DIFFICULT LIBERATION

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CLASSIFICATION

- Simple wean :
- they pass their first spontaneous breathing trial (SBT). Approximately half to two-thirds of patients in intensive care units (ICUs) undergo simple weaning
- Difficult-to-wean
- They fail their first SBT and then require up to three SBTs or seven days to pass an SBT (26 to 39 percent)
- Prolongedweaning
- they fail at least three SBTs or require more than seven days to pass an SBT (6 to 14 percent)
- (are at increased risk for death and are also more likely to fail extubation)

CAUSES

- incomplete resolution precipitating illness
- development new problems
- Respiratory and cardiac issues are common
- while psychological, ventilator, or nutrition- related issues are less common
- causing an imbalance between respiratory muscle strength and the work of breathing
- Most of the etiologies are apparent on routine clinical examination, laboratory testing, arterial blood gas analysis, electrocardiography, and chest radiography, as well as an assessment of sedative medications and the ventilator circuit.

Etiologies of the difficult-to-wean patient

Etiologies		Investigations	Treatment
Respiratory/ventilatory			
Increased ventilator demand	Hypoxemia (eg, atelectasis, morbid obesity, abdominal distension, lung disease, sepsis), elevated dead space (eg, hyperinflation, pulmonary embolism, dehydration), excess carbon dioxide production (eg, fever, infection, overfeeding [refer to nutritional, below], metabolic acidosis, or neuropsychiatric factors [eg, delirium, anxiety, pain]).	Clinical examination including neurological examination, chest radiograph, arterial blood gases, routine chemistries, thyroid function tests, nutrition assessment, and occasionally CT chest and/or abdomen or CT angiography. Rarely, nerve conduction studies or bronchoscopy.	▪ Treat underlying etiology (eg, bronchodilation, antibiotics, pulmonary toilet, fluids, diuresis). Administer oxygen. ▪ Adjust mechanical ventilator settings, when indicated (eg, for auto-PEEP). ▪ Correct feeding or metabolic disturbances. ▪ Optimize sedative analgesics. ▪ Rarely, ETT change, physical therapy, thoracocentesis.
Increased resistive load	Bronchoconstriction (eg, COPD, asthma), airway edema (eg, lower respiratory infection), secretions (eg, tracheobronchitis, pneumonia), equipment issues (refer to ventilator circuit below).		
Increased elastic load	Dynamic hyperinflation (eg, COPD, asthma, increased minute ventilation), alveolar filling (eg, pulmonary edema), atelectasis, pleural disease (eg, pleural effusion, pneumothorax), chest wall disease, or abdominal distension (eg, morbid obesity, ileus, ascites).		
Reduced neuromuscular capacity	Electrolyte abnormalities (eg, hypophosphatemia, hypomagnesemia, hypocalcemia, hypokalemia), medications (eg, steroids, neuromuscular blocking agents), malnutrition (refer to nutritional below), hypothyroidism, systemic inflammation (eg, sepsis), neuropathy (eg, Guillain-Barré syndrome, critical illness polyneuropathy), and myopathy (eg, critical illness myopathy).		

Decreased ventilatory drive	Excess sedation, metabolic alkalosis (eg, nasogastric suctioning, volume depletion, diuretics and other causes of chloride depletion), central nervous system disease (eg, stroke, encephalopathy), central sleep apnea, or obesity hypoventilation syndrome.		
Cardiac			
	Weaning may induce myocardial ischemia in susceptible patients.	A continuous multi-lead EKG during spontaneous breathing trials or EKG pre-and post-weaning trial. BNP or N-terminal pro-BNP pre-and post-weaning trial. Transthoracic echocardiography. Rarely, cardiac catheterization.	▪ Maximize cardiac medications (eg, beta blockade, diuresis, ACE inhibition, or vasodilators before or during SBT). ▪ Rarely, coronary re-perfusion interventions or inotropic agents.
	Pulmonary edema may develop in patients with cardiac dysfunction or ischemia.		
	Fluid overload may present similarly in patients with normal cardiac function.		
Psychological			
	Psychologic issues (eg, depression, anxiety, delirium, pain) and oversedation may limit ventilation and impede cooperation with a SBT.	Clinical history and examination including pain assessment.	▪ Patients education, optimize sedative analgesia medications, which may involve increasing, adjusting, or weaning psychoactive medications.
Ventilator circuit			
	Equipment dead space, circuit compliance, gas compression volume, exhalation valve dysfunction, and increased resistance (eg, endotracheal tube luminal narrowing due to	Examine waveforms (eg, ventilator asynchrony), ventilator pressures (eg, peak inspiratory	▪ Equipment modifications (eg, change tubing, ventilator, endotracheal

