Supplementary materials

Overview of the analyzed papers

Author (Year): Aladin et al. (2025)

Title: Unplanned extubation prevention in the neuroscience ICU at a High Reliability Organization

Journal: Journal of Clinical Neuroscience

Context: intubated neuroscience ICU patients are at risk for unplanned extubation (UE), which is an indicator of ICU quality of care. UE increases the risk of pneumonia, ventilator days, tracheostomy, and prolonged ICU and hospital length-of-stay. Following serial UEs, a multidisciplinary unit-based practice standard was introduced as a quality improvement initiative in the neuroscience ICU of a large academic medical center at a High Reliability Organization (HRO).

Method: single-center pre-post quality improvement study in a neuroscience ICU. Pre-initiative UEs (June 2020–May 2021) were identified via retrospective audit of prospective incident reports from the PSI registry; post-initiative UEs (July 2021–March 2024) via prospective audit. Chart review collected data on age, sex, diagnosis, intubation day, RASS goal, sedation/analgesia, restraints, constant observation, shift, and reintubation. Total intubated patients and ventilator days were retrieved retrospectively from the electronic medical record. UE incidence was calculated per 100 ventilator days.

Population: adult intubated patients admitted to the neuroscience ICU at NYU Langone Health (NY, USA). Pre-initiative: 214 intubated patients, 968 ventilator days; 9 UEs (8 males, median age 63 years, IQR 47–67). Post-initiative: 576 intubated patients, 2,730 ventilator days; 6 UEs (6 males, median age 53 years, IQR 27–78). Diagnoses included: ischemic stroke, intracranial hemorrhage, traumatic brain injury, status epilepticus, disc disease post-spinal surgery, spinal cord tumor.

Intervention: multidisciplinary unit-based practice standard introduced in May 2021, focused on: multidisciplinary communication and bedside nurse-to-nurse handoff; timely escalation of patient safety concerns; sedation/analgesia targeting RASS ≤ -1 for all intubated patients; nonviolent soft wrist restraints (unless exclusion criteria met: imaging/EEG findings with no expected arm movement, continuous midazolam/pentobarbital infusion for burst suppression, neuromuscular weakness, paralytic use); continuous observation for patients at high risk of agitation. Education provided to nursing staff, APPs, and physicians by the unit's clinical resource nurse. Multidisciplinary debriefing after each UE with dissemination of lessons learned via weekly HRO rounds and newsletter

Outcomes: primary outcome: UE incidence per 100 ventilator days in the pre- and post-initiative periods. Secondary outcomes: need for immediate reintubation, clinical characteristics of patients experiencing UE (RASS goal, use of restraints, constant observation, shift of occurrence).

Results: pre-initiative: 9 UEs (0.93/100 ventilator days); 4 patients had no sedation/analgesia order or a RASS goal of 0; no patients were in nonviolent soft wrist restraints; 4 required immediate reintubation. Post-initiative: 6 UEs (0.22/100 ventilator days); all 6 patients had a RASS goal of −1 to −3 and were in bilateral nonviolent soft wrist restraints; no patient required immediate reintubation. UE incidence reduced from 0.93 to 0.22/100 ventilator days.

Conclusion: the quality improvement initiative effectively reduced UE incidence in the neuroscience ICU. The practice standard — based on multidisciplinary communication, adequate sedation/analgesia, nonviolent restraints, and continuous observation — is implementable in other ICUs, with potential need for adaptation based on local staffing models and resources. Further research specific to the neuroscience ICU patient population is warranted.

Author (Year): Guillemin et al. (2024)

Title: Prospective multi-center evaluation of the incidence of unplanned extubation and its outcomes in French intensive care units. The Safe-ICU study

Journal: Anaesthesia Critical Care & Pain Medicine

Context: unplanned extubation (UE) is common among mechanically ventilated ICU patients, with an incidence ranging from 0.1 to 3.6 per 100 MV days. UE includes self-extubation and accidental extubation, which differ in mechanism and prognosis. Previous studies evaluating outcomes were often retrospective, small, or did not distinguish between UE mechanisms, leading to conflicting results. A large prospective multicentre study was needed to assess UE epidemiology, characteristics, and outcomes by mechanism.

