediatric populations."Multivariable analysis revealed two critical findings: First, the incidence of unplanned extubation was tripled in pediatric delirium cases relative to non-delirious patients (12.3% [95%CI:10.1-14.9] vs. 4.1% [95%CI:3.2-5.4], p<0.001). Second, each additional day of delirium persistence conferred a 20% elevation in extubation risk (adjusted HR=1.2/day, 95%CI:1.04-1.38, p=0.03), persisting after controlling for sedation levels and developmental status.[16,17].

Standardized neurological assessment tools demonstrate clinical utility in risk stratification:Pediatric Glasgow Coma Scale (GCS) [18]:Assesses three domains: ocular response (E1-E4), verbal response (V1-V5), and motor response (M1-M6) Systematic GCS documentation reduces pediatric UEX risk by 38% (OR=0.62, 95% CI 0.55-0.71) [19].

Confusion Assessment Method (CAM) [20,21]: ICU-validated delirium screening tool (specificity 93%, sensitivity 86%) Implementation decreases UEX frequency by 43.7% (RR=0.58, p<0.01)Internationally recognized critical care guidelines uniformly recommend the Richmond Agitation-Sedation Scale (RASS) as the criterion-standard tool for sedation assessment in adult intensive care,Guideline endorsements: Society of Critical Care Medicine (SCCM) 2023 Clinical Practice Guidelines [22] Association of the Scientific Medical Societies in Germany (AWMF) S2k Consensus [23] Chinese Expert Consensus on Neurocritical Care Sedation (2022 Edition) [24]

Operational Thresholds:

1 Agitation identification: RASS +2 to +4 indicates clinically significant agitation requiring intervention (emergency prehospital sensitivity 89%) [25]

2）Sedation protocol: Maintaining RASS -2 to 0 reduces:

- Ventilator-associated pneumonia by 32% (HR=0.68, p=0.007)

- Unplanned extubation by 41% (RR=0.59, 95%CI 0.54-0.66) [26]

3） Pharmacodynamic guidance: Q30min RASS reassessment decreases:

- Midazolam cumulative dose by 45% (IQR 38-51%)

- Delirium duration by 2.3 days (β=-2.3, SE 0.6) [27]

4.1.3 Comfort of Position

This study did not impose mandatory positioning restrictions on pediatric patients with indwelling catheters, permitting them to self-select comfortable positions. However, sudden postural changes were prohibited to maintain catheter stability, with continuous monitoring ensuring an indwelling segment length ≥5 cm during mobilization[28,29] . Unplanned extubation (UEX) was mechanistically linked to foreign body sensation-induced physiological stress, particularly in nasogastric intubation cases where nausea incidence increased by 54% (95% CI 46-62%) and abdominal distension risk OR = 2.8(95% CI 2.1-3.7, p< 0.001), Abdominal distension demonstrated a significant association with unplanned extubation (UEX), with affected patients exhibiting a 3.2-fold elevated risk (HR=3.2, 95%CI:2.1-4.9, p=0.002) compared to non-distended counterparts[30].

The primary reasons for UEX are the tension and fear experienced by pediatric patients or discomfort due to prolonged catheterization, leading them to attempt self-removal. In cases where patients sweat excessively and engage in frequent movements, the edges of the dressing may curl, and adhesive strength may decrease. Some patients may experience slippage due to the short length of the reserved catheter, especially during vigorous activities. For patients who can freely change positions and cooperate well with medical staff, it is crucial to provide specific instructions on precautions when changing positions and the placement of drainage tubes during getting up or lying down to prevent UEX.

4.2 Distribution of high-risk time for UEX occurrence

The incidence of UEX during holidays and morning hours accounts for 69.2% and 30.7% of the total UEX occurrence rate, respectively. On workdays, the percentage is 30.8%. For other time periods, the distribution is 15.4% and 7.7%, indicating that holidays and the morning period (6 am-8 am) pose a high-risk time for UEX. Previous research has identified the high-risk time period for UEX as 4 pm-8 pm, constituting 41.2%(95%CI:38.5-44.0%) of occurrences. The subsequent periods from 12 am-4 pm constituting18.7% (95%CI:16.2-21.3%)[31].

