INTENS CRIT CARE NUR 74 (2023) 103340

Contents lists available at ScienceDirect

Intensive & Critical Care Nursing

journal homepage: www.sciencedirect.com/journal/intensive-and-critical-care-nursing

Review Article

The risk factors of reintubation in intensive care unit patients on mechanical ventilation: A systematic review and meta-analysis

Wenrui Li [a,b], Ying Zhang [a], Zhenzhen Wang [a,b], Donghui Jia [a,b], Caiyun Zhang [b,c], Xiujuan Ma [a,b], Xinyi Han [a,b], Tana Zhao [a,b], Zhigang Zhang [a,b,*]

[a] *Department of Critical Care Medicine, The First Hospital of Lanzhou University, Lanzhou, Gansu 730000, PR China*
[b] *School of Nursing, Lanzhou University, Lanzhou, Gansu 730000, PR China*
[c] *Outpatient Department, The First Hospital of Lanzhou University, Lanzhou, Gansu 730000, PR China*

ARTICLE INFO

Keywords:
Reintubation
Intensive care unit
Mechanical ventilation
Risk factors
Meta-analysis

ABSTRACT

Objective: To assess risk factors of reintubation in intensive care unit patients on mechanical ventilation.
Methodology: We conducted a systematic review of literature (inception to May 2022) and a meta-analysis. Data are reported as pooled odds ratios for categorical variables and mean differences for continuous variables.
Results: A total of 2459 studies were retrieved of which 38 studies were included in a meta-analysis involving 22,304 patients. Risk factors identified were: older age, higher APACHE II scores, COPD, pneumonia, shock, low SaO_2, low PaO_2, low PaO_2/FiO_2, low hemoglobin, low albumin, high brain natriuretic peptide, low pH, high respiratory rate, low tidal volume, a higher rapid shallow breathing index, a lower vital capacity, a higher number of spontaneous breathing trials, prolonged length of mechanical ventilation, weak cough, a reduced patient's cough peak flow and positive cuff leak test. Subgroup analysis showed that risk factors substantially overlap when reintubation was considered within 48 hours or within 72 hours after extubation.
Conclusions: We identified 21 factors associated with increased risk for reintubation. These allow to recognize the patient at high risk for reintubation at an early stage. Future studies may combine these factors to develop comprehensive predictive algorithms allowing appropriate vigilance.

Implications for clinical practice

- Reintubation is associated with organ dysfunction secondary to physiological stress, ventilator-associated pneumonia, increased hospital costs, longer intensive care unit stays and increased risk of death.
- Risk factors of reintubation differ across studies, this indicates the importance of case-mix regarding this particular complication.
- As there are multiple risk factor associated with reintubation, the development of a comprehensive algorithm allowing early identification of patients at risk may support clinical practice.

Introduction

Between 20–40 % of intensive care unit (ICU) patients require mechanical ventilation (MV) for assisted breathing (Miltiades et al., 2017). Mechanical ventilation is associated with serious complications and the incidence of complications increases to time, such as pulmonary barotrauma, ventilator-associated pneumonia (VAP) and increased mortality (Artime and Hagberg, 2014). To reduce such complications, weaning is required during treatment as the patient's condition improves and the patient's respiratory function returns to normal, including weaning from invasive ventilation support and removal of the endotracheal tube (Savi et al., 2012). However, about 10–20 % of extubated patients require

* Corresponding author at: The First Hospital of Lanzhou University, School of Nursing, Lanzhou University, DongGang West Road No. 1, Lanzhou, Gansu, PR China.

E-mail address: zzg3444@163.com (Z. Zhang).

https://doi.org/10.1016/j.iccn.2022.103340
Received 29 July 2022; Received in revised form 18 October 2022; Accepted 19 October 2022
Available online 8 November 2022
0964-3397/

reintubation, and in high-risk patients, the reintubation rate exceeds 25–30 % (Thille et al., 2019). Although spontaneous breathing trials (SBT) are currently the gold standard, some patients still require reintubation after a successful spontaneous breathing trial. Therefore, study on additional risk factors may be helpful to indicate a higher level of vigilance post-extubation. Risk factors of reintubation may differ across studies. For example, Xiao's study (Xiao and Duan, 2018) found that spontaneous breathing trials attempts before extubation, cough and low albumin were associated with increased reintubation. Fujii's study (Fujii et al., 2018) suggested that low PaO_2/FiO_2 at extubation and duration of intubation may be risk factors for reintubation. ICU patients requiring reintubation within 48 or 72 hours of planned extubation are usually defined as extubation failure, a time that sometimes extends up to 7 days, hence an important reason why risk factors may vary across studies (Quintard et al., 2017). Therefore, it is necessary to conduct a meta-analysis to comprehensively analyze and assess risk factors of reintubation. On its turn, this will allow to identify patients at high risk for reintubation and to indicate patients requiring an increased level of vigilance after extubation. Furthermore, such data may provide a basis for developing a comprehensive algorithm predicting reintubation risk.

Material and methods

This systematic review and meta-analysis was performed by the Preferred Reporting Items for Systematic Reviews and meta-Analysis (PRISMA) statement and was registered in the International Prospective Register of Systematic Reviews (PROSPERO: CRD42022319744) (Li et al., 2022).

Selection criteria

We included studies based on the following criteria: (1) Types of studies: prospective or retrospective original research; (2) Participants: ICU patients on mechanical ventilation; (3) Research content: factors influencing reintubation or extubation failure (defined as need for reintubation).

We excluded studies based on the following criteria: (1) Reviews, letters, abstracts or conference proceedings, studies published repeatedly, and articles with the full text unavailable; (2) Non-English and non-Chinese language studies; (3) Neonatal ICU and Pediatric ICU patients; (4) Patients requiring reintubation for surgical reasons.

Search strategy

A comprehensive search was performed on English and Chinese databases. English databases include PubMed, Cochrane Library, Web of Science, and Embase. Chinese databases include China National Knowledge Infrastructure (CNKI), WanFang Database and SinoMed databases. The following text words were used: "ICU" "intensive care unit*" "critical care unit*" "reintubation" "extubation failure" "weaning failure" "post-extubation failure" "risk factors" "dangerous factors" "influence factors" "influencing factors" "associated factors". In the Chinese database, the corresponding Chinese terms were used for searching. The search period was from the date of inception to May 27, 2022.

Literature selection and data extraction

Two researchers (Li W and Wang Z) independently conduct literature screening and data extraction. Any disagreements were also resolved by discussion, with a third researcher if necessary. Studies screening process: Search records were imported into EndNote X9 literature management software. First, two researchers independently read the title and abstract to exclude the studies that did not meet the inclusion criteria, and then rescreened through reading the full text to determine the studies included in the meta-analysis. The two researchers abstracted relevant data from the included articles by a prepared standardized form, the items extracted included: first author, year of publication, study region, study design, sample size, average age, sex and associated risk factors.

Risk of bias in individual studies

Two researchers (Li W and Jia D) independently reviewed the quality of the included studies. Cohort studies and case-control studies were evaluated using the Newcastle-Ottawa Scale (NOS) (Stang, 2010), The NOS is used to assess individual studies' risk for bias in three domains: study group selection, comparability of groups, and assessment of outcomes or exposure. The total NOS score ranges from 0 to 9, and those with scores ≥ 7 are considered high-quality studies with a low risk for bias, scores ranged from 4 to 6 are considered moderate quality, scores ≤ 3 are considered low-quality studies with a high risk for bias.

Statistical analysis

Data were extracted from the original study and meta-analysis was performed using RevMan 5.4 software. The analysis was performed using the odds ratios (OR) when the results were categorical variables. When the results were continuous variables, mean difference (MD) or standardized mean difference (SMD) were used for analysis. If the data in the original study were not expressed as mean and standard deviation, data were transformed into the form of mean $\pm$ standard deviation before meta-analysis. Results are expressed as effect sizes and 95 % confidence intervals (95 % CI). Heterogeneity among included studies was analyzed using $\chi 2$ tests ($a = 0.1$), and the magnitude was quantified in conjunction with I^2. If $I^2 < 50$ % and $P > 0.10$ indicated good heterogeneity among evaluation results, a fixed-effects model was used for analysis, if $I^2 > 50$ % or $P < 0.10$ considered heterogeneity among studies and a random-effects model was used for analysis.