Method: multicentre prospective observational cohort study conducted in 47 French ICUs, approved by CERAR (IRB 00010254-2020-235); informed consent waived. Two-phase design over 12 months (March 2021–March 2022): Phase 1 (3 months, mandatory) — all planned and unplanned extubations recorded with total MV days; Phase 2 (up to 12 months, optional) — consecutive UE patients only. UE defined as removal of oral/nasal ETT without possibility of reinsertion without new laryngoscopy. Self-extubation: ETT removal by the patient. Accidental extubation: removal due to ICU staff manipulation. Failed self-extubation: re-intubation by day 7. Only first episode of planned or unplanned extubation included per patient. Exclusion: patients refusing data use, patients under legal protection, missing re-intubation outcome at day 7. Statistical analysis: descriptive statistics with medians and IQR; Mann-Whitney U test and Chi-2/Fisher's exact test for comparisons; Log-rank test for time-to-reintubation; propensity score matching (nearest neighbor, 1:1) for self-extubation vs. planned extubation comparison; multivariable logistic regression for mortality determinants and predictors of self-extubation failure; E-value calculated for unmeasured confounding.

Population: 605 UE patients from 47 French ICUs (45 completed full prospective monitoring). Median bed capacity 15 [IQR 12–23]; nurse/patient ratio >1:2 in 68% of centers. Total: 41,574 MV days, 4,453 planned extubations, 428 UEs over the epidemiological period. Of 605 UE patients: 535 (88%)

self-extubations, 70 (12%) accidental extubations; 463 (77%) males; median age 57 years [IQR 43–67]; median SAPS-2 44 [IQR 29–57]; 357 (58%) medical admissions; 109 (18%) SARS-CoV-2. Median ICU LOS at UE: 4 days [IQR 1–9]. Planned extubation comparison group: 1,240 patients.

Intervention: no intervention applied. Observational study evaluating UE incidence by mechanism (self-extubation vs. accidental extubation) and comparing self-extubation outcomes with planned extubation via propensity score matching. Independent risk factors for self-extubation failure (re-intubation by day 7) assessed by multivariable logistic regression. |

Outcomes: primary outcome: UE incidence per 100 MV days. Secondary outcomes: extubation failure (re-intubation by day 7), ICU mortality (D28), ICU length of stay, duration of mechanical ventilation, immediate complications (1h post-UE: cardiorespiratory arrest, severe hemodynamic and respiratory complications), time to re-intubation, independent predictors of self-extubation failure. |

Results: pooled UE incidence: 1.0/100 MV days; median per-ICU incidence 0.9 [IQR 0.5–1.4], range 0–4.3. UEs accounted for 9% of all endotracheal removals. Accidental vs. self-extubation: higher ICU mortality (34% vs. 8%, $p<0.001$), higher re-intubation rate at day 7 (83% vs. 35%, $p<0.001$), shorter time to re-intubation (4 min [IQR 1–14] vs. 102 min [IQR 14–1122], $p<0.001$), longer MV duration (17 vs. 6 days, $p<0.001$), longer ICU LOS (26 vs. 13 days, $p<0.001$). After propensity score matching, self-extubation vs. planned extubation: higher extubation failure rate (35% vs. 15%, $p<0.001$), longer MV duration (6 vs. 4 days, $p<0.001$), similar mortality (8% vs. 11%, $p=0.075$). Multivariable analysis: self-extubation independently associated with reduced mortality (OR 0.53 [95% CI 0.33–0.85], $p<0.01$); extubation failure independently associated with increased mortality (OR 2.56 [95% CI 1.50–4.36], $p<0.01$). Independent predictors of self-extubation failure: cancer (OR 2.80 [95% CI 1.48–5.27], $p<0.01$), higher respiratory rate (OR 1.05 [95% CI 1.01–1.09], $p<0.01$), lower PaO2/FiO2 (OR 1.03 [95% CI 1.00–1.06], $p=0.03$), weaning process not ongoing (OR 2.26 [95% CI 1.41–3.64], $p<0.001$), immediate severe respiratory complication (OR 7.54 [95% CI 4.78–11.90], $p<0.001$). Discomfort was the main self-reported reason for self-extubation (76% of communicating patients); 87% of self-extubations occurred without staff or family present.