3

	inspissated secretions and debris or small-sized ETT).	pressure, plateau pressure), and equipment (eg, blocked exhalation valve, excess condensation).	tube, etc), pulmonary toilet.
Nutritional			
	Protein catabolism and underfeeding leading to respiratory muscle weakness. Overfeeding leading to increased carbon dioxide production and increased ventilatory load.	Calculate nutrition needs.	▪ Administer adequate nutrition.

RESPIRATORY OR VENTILATORY CAUSES

- Auto-PEEP
- Over ventilation : specially in chronic hypercapnic patients with normalizing pco2. patients with chronic hypercapnia should be mechanically ventilated in between SBTs with a minute ventilation that maintains the patient's usual PaCO2.
- Endotracheal tubes : narrow or secretion pressure support SBT may overcome the imposed work of breathing
- Moderate to large pleural effusions : in one prospective observational study were found to be an independent predictor of weaning failure . However, while drainage may improve oxygenation and lung volumes it has not been conclusively shown to reduce mechanical ventilation days

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Pleural effusion during weaning from mechanical ventilation: a prospective observational multicenter study

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- Background
- Pleural effusion is common during invasive mechanical ventilation, but its role during weaning is unclear. We aimed at assessing the prevalence and risk factors for pleural effusion at initiation of weaning. We also assessed its impact on weaning outcomes and its evolution in patients with difficult weaning.
- Methods
- We performed a prospective multicenter study in five intensive care units in France. Two hundred and forty-nine patients were explored using ultrasonography. Presence of moderate-to-large pleural effusion (defined as a maximal interpleural distance ≥ 15 mm) was assessed at weaning start and during difficult weaning.
- Results
- Seventy-three (29%) patients failed weaning, including 46 (18%) who failed the first spontaneous breathing trial (SBT) and 39 (16%) who failed extubation. Moderate-to-large pleural effusion was detected in 81 (33%) patients at weaning start. Moderate-to-large pleural effusion was associated with more failures of the first SBT [27 (33%) vs. 19 (11%), $p < 0.001$], more weaning failures [37 (47%) vs. 36 (22%), $p < 0.001$], less ventilator-free days at day 28 [21 (5–24) vs. 23 (16–26), $p = 0.01$], and a higher mortality at day 28 [14 (17%) vs. 14 (8%), $p = 0.04$]. The association of pleural effusion with weaning failure persisted in multivariable analysis and sensitivity analyses. Short-term (48 h) fluid balance change was not associated with the evolution of interpleural distance in patients with difficult weaning.
- Conclusions
- In this multicenter observational study, pleural effusion was frequent during the weaning process and was associated with worse weaning outcomes.

› Ann Am Thorac Soc. 2014 Sep;11(7):1018-24. doi: 10.1513/AnnalsATS.201404-152OC.