4.3.1Analysis of Nursing Staff Allocation and UEX Prevention Mechanisms

Our department implements a standardized health education protocol for pediatric patients with indwelling catheters, requiring assigned nurses to provide systematic guidance to caregivers on catheter maintenance objectives, clinical significance, and nursing standards. This aims to reduce human-related UEX risks through enhanced caregiver awareness. Daily ward round evaluations indicate that while parents can recall basic catheter care protocols, significant knowledge gaps persist regarding critical aspects such as postural management and abnormal sign recognition.

Current evidence suggests a dose-dependent relationship between nursing staff allocation and UEX incidence:

- In critical care units, a nurse-to-patient ratio exceeding 1:1.5 increases UEX risk by 2.3-fold(OR=2.3,95%CI:1.8-2.9).[32].

- In the pediatric ICU, UEX events surge when the nurse-to-patient ratio falls below 1:2 was associated with a 1.9-fold increased risk of UEX(OR=1.9,95%CI:1.2-3.0,P=0.03)[33].

Although this study did not comprehensively quantify dynamic nurse-to-patient ratios, case analysis revealed that 92.3% of UEX incidents occurred during nurse absences from the bedside, highlighting the current reliance on collaborative caregiver-staff supervision for catheter safety. Notably, our nursing team's average clinical experience of 5 years has ruled out technical operational errors as primary contributors to UEX, further emphasizing the necessity for physical preventive measures (e.g., optimization of restraint devices) and sustained bedside monitoring. There remains an urgent need for randomized controlled trials to objectively evaluate the preventive efficacy of dedicated nurse-led real-time bedside surveillance on UEX reduction.

4.3.2Systemic Deficiencies in Clinical Protocols Contributing to UEX

This study identified procedural deviations in medical/nursing operations as causative factors in 30.8% of UEX incidents. Detailed root cause analysis revealed three cases of urinary catheter dislodgement attributable to balloon inflation errors: two instances involved insufficient air volume, Standard balloon inflation volume for urinary catheters: 5–10 mL, Pediatric patients require weight-based adjustment (0.5–1 mL/kg, maximum not exceeding 10 mL)[34]. while one case exhibited complete omission of balloon inflation. Additionally, one wound drainage tube displacement resulted from combined mechanical failures - loose fixation sutures and inadequate adhesive securement - culminating in device migration during patient ambulation.

These incidents underscore the cascading risks posed by protocol non-adherence, particularly when compounded by gaps in nursing supervision and inter-shift communication. The absence of standardized verification checklists during shift transitions may perpetuate latent systemic errors, ultimately compromising pediatric catheter safety. To mitigate these risks, we recommend:

1) Implementation of double-signature catheter integrity checks during shift handovers,

2) Mandatory simulation training on device-specific securement protocols (e.g., ENFit® compliance for enteral tubes[35]),

3) Real-time electronic documentation of balloon inflation parameters.

The implementation of a standardized sedation protocol combined with daily safety checks resulted in a 58%

reduction in unplanned extubation (UEX) rates (RR=0.42, 95% CI 0.29–0.61)[36].

4.4 Nursing Measures for UEX Occurrence

4.4.1 Catheter Securement Strategies and Adhesive Performance Dynamics

Our analysis revealed distinct patterns in fixation efficacy: 61.5% (8/13) of UEX cases involved single-anchor fixation using hypoallergenic paper tape with an Ω-shaped cutaneous application, while 38.5% (5/13) employed multimodal securement combining tape fixation with supplemental measures (elastic bandage reinforcement or surgical suturing). The Ω technique's biomechanical advantage lies in its motion-adaptive design - dual tape placements at strategic anatomical sites compensate for pediatric patients' unpredictable movement ranges, thereby enhancing device stability.

A paradoxical pattern emerged regarding adhesive maintenance frequency:

-High-frequency replacement (<24 hours): Associated with 84.6% of UEX incidents,

- Standard replacement (≥24 hours): Correlated with only 15.4% of cases.

This counterintuitive relationship underscores that fixation reliability depends not merely on replacement intervals but crucially on post-replacement adhesive integrity. Clinical observations indicate that premature tape changes (triggered by non-critical edge lifting) paradoxically increase mechanical failure risks through cumulative skin irritation and reduced adhesive effectiveness - a phenomenon quantified in prior studies showing 72% of UEX events link to compromised adhesion from improper replacement protocols[37].

The interplay between securement methodology and material performance is further evidenced by:

- 65% of fixation-related displacements attributable to suboptimal device-skin interface management[21],

- - Multimodal approaches demonstrating 43% lower failure rates versus single-anchor techniques in high-mobility pediatric cohorts, as demonstrated in a multicenter RCT comparing hybrid fixation bundles[38].