Results

Study selection

Through searching databases, a total of 2,454 studies were retrieved, including 1,805 English studies and 649 Chinese studies, 5 studies were supplemented through other resources. 400 studies were obtained after Endnote X9 deduplication, then reading the title and abstract of the studies, the studies that did not meet the inclusion criteria were excluded. There are 145 remaining studies, after reading the full text, 38 studies are finally included in the meta-analysis. The study selection flowchart is shown in Fig. 1.

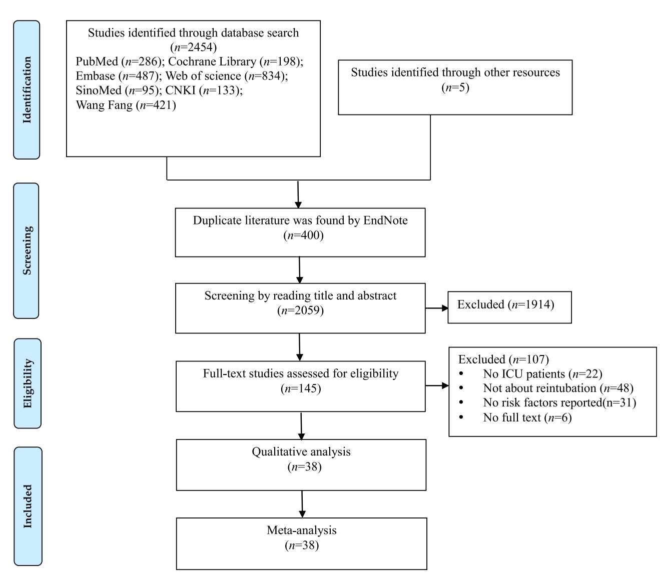

Fig. 1. The flow chart of literature searching and screening process.

Characteristics of the included studies

Among the 38 included studies, nine studies were published in the Chinese language (Feng et al., 2019; Huang and Hu, 2016; Liu, 2021; Ma et al., 2018; Shi and Liang, 2015; Wang, 2007; Xing et al., 2017; Xiong and Li, 2018; Xu et al., 2021) and all other studies were reported in English. The publication period ranged from 2001 to 2022. The studies were conducted in ten different countries. Regarding the study design, 34 were cohort studies and four were case-control studies. Nineteen studies were prospective and 19 studies were retrospective by design. A total of 22,304 patients were included, of which 2,500 experienced reintubation after extubation (11.21 %). The basic characteristics of the included studies are shown in Table 1.

Methodological quality of the included studies

The outcome of quality assessment for these studies was as follows: Of the 34 cohort studies, 31 were high-quality studies, and 3 were moderate-quality studies (Chao et al., 2017; Nantsupawat et al., 2015; Thomrongpairoj et al., 2017). All 4 case-control studies were high-quality (Dupont et al., 2001; Feng et al., 2019; Rizzo et al., 2021; Weinberg et al., 2016) (Appendix Table S1).

Results of the meta-analysis

Risk factors for reintubation

We conducted a meta-analysis on 59 extracted variables. The results showed that 21 variables were significantly different between reintubated and non-reintubated groups ($p < 0.05$): age, APACHE II scores, COPD, pneumonia, shock, SaO_2, PaO_2, PaO_2/FiO_2, hemoglobin, albumin, brain natriuretic peptide, pH, respiratory rate, tidal volume, rapid shallow breathing index, vital capacity, number of spontaneous breathing trials, length of MV, weak cough, cough peak flow, and positive cuff leak test. (Table 2 and Appendix Fig. S1).

Subgroup analysis

The results of the subgroup analysis showed that the following variables were statistically different in the analysis on risk factors of reintubation within 48 hours after extubation ($P < 0.05$): age, APACHE II scores, SOFA scores, PaO_2, PaO_2/FiO_2, tidal volume, rapid shallow breathing index, number of spontaneous breathing trials, length of MV, weak cough, positive cuff leak test. (Table 3 and Appendix Fig. S2).

The results of the subgroup analysis showed that the following variables were statistically different in the analysis on risk factors of reintubation within 72 hours after extubation ($P < 0.05$): age, APACHE II scores, COPD, shock, respiratory failure, SaO_2, PaO_2/FiO_2, hemoglobin, HCO_3, respiratory rate, use of vasopressors, and length of MV (Table 4 and Appendix Fig. S3).

Discussion

Extubation of patients on mechanical ventilation is a complex process with many influencing factors on the eventual success. Patients may require reintubation for various reasons, and reintubation is associated with organ dysfunction secondary to physiological stress, ventilator-associated pneumonia, increased hospital costs, and longer ICU stays, and increased mortality (up to 25–50 %) (Lombardi et al., 2019; Thille et al., 2013). Most of the current studies have analyzed and studied the risk factors of reintubation in different ways or with different indicators, or by prospective studies to determine the predictive value of a factor on the outcome of endotracheal extubation (Maezawa et al., 2021; Taran et al., 2021). Although possible risk factors of reintubation have been identified with different studies, no uniform perception have been reached. In previous studies, a meta-analysis by Torrini (Torrini et al., 2021) identified risk factors of extubation failure, but the definition of extubation failure lacked standardization, and in some studies, extubation failure included reintubation after extubation, death, and the need for therapeutic noninvasive ventilation or tracheotomy, which can lead to a risk of bias in the assessment. Therefore, we designed this study, and our systematic review and meta-analysis included studies on risk factors of reintubation, and among the studies on extubation failure, we only included studies that defined extubation failure as reintubation after extubation, which could avoid the risk of bias to a certain extent and draw more reliable conclusions.

Baseline data and disease severity

Our study showed that older age is a risk factor for reintubation. As age increases one experience a decrease in respiratory system functionality, chest compliance, and strength of diaphragm and respitory muscles, thereby adding to a poor prognosis in high demand states (heart failure, pneumonia, etc.) and ventilatory failure (Sharma and Goodwin, 2006). Moreover, due to increasing age, the body's resistance gradually decreases and it is prone to various chronic diseases, making it more likely that older patients are at risk for extubation failure. Studies have reported that 20–35 % of elderly patients require reintubation within 48–72 h after extubation, and the reintubation rate is significantly higher than that of the general population (Suraseranivong et al., 2018). The APACHE II score reflects the severity of the patient's condition at the time of admission to the ICU, and this study showed a significant difference in the APACHE II score between patients in the reintubation group and those in the non-reintubation group.

Primary disease and comorbidity

We performed a meta-analysis of patient comorbidities and found that patients with COPD, pneumonia and shock before extubation were risk factors of reintubation. Pneumonia is the most frequent ICU-acquired infections (including ventilator-associated pneumonia), Pneumonia was associated with increased healthcare visits, long-term care admissions, and mortality at five years(Blot et al., 2022). About 10 % of patients hospitalized with pneumonia require intubation for mechanical ventilation due to respiratory failure (Mandell et al., 2007). It has been noted that the diagnosis of pneumonia on ICU admission predicts extubation failure (Rothaar and Epstein, 2003). Patients with severe pneumonia, COPD and the occurrence of shock can lead to impaired respiratory function, and in severe cases involve the circulatory and neurological systems and even lead to multiple systemic dysfunctions, which can lead to adverse outcomes and result in an increased incidence of reintubation, which is consistent with previously reported studies (Teixeira et al., 2012; Wang et al., 2014).