Effects of pleural effusion drainage on oxygenation, respiratory mechanics, and hemodynamics in mechanically ventilated patients

Keyvan Razazi [1], Arnaud W Thille, Guillaume Carteaux, Olfa Beji, Christian Brun-Buisson, Laurent Brochard, Armand Mekontso Dessap

- **Abstract**
- **Objectives:** In mechanically ventilated patients, the effect of draining pleural effusion on oxygenation is controversial. We investigated the effect of large pleural effusion drainage on oxygenation, respiratory function (including lung volumes), and hemodynamics in mechanically ventilated patients after ultrasound-guided drainage. Arterial blood gases, respiratory mechanics (airway, pleural and transpulmonary pressures, end-expiratory lung volume, respiratory system compliance and resistance), and hemodynamics (blood pressure, heart rate, and cardiac output) were recorded before and at 3 and 24 hours (H24) after pleural drainage. The respiratory settings were kept identical during the study period.
- **Measurements and main results:** The mean volume of effusion drained was 1,579 ± 684 ml at H24. Uncomplicated pneumothorax occurred in two patients. Respiratory mechanics significantly improved after drainage, with a decrease in plateau pressure and a large increase in end-expiratory transpulmonary pressure. Respiratory system compliance, end-expiratory lung volume, and PaO2/FiO2 ratio all improved. Hemodynamics were not influenced by drainage. Improvement in the PaO2/FiO2 ratio from baseline to H24 was positively correlated with the increase in end-expiratory lung volume during the same time frame ($r = 0.52$, $P = 0.033$), but not with drained volume. A high value of pleural pressure or a highly negative transpulmonary pressure at baseline predicted limited lung expansion following effusion drainage. A lesser improvement in oxygenation occurred in patients with ARDS.
- **Conclusions:** Drainage of large (≥500 ml) pleural effusion in mechanically ventilated patients improves oxygenation and end-expiratory lung volume. Oxygenation improvement correlated with an increase in lung volume and a decrease in transpulmonary pressure, but was less so in patients with ARDS.

CARDIAC CAUSES 1

- Weaning-induced myocardial ischemia or cardiac dysfunction (ie, heart failure) may contribute to difficult weaning in 20 to 60 percent of patients
- Because of the increased work involved in spontaneous breathing, myocardial demand increases, thereby resulting in ischemia in susceptible individuals, and pulmonary edema in those with underlying cardiac dysfunction. Ischemia and/or pulmonary edema, in turn, further increase the work of breathing, creating a vicious cycle.
- PEEP is a treatment for heart failure, weaning-induced cardiac dysfunction may be hard to detect when SBT strategies that include PEEP , Thus, cardiac dysfunction should be suspected in patients who pass an SBT that included PEEP but who fail extubation and require re-intubation because of acute heart failure.
- Patients rarely complain of chest pain, and ST depressions are only occasionally appreciated on a bedside monitor. Risk factors identified in one retrospective study included chronic obstructive pulmonary disease, previous cardiomyopathy, and obesity

2

- EKG : continuous multi-lead electrocardiography (EKG) during the SBT, or record an EKG pre- and post-the trial
- BNP levels : an elevated BNP or N-terminal pro-BNP prior to the weaning trial, an elevated N- terminal pro-BNP at the end of the trial, or a >20 percent increase in BNP during the SBT .Interventions based upon BNP levels alone are not typically routine.
- Passive leg raising (PLR) : patients who fail to increase cardiac output by >10 percent during PLR (negative PLR test) are significantly more likely to fail an SBT with a pulmonary artery occlusion pressure (PAOP) >18 mmHg at the end of the trial and
- positive PLR was associated with a successful weaning trial while a negative one was associated with failure

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- Others : >5 to 6 percent increase in plasma protein and hemoglobin during an SBT .
- Lung ultrasound, by the demonstration of B lines

Randomized Controlled Trial > Am J Respir Crit Care Med. 2012 Dec 15;186(12):1256-63.
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Natriuretic peptide–driven fluid management during ventilator weaning: a randomized controlled trial