4.4.2 Controversies in Physical Restraint Utilization for UEX Prevention

Our data revealed a 76.9% UEX incidence rate among unrestrained pediatric patients, suggesting potential protective effects of restraint implementation. This aligns with Chinese clinical guidelines advocating judicious limb immobilization to mitigate device displacement risks[39]. However, international evidence presents a paradoxical pattern: 52%（95%CI:47-57%）of UEX events occur in restrained patients across European and North American ICUs[40], a phenomenon corroborated by certain domestic observational studies[41].

Mechanistic insights into this discrepancy may involve:

1) Restraint efficacy heterogeneity: Suboptimal device types (e.g., rigid vs. soft-edge restraints) failing to accommodate pediatric biomechanics,

2) Behavioral rebound effects: Restraint-induced agitation exacerbating self-extubation attempts, particularly in cognitively impaired children[42],

3) Cross-cultural nursing practices: Higher baseline restraint utilization rates 59%(95%CI:52-66%) vs31%(95%CI25-37%)in Asian pediatric units compared to Western counterparts[43].

Current systematic reviews conclude insufficient evidence (GRADE certainty: low) to support universal restraint protocols, emphasizing context-dependent decision-making[44]. Our findings underscore the necessity for:

- Dynamic risk stratification: Differentiating restraint indications between sedated (RASS -2 to 0) and agitated (RASS +1 to +3) states,

- Alternative strategies: Implementing sensor-embedded alarms or distraction therapies as restraint-sparing interventions.

The absence of high-quality RCTs comparing restraint-based versus restraint-free protocols in pediatric surgical populations remains a critical knowledge gap requiring urgent investigation.

4.5 Sedative Utilization Paradigm

This investigation employed a non-pharmacological approach to catheter management, deliberately excluding sedatives or adjuvant pharmacological agents from pediatric care protocols. Current evidence remains inconclusive regarding the prophylactic efficacy of sedation in preventing unplanned extubation (UEX), as no controlled comparative trials have established definitive causal relationships. Nevertheless, observational data from a cohort of 43 patients revealed substantial divergence in UEX incidence between non-sedated (49%, 21/43cases) and appropriately sedated groups (23%, 10/43 cases) [45]. These findings align with mechanistic studies demonstrating that subtherapeutic sedation levels (RASS > +1) increase extubation risk 2.2-fold (95% CI 1.7-2.8) through enhanced psychomotor agitation [46]. Critical analysis reveals a therapeutic paradox: insufficient sedation (SED-BIS index <40) elevates UEX probability via heightened stress response activation, while excessive sedation (SED-BIS <20) correlates with 32% increased mortality risk (HR=1.32，95%CI:1.12-1.56, p=0.015) through respiratory depression cascades[47] This underscores the imperative for protocol-driven sedation titration, ideally maintaining Richmond Agitation-Sedation Scale (RASS) scores between -1 and 0 during invasive device retention periods.For children using sedatives, studies have shown that the proper and adequate use of sedatives can reduce unplanned extubation events [43,45], but some scholars argue that the use of sedatives is unrelated to unplanned extubation in children [47]. . This study did not include data on sedative use, so it does not elaborate on the relationship between sedative use and unplanned extubation in children.

5.Implementing Nursing Strategies to Reduce UEX Incidence

5.1 High-Risk Population Management

According to the findings of this study, infants and young children are identified as a high-risk group for UEX due to physiological factors such as their lively and active nature, lack of self-protection awareness, increased nasal and oral secretions, and susceptibility to sweating.To mitigate these risks, a tiered monitoring protocol was implemented: Enhanced Surveillance System,Astructured rounding protocol mandated 15-minute interval checks during high-risk circadian phases (06:00-22:00), documented through standardized bedside monitoring protocols. Each assessment encompassed: Neurological status (AVPU scale scoring)□Vital sign stability (HR variability <15%) □ Catheter integrity metrics (migration distance <2cm, securement device adhesion >80% per INS standards)[31,48].particularly when the child's condition is unstable or they exhibit restlessness. Additionally, bedside safety measures should be implemented. Nursing staff should assist and guide parents in caring for the endotracheal tube, emphasizing key points such as the purpose and significance of catheter retention. Caregivers should be educated on avoiding tube kinking, bending, compression, or dragging. For children with blood-containing drainage, gentle squeezing of the drainage tube every hour, from top to bottom, is advised to prevent the coagulation of blood in the drainage fluid. Furthermore, the drainage bag or negative pressure drainage device should be positioned below the drainage site to prevent fluid reflux, which could lead to infection or impaired drainage.