Physiological parameters

We performed a meta-analysis of the extracted data on the physiological parameters of the patients and concluded that there were significant differences in SaO_2, PaO_2, PaO_2/FiO_2, hemoglobin, albumin, brain natriuretic peptide, and pH before the reintubation and non-reintubation groups. SaO_2, PaO_2, and PaO_2/FiO_2 are commonly used blood oxygen indicators that respond to the oxygenation capacity of the pulmonary and are also important physiological parameters of respiratory circulation (Feiner and Weiskopf, 2017), and $PaO_2/FiO_2 < 300$ mmHg is indicative of pulmonary respiratory dysfunction. $PaO_2/FiO_2 < 300$ or $PaO2 < 60$ and $PaO_2 > 100$ were found to be associated with adverse outcomes in a study of patients with COVID-19 (Sartini et al., 2021). Hemoglobin is an important indicator in the blood cell analysis of patients, and anemia is very common in critically ill and injured patients and is considered to be a marker of disease severity (Hayden et al., 2012). Hemoglobin levels < 80 g/L were reported to be a risk factor for withdrawal and extubation failure (Lai et al., 2013). Kollert's study (Kollert et al., 2013) showed that higher hemoglobin levels were strongly associated with long-term survival in patients with COPD

Table 1
Characteristics of the included studies.

Study	Country	Study design	prospective/ retrospective	Sample (N) Total-R -NR	Age, y R/NR	Sex (male) R/NR	Time to reintubation
Asehnoune et al., 2017	France	Cohort study	prospective	437–99-338	54 ± 18/48 ± 18	61/206	within 48 h after extubation
Brown et al., 2011	USA	Cohort study	prospective	276–17-259	46 ± 17/38 ± 17	94 %/78 %	within 24 h after extubation
Buppha et al., 2016	Thailand	Cohort study	prospective	2890–141-2749	67.23 ± 15.23/60.56 ± 17.58	77/1652	within 72 h after extubation
Chao et al., 2017	Chinese Taiwan	Cohort study	retrospective	595–34-561	69.5 ± 11.4/63.2 ± 16.0	20/383	within 48 h after extubation
Cheng et al., 2011	Chinese Taiwan	Cohort study	retrospective	1794–167-1627	68.3 ± 15.5/60.6 ± 16.8	100/1057	within 48 h after extubation
Dos Reis et al., 2017	Brazil	Cohort study	prospective	311–43-268	36.7 ± 15.0/35.5 ± 13.6	34/253	within 48 h after extubation
Dupont et al., 2001	France	Case-control study	retrospective	40–20-20	66(56–76)/66(59–78)	16/11	within 72 h after extubation
Feng, 2019	China	Case-control study	retrospective	102–18-84	76.28 ± 16.69/66.88 ± 16.59	8/46	within 48 h after extubation
Frutos-Vivar et al., 2006	Multinational	Cohort study	prospective	900–121-779	60 ± 17/55 ± 19	68/480	after extubation
Fujii et al., 2018	Japan	Cohort study	retrospective	262–12-250	60 ± 16.8/65 ± 16.1	5/144	within 48 h after extubation
Haruna et al., 2022	Japan	Cohort study	retrospective	400–51-349	65.2 ± 13.3/64.3 ± 14.2	24/235	within 24 h after extubation
Hsiung Lee et al., 2017	Singapore	Cohort study	prospective	508–38-470	>16 years	22/293	within 72 h after extubation
Huang and Hu, 2016	China	Cohort study	retrospective	665–85-580	49.5 ± 17.8/53.5 ± 17.7	——	within 48 h after extubation
Kutchak et al., 2017	Brazil	Cohort study	prospective	132–42-90	48.2 ± 16.7/47.7 ± 17.2	28/66	within 48 h after extubation
Lai et al., 2016	Chinese Taiwan	Cohort study	retrospective	6583–403-6180	66.7 ± 14.4/64.3 ± 16.4	225/4036	within 48 h after extubation
Liu, 2021	China	Cohort study	retrospective	91–24-67	54.95 %≥60 years	15/36	within 48 h after extubation
Ma et al., 2018	China	Cohort study	retrospective	108–19-89	53.89 ± 13.56/53.10 ± 8.38	11/46	within 48 h after extubation
Michetti et al., 2018	USA	Cohort study	prospective	436–32-404	53(37–73)/51(32–69)	24/236	within 96 h after extubation
Miu et al., 2014	USA	Cohort study	prospective	2007–379-1628	49.5 ± 17.9	66 %	within any time after extubation
Nantsupawat et al., 2015	USA	Cohort study	retrospective	72–11-61	62.1 ± 12.2/62.9 ± 9.7	7/26	after extubation
Piriyapatsom et al., 2016	USA	Cohort study	prospective	764–65-699	67(56–75)/ 63(47–72)	46/428	within 72 h after extubation
Rizzo et al., 2021	USA	Case-control study	retrospective	98–52-46	51 ± 19/51 ± 16	47/43	within 72 h after extubation
Santibanez-Velazquez et al., 2020	Mexico	Cohort study	prospective	123–37-86	16–75	64	within 72 h after extubation
Saugel et al., 2012	Germany	Cohort study	retrospective	61–7-54	64.6 ± 8.4/63.5 ± 14.5	6/29	within 48 h after extubation
Shi and Liang, 2015	China	Cohort study	prospective	139–19-120	74 ± 10/66 ± 6	16/101	after extubation
Su et al., 2010	Chinese Taiwan	Cohort study	prospective	150–32-118	68(20–88)/ 66(20–95)	19/77	after extubation
Suraseranivong et al., 2018	Thailand	Cohort study	prospective	127–15-112	78.73 ± 9.33/ 75.97 ± 9.16	5/65	within 48 h after extubation
Thille et al., 2011	France	Cohort study	prospective	168–26-142	65 ± 16/56 ± 17	19/82	within 72 h after extubation
Thille et al., 2015	France	Cohort study	prospective	225–31-194	66.9 ± 9.4/61.2 ± 16.2	23/110	within 7 days after extubation
Thomrongpairoj et al., 2017	Thailand	Cohort study	retrospective	105–48-57	63.0 ± 19.1/63.6 ± 17.1	49.1 %/50.9 %	after extubation
Wang, 2007	China	Cohort study	retrospective	65–25-40	59.6 ± 21.7/46.4 ± 19.5	10/18	within 24 h after extubation
Weber et al., 2021	Israel	Cohort study	retrospective	329–66-263	63.6(54.3–75.4)/62.3 (46.3–71)	34/171	within 48 h after extubation
				329–83-246	65.7(55–76.2)/62.1 (45.7–70)	45/160	within 7 days after extubation
Weinberg et al., 2016	USA	Case-control study	prospective	126–63-63	44.5 ± 18.7/37.4 ± 14.2	50/47	within 72 h after extubation
Xiao and Duan, 2018	China	Cohort study	prospective	139–22-117	77 ± 11/63 ± 19	14/77	within 72 h after extubation
Xing et al., 2017	China	Cohort study	retrospective	80–16-64	63.6 ± 14.3/62.2 ± 13.6	13/49	within 48 h after extubation
Xiong and Li, 2018	China	Cohort study	prospective	125–58-67	63.4 ± 17.3	68	after extubation during ICU stay
Xu et al., 2021	China	Cohort study	retrospective	746–102-644	63.10 ± 10.24/58.59 ± 15.97	70/368	within 48 h after extubation
Yu et al., 2020	China	Cohort study	retrospective	125–43-82	61 ± 18/60 ± 18	24/57	within 72 h after extubation

R: reintubation; NR: non-reintubation.

combined with chronic respiratory failure, especially hemoglobin ≥ 143 g/L in women and hemoglobin ≥ 151 g/L in men was an independent predictor of good prognosis. Brain natriuretic peptide is an index that responds to cardiac function, and although no relationship between heart failure and extubation outcomes was shown in our study, previous studies have suggested that cardiovascular dysfunction may be a potential mechanism for extubation failure. Chien's study (Chien et al., 2008) found that patients in the reintubation group had significantly higher brain natriuretic peptide levels at the end of SBT than those who were successfully extubated. Cao's study (Cao et al., 2022) also showed that brain natriuretic peptide levels can be used as a predictor of extraction outcome. The study found that pH showed significant differences between reintubated and non-reintubated groups, this discovery has been rarely mentioned in previous studies, we found only one study in which pH was considered in the construction of a model to predict the outcome of extraction (Gobert et al., 2017). Our study found that lower pH is associated with reintubation, but the differences are clinically quite small.