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- **Rationale:** Difficult weaning from mechanical ventilation is often associated with fluid overload. B-type natriuretic peptide (BNP) has been proposed as a tool for predicting and detecting weaning failure of cardiovascular origin.
- **Objectives:** To investigate whether fluid management guided by daily BNP plasma concentrations improves weaning outcomes compared with empirical therapy dictated by clinical acumen.
- **Methods:** In a randomized controlled multicenter study, we allocated 304 patients to either a BNP-driven or physician-driven strategy of fluid management during ventilator weaning. To standardize the weaning process, patients in both groups were ventilated with an automatic computer-driven weaning system. The primary end point was time to successful extubation.
- **Measurements and main results:** In the BNP-driven group, furosemide and acetazolamide were given more often and in higher doses than in the control group, resulting in a more negative median (interquartile range) fluid balance during weaning (-2,320 [-4,735, 738] vs. -180 [-2,556, 2,832] ml; $P < 0.0001$). Time to successful extubation was significantly shorter with the BNP-driven strategy (58.6 [23.3, 139.8] vs. 42.4 [20.8, 107.5] h; $P = 0.034$). The BNP-driven strategy increased the number of ventilator-free days but did not change length of stay or mortality. The effect on weaning time was strongest in patients with left ventricular systolic dysfunction. The two strategies did not differ significantly regarding electrolyte imbalance, renal failure, or shock.
- **Conclusions:** Our results suggest that a BNP-driven fluid management strategy decreases the duration of weaning without increasing adverse events, especially in patients with left ventricular systolic dysfunction.

Anaesth Intensive Care. 2016 Jul;44(4):466-73. doi: 10.1177/0310057X1604400408.

Left ventricular diastolic dysfunction--an independent risk factor for weaning failure from mechanical ventilation

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- **Abstract**
- The objective of this study was to investigate the contribution of left ventricular (LV) diastolic dysfunction to weaning failure, along with the levels of the currently used cardiac biomarkers. Forty-two mechanically ventilated patients, who fulfilled criteria for weaning from mechanical ventilation (MV), underwent a two-hour spontaneous breathing trial (SBT). Transthoracic echocardiography (TTE) was performed before the start of the SBT. The grade of LV diastolic dysfunction was assessed by pulsed-wave Doppler and tissue Doppler imaging at the level of the mitral valve. Haemodynamic and respiratory parameters were recorded. Blood levels of B-type natriuretic peptide (BNP), troponin I, creatine kinase-MB, and myoglobin were measured on MV and at the end of the SBT. Weaning success was defined as the patient's ability to tolerate spontaneous breathing for more than 48 hours. Fifteen patients failed to wean. LV diastolic dysfunction was significantly associated with weaning failure ($P<0.001$). The grade of diastolic dysfunction was significantly correlated with BNP levels both on MV and at the end of the SBT ($P<0.001$, $r=0.703$ and $P<0.001$, $r=0.709$, respectively). BNP levels on MV were lower in patients who successfully weaned compared to those who did not (361±523 ng/l versus 643±382 ng/l respectively, $P=0.008$). The presence of diastolic dysfunction was independently associated with weaning failure (odds ratio [OR] 11.23, confidence interval [CI] 1.16-109.1, $P=0.037$) followed by respiratory frequency/tidal volume (OR 1.05, CI 1.00-1.10, $P=0.048$). Therefore, assessment of LV diastolic function before the start of weaning could be useful to identify patients at risk of weaning failure.

PSYCHOLOGICAL CAUSES

- depression, anxiety, delirium, pain are common in ventilated individuals
- Depressive disorders are present in approximately 40 percent of patients undergoing weaning from prolonged mechanical ventilation and their presence adversely affects weaning success
- patients with delirium were twice as likely to be difficult-to-wean compared with those without delirium

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Impact of delirium on weaning from mechanical ventilation in medical patients