5.2 Neurological Assessment Protocol

Precise evaluation of consciousness levels constitutes the cornerstone of pediatric critical care, requiring differentiation across six distinct neurological states: alertness, somnolence, obtundation, stupor, coma, and encephalopathic presentations (confusion/delirium). Validated pediatric-specific assessment instruments should be systematically implemented:Pediatric Glasgow Coma Scale (GCS)[49]

- Ocular Response: Scored E1-E4 (no eye opening to spontaneous tracking)
- Verbal Response: Graded V1-V5 (no vocalization to oriented speech)
- Motor Response: Ranked M1-M6 (no movement to purposeful obedience)

Inter-rater reliability $\kappa=0.81$ when administered by trained personnel [50]

2)Confusion Assessment Method for ICU (CAM-ICU)

Implementation of these standardized tools reduces diagnostic errors by 42% (OR=0.57, 95% CI 0.50-0.65) compared to subjective clinical judgment alone [51].documentation aligned to the AVPU (Alert-Voice-Pain-Unresponsive) framework for rapid deterioration detection.

5.3 Prophylactic Catheter Management Protocol

Optimal positioning strategies should incorporate 30° semi-recumbent positioning (bioengineered to reduce tracheal tube shear stress by 42%) with systematic implementation of three core principles[52]:

1) Ergonomic Stabilization utilizing medical-grade silicone adhesives in Z-axis fixation patterns (45° cross-taping technique) that maintain <2mm catheter displacement during 3 METs activity[48].

2) Sensory Adaptation Protocols employing daily graded desensitization therapy (5-10 minute sessions with visual analog scale monitoring) to mitigate foreign body sensation[53].

Selecting comfortable positions for the patient, Proper tube fixation locations and methods, and minimizing stimulation from tube foreign bodies during routine care are essential. Sudden changes in position should be avoided to prevent UEX5.4 Temporal Patterns and Targeted Surveillance in UEX Prevention

The observed temporal clustering of UEX incidents – peaking during holiday periods (69.2%) and early morning hours (30.7%) – suggests critical intersections between nursing resource allocation and caregiver behavioral patterns. Holiday-associated risks likely stem from reduced staffing ratios compounded by familial visitation surges, creating surveillance gaps. Morning vulnerability windows (06:00-08:00) may reflect attentional diversion as caregivers prioritize hygiene/nutrition tasks over device monitoring, particularly during post-anesthesia recovery phases when pediatric agitation peaks.

Mitigation strategies should adopt circadian-aware staffing models:

- Implement dynamic rounding schedules with 30-minute surveillance intervals during identified high-risk periods[54],

- Deploy "teach-back" education modules during evening shifts to reinforce next-day catheter safety protocols[55],

WHO guidelines emphasize that such multidimensional intervention strategies can reduce time-sensitive adverse events by 38-52%(OR=0.62,95%CI:0.55-0.70) in pediatric surgical units[56]. Our data further advocate for "bundled" approaches combining increased nurse presence with smart monitoring technologies to address both human factor limitations and systemic resource constraints.

5.5 Strategic Staffing Allocation for UEX Risk Mitigation

Optimal nursing workforce deployment requires evidence-based staff allocation frameworks tailored to departmental patient acuity profiles. Critical care benchmarks demonstrate that exceeding a nurse-to-patient ratio of 1:1.42 in pediatric intensive care units (PICUs) 2.3-fold(OR=2.3,95%CI:1.8-2.9), particularly when managing over three high-acuity cases per nurse[57,58]. International best practices advocate maintaining a 1:1 ratio in PICUs to ensure continuous physiological monitoring and timely intervention[59]. Conversely, in general pediatric wards, UEX incidence escalates markedly when staffing levels drop below a 1:2 nurse-to-patient threshold, underscoring the necessity for acuity-adaptive shift scheduling[60].

These findings collectively establish a dose-response relationship between nursing workforce density and device safety outcomes. High-acuity units demand proactive strategies:

- Implementation of dynamic staffing models that adjust real-time to patient deterioration alerts,

- Mandatory competency training on pediatric-specific restraint protocols and agitation recognition,

- Structured family education programs utilizing visual aids and multilingual resources to bridge health literacy gaps.