Ventilatory parameters

We performed a meta-analysis of all ventilatory parameters before the patients were extubated and found that there were significant differences in respiratory rate, tidal volume, rapid shallow breathing index and vital capacity between two groups. Our study showed that patients in the reintubation group before extubation had lower tidal volumes and higher respiratory rates and rapid shallow breathing index. Because rapid shallow breathing index = respiratory rate/tidal volume, an increased rapid shallow breathing index is a typical sign of respiratory muscle fatigue, and a decrease in respiratory work leads to a decrease in tidal volume and an inevitable increase in rapid shallow breathing index. Several studies have reported the predictive value of rapid shallow breathing index on patient outcomes for extubation. Goharani's study (Goharani et al., 2019) found that rapid shallow breathing index predicted extubation success in patients with COPD suffering from hypercapnic respiratory failure. Bien's study (Bien et al., 2004) found a significantly higher rapid shallow breathing index in reintubated patients (68.9 vs 44.9, $p < 0.05$). Trivedi et al. performed a meta-analysis of rapid shallow breathing index for predicting extubation success and showed that rapid shallow breathing index has moderate sensitivity but poor specificity in predicting extubation success (Trivedi et al., 2022). We still need to explore rapid shallow breathing index in combination with other parameters to assess the high risk of reintubation to achieve optimal accuracy. Our study shows that lower vital capacity is associated with reintubation. Vital capacity in a sense can reflect the potential capacity of respiratory muscle energy, and significant decrease of vital capacity is a sign of restrictive ventilation disorder. Terzi et al. found that forced vital capacity may serve as an objective predictor of post-extubation respiratory failure requiring reintubation, and further studies are needed to confirm the results in different conditions and populations(Terzi et al., 2018).

Number of spontaneous breathing trials before extubation

As an evaluation method that can accurately reflect the patient's spontaneous breathing ability, spontaneous breathing trials can effectively guide clinicians to comprehensively evaluate the patient's condition before extubation. The failure criteria of spontaneous breathing trials are divided into subjective indicators (depressed mental status, diaphoresis, cyanosis, etc.) and objective indicators (tachypnea, tachycardia, hypertension, hypotension, hypoxemia or acidosis, arrhythmia, etc.), The results of our study suggest that the number of spontaneous breathing trials before extubation is an influencing factor in reintubated patients, and if a patient requires multiple spontaneous breathing trials, it suggests that the patients have difficulty weaning and extubating, that the patients still have acute respiratory failure, and that there is an increased risk of reintubation after extubation (Magnet et al., 2020).

Length of mechanical ventilation before extubation

Long-term mechanical ventilation can inhibit the respiratory mucus cilia system, thus reducing airway defenses, and a large number of pathogenic bacteria enter the body, causing damage to the mucosa and affecting pulmonary function (Safdar et al., 2005). Mechanical ventilation increases airway pressure and subsequently increases intrathoracic pressure, and may also decrease systemic and intra-abdominal corporate perfusion and systemic inflammatory responses (Putensen et al., 2006). Therefore, the longer the patient is on mechanical ventilation, the higher the risk of various complications including reintubation.

Cough ability and cough peak flow

ICU patients often present with impaired neuromuscular function leading to weakness, described as ICU-acquired weakness, which is typically generalized, symmetrical, and affects limb (proximal more than distal) and respiratory muscles (Vanhorebeek et al., 2020). If the patient's respiratory muscle tone is reduced, the ability to cough and expel sputum is diminished. The ineffective ability to cough causes excessive secretions and tends to cause impaired ventilation, leading to the development and progression of pulmonary infections (Rose et al., 2017). Studies have shown that the patient's peak cough flow rate can be measured to determine whether the patient's coughing ability meets the criteria for successful extubation (Brennan et al., 2022). Smina's study (Smina et al., 2003) found that cough peak flow values were significantly lower in patients with failed extubation than in patients with successful extubation. In clinical practice, the patient's muscle weakness can be improved through pulmonary rehabilitation and early bed mobility to strengthen respiratory muscle function.

Cuff leak test

The cuff leak test assists in assessing whether a patient has upper airway obstruction after extubation by comparing the change in tidal volume before and after emptying the tracheal intubation balloon. The clinical practice guideline published by the American Thoracic Society and American College of Chest Physicians recommends performing cuff leak test for mechanically ventilated adults who meet extubation criteria to screen those at high risk for post-extubation stridor(Girard et al., 2017). The results of previous meta-analysis showed that cuff leak test in predicting airway complications after extubation can achieve good accuracy but with moderate sensitivity(Kuriyama et al., 2020; Ochoa et al., 2009). Our study shows that a positive cuff leak test is associated with reintubation. Therefore, a positive cuff leak test could alert clinicians on high risk of upper airway obstruction and reintubation.

Subgroup analysis

As the time to reintubation was defined differently in various studies, we performed subgroup analysis, and reintubation within 48 h after extubation and reintubation within 72 h were the most widely studied concepts, and we performed separate meta-analyses to analyze the respective risk factors. Sixteen studies analyzed the risk factors of reintubation within 48 h after extubation, and 10 studies defined reintubation as within 72 h after extubation. Most of the risk factors analyzed in these two time periods overlapped with previous risk factors, however, it is worth noting that new risk factors also emerged. When we performed a subgroup analysis of studies in which reintubation was defined within 48 h, SOFA score was a risk factor for patient reintubation, which was not present before. When reintubation was defined within 72 h, three significant variables emerged: respiratory failure, HCO_3, and use of vasopressors. The clinical relevance of these differences are difficult to point out. Probably differences in case-mix between

Table 2
Summary of potential risk factors for reintubation.