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Affiliations + expand

PMID: 26534738 DOI: 10.1111/resp.12673

- **Methods:** This is a retrospective analysis with prospectively collected data on weaning from mechanical ventilation (MV) and delirium, as assessed by bedside ICU nurses using the Confusion Assessment Method for the ICU (CAM-ICU) between October 2011 and September 2013.
- **Results:** During the study period, a total of 393 patients with MV support underwent a spontaneous breathing trial (SBT) according to the standardized protocol. Of these patients, 160 (40.7%) were diagnosed with delirium on the day of the first SBT. Patients without delirium were more successfully extubated than those with delirium (81.5% vs 69.4%, P = 0.005). Delirium was found to be associated with final weaning outcomes, including difficult (OR 1.962, 95% CI 1.201-3.205) and prolonged weaning (OR 2.318, 95% CI 1.272-4.226) when simple weaning was used as a reference category. After adjusting for potential confounding factors, delirium was still significantly associated with difficult weaning (adjusted OR 2.073, 95% CI 1.124-3.822), but not with prolonged weaning (adjusted OR 2.001, 95% CI 0.875-4.575).
- **Conclusion:** Delirium, as assessed by the CAM-ICU at the time of first weaning trial, was significantly associated with weaning difficulties in medical patients.

FOR MINIMIZE THESE FACTORS

- explaining the weaning plan to the patient, family, and other caretakers;
- arranging for a trusted caretaker to provide reassurance and explanation during weaning trials
- ensuring adequate sleep
- environmental stimulation during the trial, such as television, radio, or books.
- Efforts to optimize medications for treating delirium, anxiety (eg, switching anxiolytic to dexmedetomidine)
- and pain should also be performed. But
- Oversedation should be avoided.

Meta-Analysis > J Intensive Care Med. 2021 Aug;36(8):925-936.
doi: 10.1177/0885066620937673. Epub 2020 Jul 6.

Dexmedetomidine for Facilitating Mechanical Ventilation Extubation in Difficult-to-Wean ICU Patients: Systematic Review and Meta-Analysis of Clinical Trials

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Results: A total of 6 trials (n = 306 patients) were included. Dexmedetomidine significantly reduced the time to extubation (WMD: -11.61 hours, 95% CI: -16.5 to -6.7, *P* = .005) and ICU length of stay (WMD: -3.04 days; 95% CI: -4.66 to -1.43). Hypotension risk was increased with dexmedetomidine (risk ratio [RR]: 1.62, 95% CI: 1.05-2.51), but there was no difference in bradycardia risk (RR: 3.98, 95% CI: 0.70-22.78). No differences were observed in mortality rates (RR: 1.30, 95% CI: 0.45-3.75) or hospital length of stay (WMD: -2.67 days; 95% CI: -7.73 to 2.39).

Conclusions: Dexmedetomidine was associated with a significant reduction in the time to extubation and shorter ICU stay in difficult-to-wean ICU patients. Although hypotension risk was increased with dexmedetomidine, no differences in other clinical outcomes were observed.

VENTILATOR CIRCUIT ISSUES I

- problems include equipment dead space,
- poor circuit compliance,
- low gas compression volume,
- exhalation valve function, and
- increased resistance caused by the ETT, inspiratory circuit, or expiratory circuit

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- Elevated peak inspiratory airway pressure(Ppeak)with a sizeable difference between the Ppeak and plateau pressure (Pplat) may suggest an obstructed ETT or abnormally increased resistance in ventilator circuit tubing (assuming that the patient is on volume cycled ventilation).
- Increase inboth Ppeak and Pplat may suggest a malfunction of the exhalation valve, which should be checked if this waveform abnormality is found. However, such changes may also result from issues not related to the ventilator circuit (ie, processes that decrease respiratory system compliance such as pulmonary edema, pneumothorax, pleural effusion).

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- Ventilator asynchrony. This manifests as minimal or no inspiratory flow, despite patient inspiratory effort due to continued neural inspiration (contraction of inspiratory muscles) after the ventilator has cycled to the expiratory phase (ie, premature opening of the exhalation valve).
- Such inspiratory effort increases the work of breathing and may injure the inspiratory muscles as they contract eccentrically (eg, the muscle contracts while lengthening). If suspected, the cause of ventilator asynchrony should be sought and treated (eg, auto-PEEP).