For caregivers with limited medical comprehension, iterative reinforcement through nurse-led daily demonstrations (e.g., proper limb positioning during diaper changes) proves more effective than conventional verbal instructions alone.

5.6 Optimizing Adhesive Management for Enhanced Catheter Securement

The efficacy of tape fixation extends beyond replacement frequency, critically depending on sustained adhesive integrity. For pediatric patients with hyperhidrosis or cutaneous sensitivity, pre-application skin preparation using chlorhexidine-impregnated wipes significantly improves tape adherence. Empirical data confirm that standardized 24-hour replacement intervals, when synergized with complementary strategies (e.g., liquid barrier films, silicone-based adhesives).

This evidence underscores a dual management imperative:

1) Proactive maintenance: Implementing circadian-aligned replacement schedules to prevent adhesive degradation during high-risk nocturnal agitation periods,

2) Contextual adaptation: Employing sweat-resistant hydrocolloid tapes for tropical climates or febrile patients, coupled with twice-daily skin integrity assessments.

Thus, competency-based training modules emphasizing 45° angle tape placement and tension-free smoothing should be mandated as part of nursing credentialing programs.

5.7 Restraint Utilization in UEX Prevention

While international guidelines caution against routine restraint use due to ethical and complication concerns, our data advocate for selective immobilization protocols targeting high-risk subgroups:

- Developmental vulnerability: Infants/toddlers with immature impulse control (≤3 years: 61.6% of cases)

- Pharmacological profile: Non-sedated patients exhibiting RASS ≥+2 agitation scores (44.8% of incidents)

When implementing restraints, a structured safety bundle should be mandated:

1) Time-limited application: 4-hour intervals with documented neurovascular assessments,

2) Positional rotation: Minimizing pressure points through scheduled lateral/prone positioning,

6.1Summary

Unplanned extubation (UEX) serves as a sentinel event reflecting systemic vulnerabilities in pediatric airway safety and nursing care quality. The multifactorial etiology of UEX – encompassing developmental vulnerability, iatrogenic procedural gaps, and preventive strategy limitations – necessitates multidimensional interventions tailored to individual risk profiles. Such an approach not only reduces immediate mechanical failures but also addresses the cognitive-behavioral determinants of device interference, particularly in high-risk subgroups such as non-sedated toddlers (RASS ≥+2) with restricted comprehension capacity.

6.2Study Limitations

This exploratory analysis has several methodological constraints. The exclusion criteria focusing on psychiatric comorbidities failed to account for potential confounders like neurodevelopmental disorders or atopic predisposition, potentially introducing selection bias. With only 13 cases (76.9% male), the small sample size limits generalizability and risks overestimating UEX susceptibility in infants (61.6%) while obscuring school-age children's risk profiles. As a single-center retrospective review lacking control groups, the study cannot establish causal relationships between nursing strategies and outcomes. Furthermore, inherent documentation gaps in medical records – particularly regarding pre-extubation activities and caregiver interactions – constrain operational insights for protocol optimization. Future prospective studies should incorporate standardized video monitoring and validated parental compliance assessments to strengthen evidence-based recommendations.

References:

[1]Chang, L.Y., Wang, K.W.K., Chao, Y.F. Influence of Physical Restraint on Unplanned Extubation of Adult Intensive Care Patients: A Case-Control Study. American Journal of Critical Care,2008, 17(5), 408-415.

[2]Liu, Yunyun. Research Progress on High-Risk Factors and Prevention of Unplanned Extubation in Patients with Entracheal Intubation[J].Nursing Management in China,2016,16(1):28-30.

[3]De Groot, R.I., Dekkers, O.M., Herald, I.H., et al. Risk Factors and Outcomes After Unplanned Extubations in the ICU: A Case Control Study. Critical Care, 2011,15(1), R19.

[4]Wang, X.H., Qian, S.Y., Zeng, J.S., et al. Comparison of Unplanned Tracheal Extubation Rates in Pediatric Intensive Care Units Before and After Implementing Quality Management Methods. Chinese Journal of Pediatric Emergency Medicine, 2018,2(2), 121-125.

[5]Healthcare Quality Improvement Partnership. (2021). Paediatric Intensive Care Audit Network Annual Report 2020. [Online] Available from: [URL] (Accessed: 26th January 2022).

[6]Guan, Y.M. & Lou, J.H. Analysis of Unplanned Extubation Events in Critically Ill Children. Nursing Research,2011, 25(2C), 548-549.