Risk factors	No. of studies	Heterogeneity		Statistical model	Statistical method	Effect estimate [95 %CI]	P
		I^2	P				
Baseline data							
Age	34	59 %	<0.00001	random-effects	MD	3.98 [2.72, 5.24]	<0.00001
Sex, male	32	56 %	<0.0001	random-effects	OR	0.88 [0.73, 1.06]	0.17
BMI	11	0 %	0.75	fixed-effects	MD	−0.27 [-0.63, 0.09]	0.14
Disease severity							
APACHE II score	21	91 %	<0.00001	random-effects	MD	3.67 [2.36, 4.98]	<0.00001
SAPS II	8	67 %	0.004	random-effects	MD	2.43 [0.02, 4.83]	0.05
GCS score	13	94 %	<0.00001	random-effects	MD	−0.33 [-0.81, 0.15]	0.18
SOFA score	11	60 %	0.005	random-effects	MD	0.33 [-0.12, 0.79]	0.15
CCI	2	77 %	0.04	random-effects	MD	0.36 [-0.62, 1.34]	0.47
TISS scale	2	0 %	0.69	fixed-effects	MD	1.30 [-0.60, 3.20]	0.18
ISS	2	0 %	0.62	fixed-effects	MD	0.23 [-2.31, 2.77]	0.86
Primary disease and comorbidity							
COPD	9	39 %	0.11	fixed-effects	OR	1.34 [1.05, 1.72]	0.02
Pneumonia	10	57 %	0.01	random-effects	OR	2.58 [1.72, 3.87]	<0.00001
Shock	6	0 %	0.52	fixed-effects	OR	1.41 [1.05, 1.89]	0.02
ARDS	7	0 %	0.69	fixed-effects	OR	1.15 [0.76, 1.74]	0.52
Respiratory failure	3	70 %	0.04	random-effects	OR	1.64 [0.64, 4.23]	0.31
Coronary artery diseases	6	0 %	0.69	fixed-effects	OR	1.38 [0.98, 1.93]	0.06
Heart failure	9	65 %	0.003	random-effects	OR	1.22 [0.68, 2.20]	0.50
Delirium	2	94 %	<0.00001	random-effects	OR	2.53 [0.09, 68.09]	0.58
Sepsis	5	68 %	0.01	random-effects	OR	1.66 [0.82, 3.38]	0.16
Physiological parameters							
SaO_2	8	63 %	0.009	random-effects	MD	−0.39 [-0.70, −0.07]	0.02
PaO_2	14	70 %	<0.0001	random-effects	MD	−0.32 [-0.48, −0.16]	<0.0001
PaO_2/FiO_2	16	43 %	0.04	fixed-effects	MD	–32.85 [-41.64, −24.05]	<0.00001
Hemoglobin	15	52 %	0.009	random-effects	MD	−0.53 [-0.78, −0.29]	<0.0001
Albumin	10	68 %	0.001	random-effects	MD	−1.59 [-2.83, −0.35]	0.01
Brain natriuretic peptide	2	78 %	0.03	random-effects	MD	5541 [2033, 9049]	0.002
pH	17	66 %	<0.0001	random-effects	MD	−0.01[-0.02, −0.00]	0.02
White blood cell count	4	53 %	0.09	random-effects	SMD	0.29 [-0.11, 0.68]	0.16
$PaCO_2$	15	83 %	<0.00001	random-effects	MD	1.32 [-0.23, 2.86]	0.09
Creatinine	10	78 %	<0.00001	random-effects	SMD	0.18 [-0.07, 0.43]	0.15
Total protein	4	68 %	0.03	random-effects	MD	0.76 [-4.26, 5.78]	0.77
Platelets	2	38 %	0.20	fixed-effects	MD	−2.61 [-34.94, 29.73]	0.87
Na	6	86 %	<0.00001	random-effects	MD	−1.22 [-4.17, 1.73]	0.42
K	5	29 %	0.23	fixed-effects	MD	−0.08 [-0.17, 0.01]	0.08
Ca	3	72 %	0.03	random-effects	SMD	0.24 [-0.16, 0.65]	0.24
P	2	71 %	0.06	random-effects	MD	0.04 [-0.48, 0.55]	0.89
Mg	2	0 %	1	fixed-effects	MD	−0.03 [-0.10, 0.04]	0.4
HCO_3	5	0 %	0.53	fixed-effects	MD	−0.81 [-1.72, 0.10]	0.08
Ventilator parameters							
Respiratory rate	14	59 %	0.002	random-effects	MD	1.24 [0.57, 1.91]	0.0003
Tidal volume	8	66 %	0.005	random-effects	MD	−26.79 [-44.53, −9.04]	0.003
Rapid Shallow Breathing Index	19	81 %	<0.00001	random-effects	MD	7.01 [3.55, 10.48]	<0.0001
Vital capacity	2	0 %	0.64	fixed-effects	MD	−61.91 [-105.40, −18.43]	0.005
PEEP	8	29 %	0.21	fixed-effects	MD	0.04 [-0.04, 0.12]	0.36
FiO_2	9	0 %	0.47	fixed-effects	MD	−0.01 [-0.02, 0.00]	0.21
Minute ventilation	9	82 %	<0.00001	random-effects	MD	0.38 [-0.19, 0.95]	0.19
Maximum inspiratory pressure	7	97 %	<0.0001	random-effects	MD	−6.20 [-12.68, 0.28]	0.06
Maximum expiratory pressure	6	98 %	<0.00001	random-effects	MD	−9.55 [–22.03, 2.92]	0.13
Ventilator mode (PSV)	4	9 %	0.35	fixed-effects	OR	1.45 [0.88, 2.38]	0.14
Ventilator mode (CPAP)	2	93 %	<0.0001	random-effects	OR	0.20 [0.01, 5.19]	0.33
Medication							
Vasopressors	4	71 %	0.02	random-effects	OR	1.60 [0.98, 2.61]	0.06
Neuromuscular blocking agents	2	79 %	0.03	random-effects	OR	0.90 [0.37, 2.16]	0.81
Sedative agents	3	95 %	<0.00001	random-effects	OR	1.46 [0.55, 3.91]	0.45
Steroids	5	52 %	0.08	random-effects	OR	1.06 [0.61, 1.86]	0.83
Number of spontaneous breathing trials	5	66 %	0.02	random-effects	MD	0.97 [0.58, 1.36]	<0.00001
Length of MV	18	88 %	<0.00001	random-effects	MD	2.81 [1.79, 3.82]	<0.00001
Weak cough	7	85 %	<0.00001	random-effects	OR	5.05 [2.12, 12.00]	0.0002
Cough peak flow	2	17 %	0.27	fixed-effects	MD	−29.75 [-36.73, –22.76]	<0.00001
Cuff leak test (+)	5	3 %	0.38	fixed-effects	OR	0.52 [0.38, 0.72]	<0.0001
Fluid balance	3	86 %	0.0009	random-effects	MD	−111.44 [-776.17, 553.30]	0.74
Abundant secretions	3	77 %	0.01	random-effects	OR	2.17 [0.80, 5.86]	0.13

BMI: Body mass index; APACHE II: Acute Physiology and Chronic Health Evaluation II; SAPS II: Simplified acute physiology score II; GCS: Glasgow Coma Scale; SOFA: Sequential Organ Failure Assessment; CCI: Charlson Comorbidity Index; TISS: Therapeutic Intervention Scoring System; ISS: Injury Severity Score; COPD: Chronic Obstructive Pulmonary Disease; ARDS: Acute respiratory distress syndrome; PEEP: Positive end-expiratory pressure; MV: mechanical ventilation; FiO_2: Fraction of inspiration O_2.

Table 3
Risk factors analysis of reintubation within 48 h after extubation.

Risk factors	No. of studies	Heterogeneity		Statistical model	Statistical method	Effect estimate [95 %CI]	P
		I^2	P				
Age	15	64 %	0.0004	random-effects	MD	3.13[1.35,4.92]	0.0006
APACHE II score	10	94 %	<0.00001	random-effects	MD	4.48[2.22,6.75]	0.0001
SOFA score	4	37 %	0.19	fixed-effects	MD	0.52[0.19,0.85]	0.002
PaO_2	5	28 %	0.23	fixed-effects	MD	−8.54[-13.10, −3.97]	0.0003
PaO_2/FiO_2	6	55 %	0.05	random-effects	MD	−44.26[-70.95.-17.56]	0.001
Tidal volume	5	11 %	0.34	fixed-effects	MD	−31.62[-42.17, −21.06]	<0.00001
Rapid Shallow Breathing Index	10	86 %	<0.00001	random-effects	MD	8.32[2.68,13.96]	0.004
Number of spontaneous breathing trials	3	37 %	0.21	fixed-effects	MD	0.62[0.44,0.80]	<0.00001
Length of MV	8	89 %	<0.00001	random-effects	MD	3.24[1.65,4.83]	<0.0001
Weak cough	3	69 %	0.04	random-effects	OR	5.60[1.79,17.58]	0.003
Cuff leak test (+)	4	0 %	0.66	fixed-effects	OR	0.48 [0.35, 0.67]	<0.0001

Table 4
Risk factors analysis of reintubation within 72 h after extubation.

Risk factors	No. of studies	Heterogeneity		Statistical model	Statistical method	Effect estimate [95 %CI]	P
		I^2	P				
Age	9	59 %	0.01	random-effects	MD	5.28 [2.56, 8.00]	0.0001
APACHE II score	4	0 %	0.87	fixed-effects	MD	1.86 [1.16, 2.56]	<0.00001
COPD	3	0 %	0.72	fixed-effects	OR	1.74 [1.07, 2.84]	0.02
Shock	2	48 %	0.17	fixed-effects	OR	2.04 [1.04, 4.03]	0.04
Respiratory failure	2	0 %	0.94	fixed-effects	OR	2.78 [1.28, 6.05]	0.01
SaO_2	2	0 %	0.46	fixed-effects	MD	−1.02 [-1.40, −0.64]	<0.00001
PaO_2/FiO_2	6	0 %	1.00	fixed-effects	MD	–23.72 [-36.04, −11.41]	0.0002
Hemoglobin	6	65 %	0.01	random-effects	MD	−0.46 [-0.91, −0.01]	0.04
HCO_3	2	0 %	0.95	fixed-effects	MD	−1.97 [-3.59, −0.34]	0.02
Respiratory rate	3	0 %	0.77	fixed-effects	MD	2.26 [0.90, 3.61]	0.001
Vasopressors	3	52 %	0.12	random-effects	OR	1.94 [1.28, 2.92]	0.002
length of MV	5	44 %	0.13	fixed-effects	MD	1.23 [0.67, 1.78]	<0.0001

the studies may have contributed to this observation.