Conclusion: UE is frequent in ICU, representing 9% of all extubations. Accidental extubation is rare but associated with dramatically worse outcomes compared to self-extubation. Self-extubation is not associated with increased mortality compared to planned extubation but carries a higher risk of extubation failure. Discomfort is the primary driver of self-extubation. Distinguishing between UE mechanisms is essential for future research, quality improvement, and preventive strategies.

Author (Year): Gupta et al. (2025)

Impact of performance improvement strategies on unplanned extubation in an inner-city intensive care unit

Journal: Therapeutic Advances in Respiratory Disease

Context: Unplanned extubation (UE) is a serious and frequent adverse event in ICU, with reported rates varying from 1% to 15%, tending to be higher in urban hospitals managing more critically ill and

complex patient populations. UE is associated with agitation, delirium, suboptimal sedation, inconsistent protocols, inadequate staffing, and variable use of physical restraints. Clinical consequences include emergency reintubation, ventilator-associated complications, prolonged ICU LOS, and increased healthcare costs. Data on the effects of multiple performance improvement (PI) strategies in inner-city ICU populations remain sparse.

Method: retrospective observational single-center cohort study conducted at BronxCare Hospital Center (859-bed community teaching hospital, South and Central Bronx, NY), a 36-bed adult ICU providing medical, cardiac, and surgical critical care. Nurse-to-patient ratio 1:2; two respiratory therapists available 24h/day; ICU occupancy 80–95%. Reporting conforms to STROBE statement. IRB approved (approval number 01141611). Study period January 2015–December 2023, divided into three 3-year periods: Period 1 (2015–2017, pre-PI), Period 2 (2018–2020, early-PI), Period 3 (2021–2023, sustained-PI). Inclusion: adult patients (≥18 years), intubated and mechanically ventilated >24h. Exclusion: elective extubation, MV <24h, death in ED prior to ICU admission, admission outside ICU, transfer while intubated. UE rate calculated as number of UEs divided by total mechanically ventilated ICU patients per period. Reintubation defined as re-institution of MV within 48h. Statistical analysis: Chi-square for categorical variables, ANOVA for LOS, logistic regression for predictors of UE, reintubation, tracheostomy, and mortality (OR with 95% CI); linear regression for LOS; VIF for multicollinearity; Hosmer-Lemeshow test for model calibration; Holm-Bonferroni adjustment for pairwise comparisons.

Population: 6397 mechanically ventilated adult ICU patients across three periods (Period 1: n=2,216; Period 2: n=2,017; Period 3: n=2,074). Of these, 179 (2.79%) experienced UE and were used for outcome analyses. UE patients were predominantly male (62.6%), admitted via ED (66.5%). Leading indication for intubation: respiratory failure (58.1%), airway protection (25.1%). Proportion of UE patients aged ≥71 years decreased over time (28.6% → 22.0% → 11.1%). Positive urine toxicology for benzodiazepines, opioids, and THC increased significantly across periods ($p<0.05$). |

Intervention: two-phase PI program implemented by a multidisciplinary Unplanned Extubation Committee (ICU Director, Nurse Manager, Director of Respiratory Therapy, Pulmonary Fellow), established November 2016. Phase I (January 2018, start of Period 2): standardized ETT securing method (transition from tape to ETT holders); revision of SAT/SBT protocols (daily sedation tapering from 6:00 a.m., multidisciplinary assessment); sedation practice modifications (benzodiazepines discouraged, dexmedetomidine and short-acting sedatives promoted). Phase II (January 2021, start of Period 3): visual bedside identification of high-risk airways (difficult intubation, macroglossia, BMI>35, Mallampati III–IV, neck immobility); modification of sedation guidelines (reduction in fentanyl use, SAS-guided individualized management); quarterly structured nursing education (UE risk factors, sedation/restraint practices, SAT/SBT protocols); multidisciplinary house staff education at each ICU rotation (quarterly sessions extended to fellows, attendings, RT staff); expansion of the ICU UE Committee with an intensivist champion for real-time case review and protocol adherence. Sedation assessed at least every 4h using the Riker Sedation-Agitation Scale (SAS), targeting SAS 2–4.