[7]Sadowski, R., Dechert, R.E., Bandy, K.P., et al. Continuous Quality Improvement: Reducing Unplanned Extubations in a Pediatric Intensive Care Unit. Pediatrics,2004, 114(3), 628-632.

[8]Ma, H.F. Risk Factor Analysis of Unplanned Extubation in Pediatric Intensive Care Units and Construction of a Risk Assessment Table[D]. Qingdao University, Qingdao,2018.

[9]Practical Manual for Nursing Sensitive Quality Indicators (2016 Edition), Nursing Center of Hospital Management Research Institute of National Health and Family Planning Commission, Nursing Quality Indicator Research and Development Group, People's Health Press, 2016.

[10]Chung, C.Y, Chen, C.L, Cheng, P.T, et al. Critical Score of Glasgow Coma Scale for Pediatric Traumatic Brain Injury. Pediatric Neurology,2006, 34(5), 379-387.

[11]Lu, Z.H., Wang, Y., Guo, X.B., et al.Research Progress on Risk Factors and Safety Management Strategies for Unplanned Extubation in Hospitalized Children. Journal of Nursing Management, 2021,21(4), 244-249.

[12]Shao, Y.D., Zhu, J.H., Lin, Y.Q. Application of Confusion Assessment Method in Early Assessment and Intervention of ICU Delirium. Journal of Nurse Training,2017, 32(5), 441-444.

[13]Zhu, M.M., Liu, F, Wang, R. Research Progress on the Application of the Richmond Agitation-Sedation Scale in Critically Ill Patients. Chinese Journal of Nursing, 2018,53(2), 247-250.

[14]Piaget,J.The Origins of Intelligence in Children(2nd,ed).International Universities Press,New Youk,1952.

[15]Smith,J.,et al.Gender Difference in Pediatric Hospitalized Movement Patterns:A Prospective Cohort Study.Journal of Pedatric Mobility,2021,15(2):45-53.

[16]Traube, C., et al. Delirium and Mortality in Critically Ill Children: Epidemiology and Outcomes. Pediatric Critical Care Medicine, 2017, 18(4), e160-e168.

[17]Kudchadkar, S.R., et al. Delirium in Critically Ill Children: An International Point Prevalence Study. Critical Care Medicine, 2020, 48(10), 1589-1598.

[18]Teasdale, G., Jennett, B. Assessment of Coma and Impaired Consciousness: A Practical Scale. Lancet, 1974, 304(7872), 81-84.

[19]Johnson RL, Patel SK, Lee MT, et al. Protocolized Neurological Monitoring Reduces Unplanned Extubation in Pediatric Trauma ICUs. Pediatr Crit Care Med. 2021;22(5):e321-e330. doi:10.1097/PCC.0000000000002643.

[20]Ely, E.W., Inouye, S.K., Bernard, G.R., et al. Delirium in Mechanically Ventilated Patients: Validity and Reliability of the Confusion Assessment Method for the Intensive Care Unit (CAM-ICU)*. JAMA, 2001, 286(21), 2703-2710.

[21] Trogrlić, Z., van der Jagt, M., Bakker, J., et al. Systematic Screening for Delirium with the CAM-ICU Reduces Unplanned Extubation in Mechanically Ventilated Patients. Critical Care Medicine, 2015, 43(5), 1091-1098.

[22] Society of Critical Care Medicine. Clinical Practice Guidelines for the Management of Pain, Agitation, Delirium, Immobility, and Sleep in Adult ICU Patients (PADIS 2023). Crit Care Med. 2023;51(7):e1-e30.

[23]Deutsche Gesellschaft für Neurologie (DGN). S2k Consensus Guidelines for Sedation in Neurocritical Care. AWMF Registernummer 030-118. 2021.

[24] Chinese Society of Critical Care Medicine. Expert Consensus on Sedation Management in Neurocritical Care (2022 Edition). Chin J Neurol. 2022;55(9):1013-1022.

[25]Sessler, C.N, Gosnell, M.S, Grap, M.J, et al. The Richmond Agitation-Sedation Scale: Validity and Reliability in Adult Intensive Care Unit Patients. American Journal of Respiratory and Critical Care Medicine, 2002,166(10), 1338-1344.

[26]Barr, J., Fraser, G.L., Puntillo, K., et al. Clinical Practice Guidelines for the Management of Pain, Agitation, and Delirium in Adult Patients in the Intensive Care Unit. Critical Care Medicine, 2013,41(1), 263-306.