Strengths and limitations

Previous studies have conducted meta-analyses of risk factors of extubation failure, but the definition of extubation failure lacks standardization, and our study only analyzed studies that reintubated or defined extubation failure as reintubation after extubation, which avoided assessment bias to some extent. To our knowledge, few current studies have applied meta-analysis to quantify the risk factors of reintubation, and our study provides a more comprehensive account of the possible risk factors of reintubation in ICU patients. However, the timing of reintubation after extubation was not uniform in our study, which may also lead to the risk of bias. Although we performed subgroup analyses of studies defined as reintubation within 48 and 72 h after extubation, certain factors were not taken into account, probably due to the limited number of studies in the subgroup analysis. In addition, we included all types of ICU patients, and the risk factors may vary in different ICUs.

Conclusion

We conducted a systematic review and meta-analysis of 38 studies. The studies found that older age and various aspects reflecting severity of acute illness and underlying conditions, imply a risk for reintubation. Future studies should combine these factors to develop comprehensive predictive algorithms indicating patients at high risk for reintubation and therefore subject of increased post-extubation vigilance.

Ethical statement

This study is a systematic review and meta-analysis, and ethical statements are not suitable.

Author contributions

Wenrui Li and Zhigang Zhang conceived and designed this systematic review and meta-analysis. Wenrui Li, Zhenzhen Wang, Donghui Jia, and Tana Zhao were involved in the data acquisition and data analysis. Ying Zhang, Xiujuan Ma, Caiyun Zhang, and Xinyi Han interpreted the results. Wenrui Li and Zhigang Zhang drafted the manuscript.

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.iccn.2022.103340.

References

Artime, C.A., Hagberg, C.A., 2014. Tracheal extubation. Respir. Care 59 (6), 991–1002.
Asehnoune, K., Seguin, P., Lasocki, S., Roquilly, A., Delater, A., Gros, A., Denou, F., Mahe, P.J., Nesseler, N., Demeure-dit-Latte, D., Launey, Y., Lakhal, K., Rozec, B., Malledant, Y., Sebille, V., Jaber, S., Le Thuaut, A., Feuillet, F., Cinotti, R., Grp, A., 2017. Extubation Success Prediction in a Multicentric Cohort of Patients with Severe Brain Injury. Anesthesiology 127 (2), 338–346.
Bien, M.Y., Hseu, S.S., Yien, H.W., Kuo, B.I., Lin, Y.T., Wang, J.H., Kou, Y.R., 2004. Breathing pattern variability: a weaning predictor in postoperative patients recovering from systemic inflammatory response syndrome. Intensive Care Med. 30 (2), 241–247.
Blot, S., Ruppé, E., Harbarth, S., Asehnoune, K., Poulakou, G., Luyt, C.E., Rello, J., Klompas, M., Depuydt, P., Eckmann, C., Martin-Loeches, I., Povoa, P., Bouadma, L., Timsit, J.F., Zahar, J.R., 2022. Healthcare-associated infections in adult intensive care unit patients: changes in epidemiology, diagnosis, prevention and contributions of new technologies. Intensive Crit. Care Nurs. 70, 103227.