Outcomes: primary outcomes: UE rate (number of UEs/total mechanically ventilated patients per period), reintubation rate within 48h of UE, tracheostomy incidence following UE. Secondary outcomes: ICU mortality, hospital length of stay, discharge disposition. All outcomes compared across the three study periods.

Results: UE incidence declined significantly from 3.79% (Period 1) to 2.37% (Period 2) to 2.17% (Period 3) ($p=0.002$); pairwise differences significant for Period 1 vs. Period 2 (adj-$p=0.0298$) and Period 1 vs. Period 3 (adj-$p=0.0057$); no significant difference between Periods 2 and 3 (adj-$p=0.51$). Reintubation rates: 45.2% → 22.0% → 26.7% ($p=0.011$); multivariate OR for Period 2: 0.219 (95% CI 0.09–0.55, $p=0.001$); Period 3: 0.345 (95% CI 0.14–0.85, $p=0.021$). Additional independent predictors of lower reintubation: prior intubation history (adjusted OR=0.234, 95% CI 0.08–0.68, $p=0.007$), mechanical restraint use (adjusted OR=0.360, 95% CI 0.16–0.82, $p=0.016$), active SBT (adjusted OR=0.347, 95% CI 0.16–0.74, $p=0.006$). Tracheostomy rates: 19.0% → 0.0% → 2.2% ($p<0.001$); multivariate OR for Period 3: 0.011 (95% CI 0.00–0.43, $p=0.016$). Independent predictors of tracheostomy: age ≥71 years (adjusted OR=14.007, 95% CI 1.41–139.43, $p=0.024$), positive urine toxicology for opiates (adjusted OR=45.253, $p=0.019$). Dexmedetomidine use increased from 4.8% to 33.3% across periods ($p<0.001$); midazolam use declined. UEs occurring between 8:00 p.m. and 2:00 a.m. decreased from 26.2% to 6.7% ($p=0.023$). No significant differences in ICU mortality (9.5% vs. 10.0% vs. 11.1%, $p=0.960$), hospital LOS (mean 24.49 vs. 20.30 vs. 22.53 days, $p=0.805$), or discharge disposition across periods.

Conclusion: implementation of iterative PI strategies significantly reduced UE incidence, reintubation, and tracheostomy rates in an inner-city adult ICU over a 10-year period. Mortality and LOS were not significantly affected. A multidisciplinary, protocol-driven approach -combining standardized sedation, structured weaning, staff education, and visual safety tools - is effective in high-risk urban ICU settings. Further research is needed to explore mechanistic underpinnings of identified risk factors and to define best practices for long-term UE prevention in diverse ICU populations.

Author (Year): Minda et al. (2022)

Title: Magnitude and associated factors of unplanned extubation in intensive care unit: A multi-center prospective observational study

Journal: Annals of Medicine and Surgery

Context: unplanned extubation (UE) is a commonly reported complication among mechanically ventilated ICU patients, defined as premature removal of the ETT accidentally during medical care or by patient action. UE may lead to serious complications including airway trauma, compromised hemodynamic and respiratory function, prolonged MV, prolonged hospital stay, increased mortality, morbidity, and resource utilization. UE rates in developed countries range from 0.5% to 38.5%, but data from developing countries, including Ethiopia, remain limited.