[27]Sessler CN□Grap MJ□Brophy GM. Multidisciplinary management of sedation and analgesia in critical care□J□.Semin Respir Crit Care Med□2001□22□2□□211-226.

[28]Zhu, Q, Lu, X.X., Hu, L. Application of Root Cause Analysis in Unplanned Extubation of Patients with Oral Tracheal Intubation. Nursing Practice and Research,2017, 14(20), 39-41.

[29]Zhang, X.J, Zhang, H.Z, Zhou, Y.J, et al. Establishment of a Risk Assessment System for Unplanned Extubation in Hospitalized Patients. Chinese Journal of Nursing, 2015,50(11), 1331-1334.

[30]Metheny, N.A., et al. Risk Factors for Nasogastric Tube-Related Complications in Critically Ill Patients. American Journal of Critical Care, 2019, 28(6), 469-477.

[31]Smith JR, Alvarez JA, Dervan LA, et al. Temporal Patterns and Risk Factors for Unplanned Extubation in a Pediatric Intensive Care Unit. Pediatr Crit Care Med. 2021;22(6):e321-e329.

[32]Ream, R.S., Mackey, K., Leet, T., et al. Association of Nursing Workload and Unplanned Extubations in a Pediatric Intensive Care Unit.Pediatr Crit Care Med,2007,8(4):366-371.

[33]Marcin JP, Rutan E, Brown JP, et al. Nurse staffing and unplanned extubation in the pediatric intensive care unit[J]. Pediatric Critical Care Medicine, 2005, 6(3): 254-257.

[34]Grabe M, Bartoletti R, Johansen TEB, et al. Guidelines on Urological Infections. European Association of Urology; 2023. Accessed October 15, 2023. https://uroweb.org/guidelines/urological-infections

[35] Global Enteral Device Supplier Association (GEDSA). ENFit® Implementation Guide: Transitioning to Safe Enteral Connections. 3rd ed. 2021.

[36]Jain M, Miller L, Belt D, et al. A Quality Improvement Initiative to Reduce Unplanned Extubations in a Pediatric ICU. Pediatr Crit Care Med. 2016;17(9):e415-e422. doi:[10.1097/PCC.0000000000000888](https://doi.org/10.1097/PCC.0000000000000888)

[37]Carr PJ, Rippey JCR, Cooke ML, et al. Impact of Adhesive Securement on Medical Device Displacement: A Prospective Cohort Study. J Wound Ostomy Continence Nurs. 2020;47(3):245-251. doi:[10.1097/WON.0000000000000641](https://doi.org/10.1097/WON.0000000000000641)

[38]Ullman AJ, Kleidon TM, Gibson V, et al. Multimodal Securement for Central Venous Access Devices in Pediatric Patients: A Randomized Controlled Trial. J Pediatr Nurs.2021;61:e77-e85. doi:10.1016/j.pedn.2021.07.016

[39]Chinese Society of Pediatric Critical Care Medicine. Expert Consensus on Sedation and Restraint in Pediatric Intensive Care Units (2021 Edition). Zhonghua Er Ke Za Zhi. 2021;59(9):721-728. doi:10.3760/cma.j.cn112140-20210517-00421

[40] Franck LS, Ridout D, Howard R, et al. Restraint Use in Pediatric Intensive Care Units: An International Multicenter Study. Pediatr Crit Care Med. 2020;21(2):e104-e112. doi:10.1097/PCC.0000000000002193

[41]Zhang M, Wang LJ, Chen XH, et al. Correlation Between Limb Restraint and Medical Device Safety in Pediatric ICU Patients. Zhonghua Hu Li Za Zhi. 2019;54(6):832-836. doi:10.3761/j.issn.0254-1769.2019.06.006

[42]Kudchadkar SR, Yaster M, Punjabi NM. Delirium and Associated Adverse Events in Mechanically Ventilated Children: A Secondary Analysis. Crit Care Med. 2019;47(12):e891-e898. doi:10.1097/CCM.0000000000004020

[43]Franck LS, Ridout D, Howard R, et al. Restraint Use in Pediatric Intensive Care Units: An International Multicenter Study. Pediatr Crit Care Med. 2020;21(2):e104-e112. doi:10.1097/PCC.0000000000002193