NUTRITIONAL ISSUES

- Protein catabolism induced by critical illness leads to decreased respiratory muscle mass, strength, and endurance, which may lead to difficulty weaning from mechanical ventilation
- it is rare for malnutrition to be the sole cause
- Overfeeding with excessive carbohydrates can impair weaning success .presumably by leading to excess carbon dioxide production and an increased ventilatory load on the respiratory muscles. While in the past overfeeding was common, it is now a rare phenomenon.

RESUMING WEANING TRIALS I

ONCE THE POTENTIAL CAUSES HAVE BEEN IDENTIFIED AND TREATED, WEANING TRIALS MAY RESUME

- **Posture :**patients with diaphragmatic paralysis generally prefer and perform better in an upright position because their vital capacity decreases when they are horizontal
- patients with intercostal muscle weakness (eg, due to a low cervical cord lesion) may prefer being supine because their lung volumes tend to increase when they move from an upright to a supine position
- **Airway management**
- Airway secretions should be suctioned before every weaning trial.
- bronchodilators may facilitate weaning in patients with airway obstruction by reducing airway resistance and the work of breathing

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- **Trials longer than 30 minutes :** spontaneous breathing trials (SBTs) are the same as those in patients who are weaning for the first time with one major difference, that trials are longer than the typical 30 minutes in duration (2 h)
- weaning trial should be terminated early if the patient is failing, since respiratory muscle fatigue may develop and further decrease the chances of successful weaning. Rest is the only treatment for such fatigue, and recovery can take several days.

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- **Method of weaning trial :** once daily SBTs to wean
- patients who have failed an initial weaning attempt. return to a supportive mode of mechanical ventilation after a failed SBT,
- look for and correct reversible causes of weaning intolerance, and
- reassess their readiness to wean the next day.

4

- typically use SBT with pressure support (5 to 8 cm H2O) and positive expiratory pressure PEEP; (5 cm H2O) with one exception, that in patients with weaning failure due to cardiac dysfunction, some experts prefer to resume SBTs using a T-tube or pressure support **without** PEEP; this preference ensures that weaning-induced heart failure is not concealed by the use of PEEP (which is a therapy for heart failure)
- extubation with immediate application of noninvasive ventilation (NIV) may facilitate earlier extubation in select patients who might otherwise be difficult to wean

5

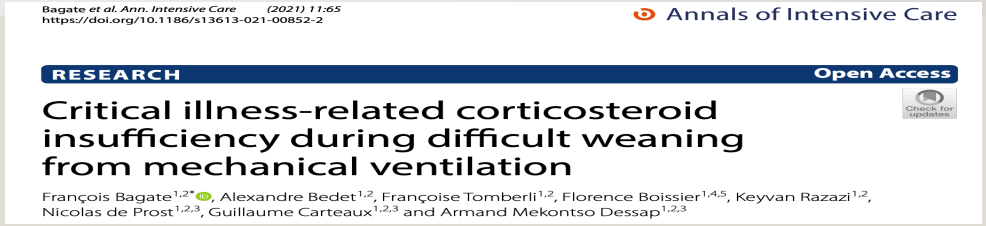
- **Mechanical ventilation between weaning trials**
- Appropriate ventilator settings in between SBTs allow the muscles to rest and recover from the fatigue caused by the weaning trial
- tidal volume, respiratory rate, and/or pressure level) are such that the patient is comfortable and performing minimal work
- Reasonable settings are those that result in a respiratory rate between 12 and 20 breaths per minute, a tidal volume between 6 and 8 mL/kg, and a minute volume between 6 and 12 L/min. For those on pressure-controlled ventilation a reasonable goal is a plateau pressure <30 cm H2O (the lower the better). For those on pressure support ventilation (PSV), a pressure of 7 to 15 cm H2O usually achieves these goals. Most patients who undergo weaning have a PEEP between 5 and 8 cm H2O. Importantly, patients who have chronic hypercapnia should receive a minute ventilation that targets their baseline arterial carbon dioxide tension

6

- A trigger sensitivity of -1 to -2 cm H2O during pressure triggering or -1 to -2 L/min during flow triggering is appropriate. An initial inspiratory flow rate of 60 L/min reasonable for most patients. The flow rate can be increased to as needed if a patient appears to be struggling.