Method: institutional-based multicenter prospective observational study conducted in 5 selected public referral hospitals in Addis Ababa, Ethiopia (Tikur Anbesa Specialized Hospital, Saint Paul Millennium Hospital, Zewditu Memorial Hospital, Yekatit 12 Hospital, Minillik Second Hospital), from January 8

to May 9, 2021. Hospitals selected by simple random sampling (lottery method) among 9 ICU-providing public hospitals. All 317 intubated ICU patients during the study period were included; 3 excluded for incomplete data (final n=314). Exclusion: COVID-19 ICU patients. Data collected via structured questionnaire by trained data collectors under principal investigator supervision. Variables included: sociodemographic characteristics, GCS, RASS, physical restraint, previous intubation history, nurse-to-patient ratio, caregiver experience, staff presence, ETT securing method, sedation agents, shift time. Analysis: Epi Data 4.6.0.2 for data entry, SPSS version 26 for analysis; binary logistic regression followed by multivariable logistic regression for variables with $p<0.25$ in univariate analysis; significance threshold $p<0.05$; results reported as COR and AOR with 95% CI. Reported according to STROCSS criteria.

Population: 314 intubated adult and pediatric ICU patients (response rate 99.05%). Median age 40 years. Male: 55.7%. Route of admission: emergency department 32.5%, ward 30.9%, operating theatre 21.3%, other hospital 15.3%. Indication for intubation: respiratory distress/airway protection 40.4%, trauma 24.2%, septic shock 18.8%. Route of intubation: oral 99.4%. ETT type: cuffed 97.5%. Majority had no prior intubation history (96.5%). Physical restraints applied in 43.9%. Night shift extubation: 38.5%. Sedation: ketamine 34.4%, benzodiazepines 33.1%. Junior resident as managing physician: 48.4%. Agitation present: 24.8%.

Intervention: no intervention applied. Observational study assessing the prevalence of UE and identifying associated risk factors through bivariable and multivariable logistic regression. |

Outcomes: primary outcome: prevalence of UE (number of UE events/total intubated ICU patients). Secondary outcomes: type of UE (self-extubation vs. accidental), location of UE occurrence (ICU vs. outside ICU), situational context of UE (during weaning, procedural activities, ventilation mode), and identification of independent risk factors associated with UE occurrence.

Results: UE prevalence: 19.74% (62/314 patients); 5 patients experienced UE twice (total 67 episodes). Self-extubation: 49 (15.6%); accidental extubation: 15 (4.8%). Location: 90.3% in ICU, 9.7% outside ICU. Context: 47 (15%) occurred with staff at bedside, 15 (4.7%) without staff. UE occurred during weaning in 10.2%, procedural activities in 6.1%, ACVCV mode in 5.1%, SIMV VCV mode in 0.6%. Independent factors significantly associated with UE in multivariable analysis: male sex (AOR=3.132, 95% CI 1.276–7.691, p=0.013); intubation duration <5 days (AOR=2.659, 95% CI 1.110–6.370, p=0.028); management by junior resident (AOR=5.890, 95% CI 2.344–14.800, $p<0.001$); agitation (AOR=5.014, 95% CI 1.992–12.621, p=0.001); physical restraint (AOR=4.352, 95% CI 1.788–10.596, p=0.001); night shift (AOR=3.307, 95% CI 1.461–7.487, p=0.004). GCS, drug type, route of admission, and age were not independently associated with UE.

Conclusion: the prevalence of UE was high (19.74%) in Addis Ababa governmental hospitals compared to most worldwide and African studies. Male sex, management by junior residents, intubation duration <5 days, agitation, physical restraint, and night shift were independently associated with UE occurrence. ICU management and hospital administration should develop appropriate sedation protocols, rearrange shift schedules, and implement targeted educational programs for ICU staff to reduce UE incidence.

Author (Year): Zuo et al. (2024)

Title: protective Restraint Nursing Interventions in ICU Patients: Assessing their Influence on Unplanned Extubation and Skin Injury Incidence

Journal: Alternative Therapies in Health and Medicine

Context: ICU patients are a vulnerable population who frequently experience psychological distress, negative emotions (fear, anxiety, depression), and physical risks including falls, skin lesions, and unplanned extubation (UE). UE disrupts treatment and can cause patient harm and extubation-related distress. The protective restraint care model has been documented for its efficacy in reducing adverse events within the ICU, mitigating the risk of scratching, bruising, and falling, and ensuring continuous treatment. Standard nursing care alone may be insufficient to address the complexity of ICU patient needs, and protective restraint nursing interventions represent a comprehensive approach targeting both patient safety and psychological well-being.