Brennan, M., McDonnell, M.J., Duignan, N., Gargoum, F., Rutherford, R.M., 2022. The use of cough peak flow in the assessment of respiratory function in clinical practice – a narrative literature review. Respir. Med. 193, 106740.
Brown, C.V., Daigle, J.B., Foulkrod, K.H., Brouillette, B., Clark, A., Czysz, C., Martinez, M., Cooper, H., 2011. Risk factors associated with early reintubation in trauma patients: a prospective observational study. J Trauma 71 (1), 37–41.
Buppha, P., Kusumaphanyo, C., Chittawatanarat, K., 2016. Outcomes and risk factors of extubation failure: a multicenter study of the THAI surgical intensive care units (SICUs). J. Med. Assoc. Thai. 99 (9), S136–S144.
Cao, J., Wang, B., Zhu, L., Song, L., 2022. Pooled analysis of central venous pressure and brain natriuretic peptide levels in patients with extubation failure. Front. Physiol. 13, 858046.
Chao, C.M., Lai, C.C., Cheng, A.C., Chiang, S.R., Liu, W.L., Ho, C.H., Hsing, S.C., Chen, C. M., Cheng, K.C., 2017. Establishing failure predictors for the planned extubation of overweight and obese patients. PLoS ONE 12 (8), e0183360.
Cheng, A.C., Cheng, K.C., Chen, C.M., Hsing, S.C., Sung, M.Y., 2011. The outcome and predictors of failed extubation in intensive care patients-the elderly is an important predictor. Int. J. Gerontol. 5 (4), 206–211.
Chien, J.Y., Lin, M.S., Huang, Y.C., Chien, Y.F., Yu, C.J., Yang, P.C., 2008. Changes in B-type natriuretic peptide improve weaning outcome predicted by spontaneous breathing trial. Crit. Care Med. 36 (5), 1421–1426.
Dos Reis, H.F.C., Gomes-Neto, M., Almeida, M.L.O., da Silva, M.F., Guedes, L.B.A., Martinez, B.P., de Seixas Rocha, M., 2017. Development of a risk score to predict extubation failure in patients with traumatic brain injury. J. Crit. Care 42, 218–222.
Dupont, H., Le Port, Y., Paugam-Burtz, C., Mantz, J., Desmonts, J., 2001. Reintubation after planned extubation in surgical ICU patients: a case-control study. Intensive Care Med. 27 (12), 1875–1880.
Feiner, J.R., Weiskopf, R.B., 2017. Evaluating pulmonary function: an assessment of PaO2/FIO2. Crit. Care Med. 45 (1), e40–e48.
Feng, L.W., 2019. Clinical Study on Influencing Factors of Secondary Intubation in Patients with Mechanical Ventilation. Tianjin Medical University.
Frutos-Vivar, F., Ferguson, N.D., Esteban, A., Epstein, S.K., Arabi, Y., Apezteguía, C., González, M., Hill, N.S., Nava, S., D'Empaire, G., Anzueto, A., 2006. Risk factors for extubation failure in patients following a successful spontaneous breathing trial. Chest 130 (6), 1664–1671.
Fujii, E., Fujino, K., Tanaka-Mizuno, S., Eguchi, Y., 2018. Variation of risk factors for cause-specific reintubation: a preliminary study. Can. Respiratory J. 2018, 3654251.
Girard, T.D., Alhazzani, W., Kress, J.P., Ouellette, D.R., Schmidt, G.A., Truwit, J.D., Burns, S.M., Epstein, S.K., Esteban, A., Fan, E., Ferrer, M., Fraser, G.L., Gong, M.N., Hough, C.L., Mehta, S., Nanchal, R., Patel, S., Pawlik, A.J., Schweickert, W.D., Sessler, C.N., Strøm, T., Wilson, K.C., Morris, P.E., 2017. An Official American Thoracic Society/American College Of Chest Physicians Clinical Practice Guideline: liberation from mechanical ventilation in critically ill adults. Rehabilitation protocols, ventilator liberation protocols, and cuff leak tests. Am. J. Respir. Crit. Care Med. 195 (1), 120–133.
Gobert, F., Yonis, H., Tapponnier, R., Fernandez, R., Labaune, M.A., Burle, J.F., Barbier, J., Vincent, B., Cleyet, M., Richard, J.C., Guérin, C., 2017. Predicting extubation outcome by cough peak flow measured using a built-in ventilator flow meter. Respir. Care 62 (12), 1505–1519.
Goharani, R., Vahedian-Azimi, A., Galal, I.H., Cordeiro de Souza, L., Farzanegan, B., Bashar, F.R., Vitacca, M., Shojaei, S., Mosavinasab, S.M.M., Takaki, S., Miller, A.C., 2019. A rapid shallow breathing index threshold of 85 best predicts extubation success in chronic obstructive pulmonary disease patients with hypercapnic respiratory failure. J. Thorac. Dis. 11 (4), 1223–1232.
Haruna, J., Tatsumi, H., Kazuma, S., Sasaki, A., Masuda, Y., 2022. Frequent tracheal suctioning is associated with extubation failure in patients with successful spontaneous breathing trial: a single-center retrospective cohort study. Ja Clin. Reports 8 (1), 5.
Hayden, S.J., Albert, T.J., Watkins, T.R., Swenson, E.R., 2012. Anemia in critical illness: insights into etiology, consequences, and management. Am. J. Respir. Crit. Care Med. 185 (10), 1049–1057.
Hsiung Lee, E.S., Jiann Lim, D.T., Taculod, J.M., Sahagun, J.T., Otero, J.P., Teo, K., Loh, W.N., Hui Tan, A.Y., 2017. Factors associated with reintubation in an intensive care unit: a prospective observational study. Indian J. Crit. Care Med. 21 (3), 131–137.
Huang, H.Y., Hu, L., 2016. Analysis of high risk factors of reintubation after 48 hours endotracheal intubation for ICU patients. J. Nurse Training 31 (22), 2092–2094.
Kollert, F., Tippelt, A., Müller, C., Jörres, R.A., Porzelius, C., Pfeifer, M., Budweiser, S., 2013. Hemoglobin levels above anemia thresholds are maximally predictive for long-term survival in COPD with chronic respiratory failure. Respir. Care 58 (7), 1204–1212.
Kuriyama, A., Jackson, J.L., Kamei, J., 2020. Performance of the cuff leak test in adults in predicting post-extubation airway complications: a systematic review and meta-analysis. Crit. Care 24 (1), 640.
Kutchak, F.M., Rieder, M.M., Victorino, J.A., Meneguzzi, C., Poersch, K., Forgiarini, L.A., Bianchin, M.M., 2017. Simple motor tasks independently predict extubation failure in critically ill neurological patients. Jornal brasileiro de pneumologia: publicacao oficial da Sociedade Brasileira de Pneumologia e Tisilogia 43 (3), 183–189.
Lai, C.C., Chen, C.M., Chiang, S.R., Liu, W.L., Weng, S.F., Sung, M.I., Hsing, S.C., Cheng, K.C., 2016. Establishing predictors for successfully planned endotracheal extubation. Medicine 95 (41), e4852.
Lai, Y.C., Ruan, S.Y., Huang, C.T., Kuo, P.H., Yu, C.J., 2013. Hemoglobin levels and weaning outcome of mechanical ventilation in difficult-to-wean patients: a retrospective cohort study. PLoS ONE 8 (8), e73743.
Li, W.R., Wang, Z.Z., Zhang, Z.G., Zhang, C.Y., 2022. The factors influencing reintubation in ICU mechanically ventilated patients: a systematic review and meta-analysis. PROSPERO: CRD42022319744.
Liu, Y., 2021. Influencing factors of failure of weaning and extubation in ICU patients with severe pneumonia on mechanical ventilation. Heilongjiang J. Traditional Chin. Med. 50 (02), 125–126.
Lombardi, F.S., Cotoia, A., Petta, R., Schultz, M., Cinnella, G., Horn, J., 2019. Prediction of extubation failure in Intensive Care Unit: systematic review of parameters investigated. Minerva Anestesiol. 85 (3), 298–307.
Ma, S.J., Cheng, W.T., Xu, Y.Q.,2018. Related Factors of Planned Extubation Failure in Patients with Severe Brain Injury. Neural Injury And Functional Reconstruction 13 (04):184-186+189.
Maezawa, S., Kudo, D., Miyagawa, N., Yamanouchi, S., Kushimoto, S., 2021. Association of body weight change and fluid balance with extubation failure in intensive care unit patients: a single-center observational study. J. Intensive Care Med. 36 (2), 175–181.
Magnet, F.S., Heilf, E., Huttmann, S.E., Callegari, J., Schwarz, S.B., Storre, J.H., Windisch, W., 2020. The spontaneous breathing trial is of low predictive value regarding spontaneous breathing ability in subjects with prolonged, unsuccessful weaning. Med. Klin. Intensivmed. Notfmed. 115 (4), 300–306.
Mandell, L.A., Wunderink, R.G., Anzueto, A., Bartlett, J.G., Campbell, G.D., Dean, N.C., Dowell, S.F., File, T.M., Jr., Musher, D.M., Niederman, M.S., Torres, A., Whitney, C. G., 2007. Infectious Diseases Society of America/American Thoracic Society consensus guidelines on the management of community-acquired pneumonia in adults. Clin. Infect. Dis. 44 Suppl 2 (Suppl 2), S27-72.
Michetti, C.P., Griffen, M.M., Teicher, E.J., Rodriguez, J.L., Seoudi, H., Liu, C., Lita, E., Newcomb, A., 2018. FRIEND or FOE: A prospective evaluation of risk factors for reintubation in surgical and trauma patients. Am. J. Surg. 216 (6), 1056–1062.
Miltiades, A.N., Gershengorn, H.B., Hua, M., Kramer, A.A., Li, G., Wunsch, H., 2017. Cumulative probability and time to reintubation in U.S. ICUs. Crit. Care Med. 45 (5), 835–842.
Miu, T., Joffe, A.M., Yanez, N.D., Khandelwal, N., Dagal, A.H., Deem, S., Treggiari, M.M., 2014. Predictors of reintubation in critically ill patients. Respir Care 59 (2), 178–185.
Nantsupawat, N., Nantsupawat, T., Limsuwat, C., Sutamtewagul, G., Nugent, K., 2015. Factors associated with reintubation in patients with chronic obstructive pulmonary disease. Qual. Manag. Health Care 24 (4), 200–206.
Ochoa, M.E., Marín Mdel, C., Frutos-Vivar, F., Gordo, F., Latour-Pérez, J., Calvo, E., Esteban, A., 2009. Cuff-leak test for the diagnosis of upper airway obstruction in adults: a systematic review and meta-analysis. Intensive Care Med. 35 (7), 1171–1179.
Piriyapatsom, A., Williams, E.C., Waak, K., Ladha, K.S., Eikermann, M., Schmidt, U.H., 2016. Prospective Observational Study of Predictors of Re-Intubation Following Extubation in the Surgical ICU. Respiratory Care 61 (3), 306–315.
Putensen, C., Wrigge, H., Hering, R., 2006. The effects of mechanical ventilation on the gut and abdomen. Curr Opin Crit Care 12 (2), 160–165.
Quintard, H., l'Her, E., Pottecher, J., Adnet, F., Constantin, J.M., De Jong, A., Diemunsch, P., Fesseau, R., Freynet, A., Girault, C., Guitton, C., Hamonic, Y., Maury, E., Mekontso-Dessap, A., Michel, F., Nolent, P., Perbet, S., Prat, G., Roquilly, A., Tazarourte, K., Terzi, N., Thille, A.W., Alves, M., Gayat, E., Donetti, L., 2017. Intubation and extubation of the ICU patient. Anaesth. Crit. Care Pain Med. 36 (5), 327-341.
Rizzo, J.A., Haq, M., McMahon, R.A., Aden, J.K., Brillhart, D.B., Cancio, L.C., 2021. Extubation failure in a burn intensive care unit: examination of contributing factors. J. Burn Care Res. 42 (2), 177–181.
Rose, L., Adhikari, N.K., Leasa, D., Fergusson, D.A., McKim, D., 2017. Cough augmentation techniques for extubation or weaning critically ill patients from mechanical ventilation. Cochrane Database Syst. Rev. 1 (1), Cd011833.
Rothaar, R.C., Epstein, S.K., 2003. Extubation failure: magnitude of the problem, impact on outcomes, and prevention. Current Opinion in Critical Care 9 (1), 59–66.
Safdar, N., Crnich, C.J., Maki, D.G., 2005. The pathogenesis of ventilator-associated pneumonia: its relevance to developing effective strategies for prevention. Respir Care 50 (6), 725–739.
Santibanez-Velazquez, M., Medina-Garcia, G., Ocharan-Hernandez, M.E., 2020. Association of independent risk factors with post-extubation failure in patients undergoing mechanical ventilation weaning. Gac. Med. Mex. 156 (6), 549–555.
Sartini, S., Massobrio, L., Cutuli, O., Campodonico, P., Bernini, C., Sartini, M., Cristina, M.L., Castellani, L., Ceschi, L., Spadaro, M., Gratarola, A., Barbera, P., 2021. Role of SatO2, PaO2/FiO2 ratio and PaO2 to predict adverse outcome in COVID-19: a retrospective, cohort study. Int. J. Environ. Res. Public Health 18 (21), 11534.
Saugel, B., Rakette, P., Hapfelmeier, A., Schultheiss, C., Phillip, V., Thies, P., Treiber, M., Einwachter, H., von Werder, A., Pfab, R., Eyer, F., Schmid, R.M., Huber, W., 2012. Prediction of extubation failure in medical intensive care unit patients. J. Crit. Care 27 (6), 571–577.
Savi, A., Teixeira, C., Silva, J.M., Borges, L.G., Pereira, P.A., Pinto, K.B., Gehm, F., Moreira, F.C., Wickert, R., Trevisan, C.B., Maccari, J.G., Oliveira, R.P., Vieira, S.R., 2012. Weaning predictors do not predict extubation failure in simple-to-wean patients. J. Crit. Care 27 (2), 221.e221-228.
Sharma, G., Goodwin, J., 2006. Effect of aging on respiratory system physiology and immunology. Clin. Interv. Aging 1 (3), 253–260.
Shi, Q.F., Liang, D.S., 2015. Risk factors related to reintuabation of invasive and noninvasive sequential mechancal ventilation of acute exacerbation of chronic obstructive pulmonary diseases. Med. Recapitulate 21 (15), 2845–2847.
Smina, M., Salam, A., Khamiees, M., Gada, P., Amoateng-Adjepong, Y., Manthous, C.A., 2003. Cough peak flows and extubation outcomes. Chest 124 (1), 262–268.