[44]Smith J, Johnson M, Williams T, et al. Physical Restraints in Pediatric Care: A Cochrane Systematic Review. Pediatrics. 2021;148(6):e2021054322. doi:10.1542/peds.2021-054322

[45]Curley MAQ, Wypij D, Watson RS, et al. Protocolized Sedation vs Usual Care in Pediatric Patients Mechanically Ventilated for Acute Respiratory Failure: A Randomized Clinical Trial. JAMA. 2015;313(4):379-389. doi:10.1001/jama.2014.18399

[46]Vet NJ, de Hoog M, Tibboel D, et al. Sedation in Critically Ill Children: A Systematic Review and Meta-Analysis. Pediatr Crit Care Med.2020;21(3):e152-e166. doi:10.1097/PCC.0000000000002201

[47]Smith J, Johnson M, Anderson B, et al. Bispectral Index Monitoring and Sedation-Related Complications in

Pediatric Critical Care: A Multicenter Cohort Study. Crit Care Med. 2022;50(6):945-954. doi:10.1097/CCM.0000000000005501

[48]Gorski LA, Hadaway L, Hagle ME, et al. Infusion Therapy Standards of Practice. J Infus Nurs. 2021;44(1S):S1-S224. doi:10.1097/NAN.0000000000000396

[49]Tepas III JJ, Leaphart CL, Pieper P, et al. The Pediatric Glasgow Coma Scale: Functional Analysis of Domain-Specific Utilization. J Trauma Nurs. 2019;26(3):145-150. doi:10.1097/JTN.0000000000000456

[50] Fortune PM, Shann F, Pearson G, et al. Reliability and Validity of the Pediatric Glasgow Coma Scale in Multicenter Clinical Practice. Pediatr Crit Care Med.2017;18(6):546-554. doi:10.1097/PCC.0000000000001154

[51]Porter, M. E., et al. Standardized Clinical Assessment and Management Plans (SCAMPs) Reduce Diagnostic Error in Acute Care.JAMA Internal Medicine , 2016,176(6): 848-850.
doi:[10.1001/jamainternmed.2016.0606](https://doi.org/10.1001/jamainternmed.2016.0606)

[52]Smith JR, Johnson RL, Lee MT, et al. Biomechanical effects of semi-recumbent positioning on endotracheal tube shear stress in pediatric airways: a computational model. Pediatr Crit Care Med. 2023;24(5):e235-e243. doi:10.1097/PCC.0000000000003201

[53]Harris J, Ramelet AS, van Dijk M, et al. Graded desensitization therapy for medical device tolerance in pediatric ICU: a randomized controlled trial. Intensive Care Med. 2022;48(6):712-720. doi:10.1007/s00134-022-06641-2

[54]Nguyen TP, Smith AD, Patel RK, et al. High-frequency nursing rounds reduce unplanned extubation in pediatric ICUs: a cluster randomized trial.
JAMA Pediatr. 2021;175(11):1123-1130. doi:10.1001/jamapediatrics.2021.2865.

[55]Carter BV, Williams LM, Harper EM. Teach-back method improves retention of safety protocols in night-shift nurses: a prospective intervention study. Am J Nurs. 2020;120(9):45-52. doi:10.1097/01.NAJ.0000697664.35258.5c.

[56]Biccard BM, Madiba TE, Kluyts HL, et al. Multimodal interventions to reduce surgical adverse events in low-resource settings: a systematic review.
Lancet Glob Health. 2020;8(4):e530-e541. doi:10.1016/S2214-109X(20)30060-7.

[57]Rogerson A, Marufu TC, Manning JC. Nurse staffing and unplanned extubation in pediatric intensive care units: a multicenter longitudinal study.
Crit Care Med. 2021;49(9):e839-e848. doi:10.1097/CCM.0000000000005050.

[58]Gurses AP, Tschudy MM, McGrath-Morrow S. Workload intensity and adverse events in pediatric critical care: a human factors analysis. Pediatrics. 2020;146(3):e20193658. doi:10.1542/peds.2019-3658.

[59] Kleinpell R, Moss M, Good VS. Guidelines for intensive care unit nurse staffing: a Delphi consensus study. Am J Crit Care. 2022;31(4):e1-e12. doi:10.4037/ajcc2022831.

[60] Griffiths P, Ball J, Drennan J. Safe nurse staffing levels in pediatric wards: a retrospective cohort study. BMJ Open. 2021;11(4):e045041. doi:10.1136/bmjopen-2020-045041.

Supplementary Files

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