Method: randomized controlled study conducted at Hai'an People's Hospital, Jiangsu Province, China, between January 2019 and December 2020. A total of 90 ICU patients were randomly assigned in a 1:1 ratio to experimental (n=45) or control (n=45) group using computer-generated randomization. Approved by the Medical Ethics Committee of Hai'an People's Hospital (reference No. H87788). Written informed consent obtained from patients or family members. Inclusion criteria: ICU admission; criteria for mechanical ventilation and tracheal intubation; absence of extremity skin pressure ulcers and infections; absence of severe circulatory diseases; written consent obtained. Exclusion criteria: severe brain damage or severe brain injury; coagulation dysfunction; mental illness or neurological dysfunction. Statistical analysis: IBM SPSS Statistics version 20; descriptive analysis with mean ± SD for continuous variables and n (%) for categorical variables; t-test for continuous variables; chi-square test for categorical variables; normality tested by Shapiro-Wilk or Kolmogorov-Smirnov tests; $p<0.05$ considered statistically significant.

Population: 90 ICU patients (experimental group n=45, control group n=45). Mean age: 46.75±3.32 years (experimental) vs. 46.69±3.28 years (control). Sex: male 23/45 (51.1%) vs. 21/45 (46.7%). No statistically significant differences in baseline characteristics between groups (BMI, smoking, drinking, place of residence; all $p>0.05$).

Intervention: control group: conventional nursing care with close monitoring of vital signs and prompt management of abnormal conditions. Experimental group: protective restraint nursing interventions administered by a dedicated team of well-trained nurses, including: (1) initial assessment of clinical symptoms, consciousness level, and physical activity; (2) patient and family education on mechanisms, effects, and adverse consequences of protective restraint; (3) restraint techniques using soft materials and appropriately sized tools (restraint gloves and limb restraint belts) with continuous comfort monitoring; (4) optimal ward environment (temperature 25°C, humidity 55%, noise reduction); (5) psychological intervention with emotional support and positive attitude reinforcement; (6) Traditional Chinese Medicine (TCM) rehabilitation — acupoint massage twice daily (20 min/session targeting Hegu, Yanglingquan, Quchi) and acupuncture once daily (30 min targeting Zusanli, Neiguan, Hegu).

Outcomes: primary outcomes: incidence of UE and skin damage rate. Secondary outcomes: Hospital Anxiety and Depression (HAD) scale scores before and after intervention; nursing satisfaction (Patient Clinical Satisfaction Survey Questionnaire, 0–100 points); incidence of adverse reactions (wound infection, drug contamination, falling off bed); patient compliance rates.

Results: UE incidence: experimental 2/45 (4.44%) vs. control 11/45 (24.44%); skin damage rate: experimental 8/45 (11.11%) vs. control 16/45 (35.56%); both $p<0.05$. HAD scores: significantly lower in the experimental group after intervention compared to the control group ($p<0.05$). Nursing satisfaction: experimental overall satisfaction 93.33% (42/45) vs. control 73.33% (33/45); $\chi^2=6.480$, $p<0.05$. Adverse reaction incidence: experimental 2/45 (4.44%) vs. control 11/45 (24.44%), $p<0.05$. Patient compliance: experimental total compliance rate 45/45 (100%) vs. control 40/45 (88.89%); $\chi^2=5.294$, $p=0.021$. |

Conclusion: protective restraint nursing interventions significantly reduced UE incidence and skin damage in ICU patients, improved patient emotional well-being (reduced anxiety and depression), increased nursing satisfaction and patient compliance, and decreased adverse reactions compared to conventional nursing care. These findings support the clinical application and promotion of protective restraint nursing interventions in ICU settings.