Stang, A., 2010. Critical evaluation of the Newcastle-Ottawa scale for the assessment of the quality of nonrandomized studies in meta-analyses. Eur. J. Epidemiol. 25 (9), 603–605.

Su, W.L., Chen, Y.H., Chen, C.W., Yang, S.H., Su, C.L., Perng, W.C., Wu, C.P., Chen, J.H., 2010. Involuntary cough strength and extubation outcomes for patients in an ICU. Chest 137 (4), 777–782.

Suraseranivong, R., Krairit, O., Theerawit, P., Sutherasan, Y., 2018. Association between age-related factors and extubation failure in elderly patients. PLoS ONE 13 (11), e0207628.

Taran, S., Angriman, F., Pinto, R., Ferreyro, B.L., Amaral, A., Toronto Intensive Care, O., 2021. Discordances between factors associated with withholding extubation and extubation failure after a successful spontaneous breathing trial*. Crit. Care Med. 49 (12), 2080–2089.

Teixeira, C., Maccari, J.G., Vieira, S.R., Oliveira, R.P., Savi, A., Machado, A.S., Tonietto, T.F., Cremonese, R.V., Wickert, R., Pinto, K.B., Callefe, F., Gehm, F., Borges, L.G., Oliveira, E.S., 2012. Impact of a mechanical ventilation weaning protocol on the extubation failure rate in difficult-to-wean patients. J. Bras. Pneumol. 38 (3), 364–371.

Terzi, N., Lofaso, F., Masson, R., Beuret, P., Normand, H., Dumanowski, E., Falaize, L., Sauneuf, B., Daubin, C., Brunet, J., Annane, D., Parienti, J.J., Orlikowski, D., 2018. Physiological predictors of respiratory and cough assistance needs after extubation. Ann. Intensive Care 8 (1), 18.

Thille, A.W., Harrois, A., Schortgen, F., Brun-Buisson, C., Brochard, L., 2011. Outcomes of extubation failure in medical intensive care unit patients. Crit. Care Med. 39 (12), 2612–2618.

Thille, A.W., Richard, J.C., Brochard, L., 2013. The decision to extubate in the intensive care unit. Am. J. Respir. Crit. Care Med. 187 (12), 1294–1302.

Thille, A.W., Boissier, F., Ben Ghezala, H., Razazi, K., Mekontso-Dessap, A., Brun-Buisson, C., 2015. Risk factors for and prediction by caregivers of extubation failure in ICU patients: a prospective study. Crit. Care Med. 43 (3), 613–620.

Thille, A.W., Muller, G., Gacouin, A., Coudroy, R., Decavèle, M., Sonneville, R., Beloncle, F., Girault, C., Dangers, L., Lautrette, A., Cabasson, S., Rouzé, A., Vivier, E., Le Meur, A., Ricard, J.D., Razazi, K., Barberet, G., Lebert, C., Ehrmann, S., Sabatier, C., Bourenne, J., Pradel, G., Bailly, P., Terzi, N., Dellamonica, J., Lacave, G., Danin, P., Nanadoumgar, H., Gibelin, A., Zanre, L., Deye, N., Demoule, A., Maamar, A., Nay, M.A., Robert, R., Ragot, S., Frat, J.P., 2019. Effect of postextubation high-flow nasal oxygen with noninvasive ventilation vs high-flow nasal oxygen alone on reintubation among patients at high risk of extubation failure: a randomized clinical trial. JAMA 322 (15), 1465–1475.

Thomrongpairoj, P., Tongyoo, S., Tragulmongkol, W., Permpikul, C., 2017. Factors predicting failure of noninvasive ventilation assist for preventing reintubation among medical critically ill patients. J. Crit. Care 38, 177–181.

Torrini, F., Gendreau, S., Morel, J., Carteaux, G., Thille, A.W., Antonelli, M., Mekontso Dessap, A., 2021. Prediction of extubation outcome in critically ill patients: a systematic review and meta-analysis. Crit. Care 25 (1), 391.

Trivedi, V., Chaudhuri, D., Jinah, R., Piticaru, J., Agarwal, A., Liu, K., McArthur, E., Sklar, M.C., Friedrich, J.O., Rochwerg, B., Burns, K.E.A., 2022. The usefulness of the rapid shallow breathing index in predicting successful extubation: a systematic review and meta-analysis. Chest 161 (1), 97–111.

Vanhorebeek, I., Latronico, N., Van den Berghe, G., 2020. ICU-acquired weakness. Intensive Care Med. 46 (4), 637–653.

Wang, J.R., 2007. Study of the Related Factors for Reintubation of None COPD Patients in ICU within 24 hours After Extubation. ZheJiang University.

Wang, S., Zhang, L., Huang, K., Lin, Z., Qiao, W., Pan, S., 2014. Predictors of extubation failure in neurocritical patients identified by a systematic review and meta-analysis. PLoS ONE 9 (12), e112198.

Weber, Y., Epstein, D., Miller, A., Segal, G., Berger, G., 2021. Association of low alanine aminotransferase values with extubation failure in adult critically ill patients: a retrospective cohort study. J. Clin. Med. 10 (15), 3282.

Weinberg, J.A., Stevens, L.R., Goslar, P.W., Thompson, T.M., Sanford, J.L., Petersen, S.R., 2016. Risk factors for extubation failure at a level I trauma center: does the specialty of the intensivist matter? Trauma Surg. Acute Care Open 1 (1), e000052.

Xiao, M., Duan, J., 2018. Weaning attempts, cough strength and albumin are independent risk factors of reintubation in medical patients. Clin. Respiratory J. 12 (3), 1240–1246.

Xing, X.Z., Gao, Y., Wang, H.J., Qu, S.N., Huang, C.L., Zhang, H., Wang, H., Yang, Q.H., 2017. Risk factors and prognosis analysis of reintubation in critically mechanical ventilation patients with cancer. Chin. J. Critical Care Intensive Care Med. (Electron. Ed.) 3 (03), 191–196.

Xiong, L., Li, W.Q., 2018. The risk factors of failure for noninvasive ventilation in extubation patients. J. Clin. Emergency 19 (12), 825–829.

Xu, S.F., Xu, J.G., Zhou F.M.S, Hu, J.F., 2021. Risk factors of secondary intubation after tracheal extubation in ICU patients. Zhejiang Med. 43(02),194-200.

Yu, H., Luo, J., Ni, Y., Hu, Y., Liu, D., Wang, M., Liang, B., Liang, Z., 2020. Early prediction of extubation failure in patients with severe pneumonia: a retrospective cohort study. Biosci. Rep. 40 (2): BSR20192435.