IMPROVING RESPIRATORY MUSCLE STRENGTH. I

Respiratory muscle weakness is common among mechanically ventilated patients;
may be present at the time of intubation or result from intensive care unit (ICU)-acquired paresis or ventilator-induced respiratory muscle weakness.
diaphragm dysfunction, defined by vertical excursion of <10 mm or paradoxical motion during inspiration, in 29 percent of patients ready for weaning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Annals of Intensive Care

RESEARCH Open Access

Critical illness-related corticosteroid insufficiency during difficult weaning from mechanical ventilation

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- 27 percent of patients demonstrated less than a 30 percent increase in diaphragm thickening during inspiration, an indication of dysfunction
- 41 percent of patients developed signs of diaphragm atrophy (>10 percent decrease in thickness) by day four of mechanical ventilation

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- a maximal inspiratory effort; weak effort or low lung volumes suggest respiratory muscle weakness.While not routine, more objective bedside measures such as a low negative inspiratory force (eg, <60 cm H2O) and poor diaphragmatic excursion by ultrasound can be used to support clinical findings

Review > Intensive Care Med. 2017 Dec;43(12):1781-1792. doi: 10.1007/s00134-017-4914-x. Epub 2017 Sep 21.

Critical illness–related corticosteroid insufficiency (CIRCI): a narrative review from a Multispecialty Task Force of the Society of Critical Care Medicine (SCCM) and the European Society of Intensive Care Medicine (ESICM)

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Background: Critical illness-related corticosteroid insufficiency (CIRCI) is common during critical illness and is usually associated with poor outcomes, as prolonged duration of mechanical ventilation (MV) and higher mortality. CIRCI may alter cardiac and vascular functions. Weaning-induced pulmonary oedema (WiPO) is a major mechanism of weaning failure. The aim of this study was to evaluate the role of CIRCI in patients with difficult ventilator weaning and its possible relation with WiPO.

Methods: This is a prospective study conducted in the intensive care of a university hospital in France. Patients under MV for more than 24 h, meeting weaning criteria and having failed the first spontaneous breathing trial (SBT) under- went a corticotropin stimulation test, with assessment of total blood cortisol levels immediately before (*T*0) 0.25 mg iv of tetracosactrin and 30 and 60 min afterward. Δmax was defined as the difference between the maximal value after the test and *T*0. CIRCI was defined as *T*0 < 10 µg/dL (276 nmol/L) and/or Δmax < 9 µg/dL (248 nmol/L) and inadequate adrenal reserve as Δmax < 9 µg/dL. Biomarkers (natriuretic peptide and protidemia) sampling and echocardiograms were performed during the second SBT and were used to diagnose WiPO, which was defined according to two defini- tions (one liberal and one conservative) derived from recent publications on the topic. Successful extubation was defined as patient alive without reintubation 7 days after extubation. A competing risk analysis was used to assess extubation failure and mortality.

Results: Seventy-six consecutive patients (63 ± 14 years; 49 men) with difficult weaning were enrolleddecr. CIRCI and inadequate adrenal reserve occurred in 25 (33%) and 17 (22%) patients, respectively. The probability of successful extubation was significantly eased in patients with CIRCI or inadequate adrenal reserve, as compared to their counterparts, and this association persisted after adjustment on severity (SOFA score at first SBT). WiPO occurred in 44 (58%) and 8 (11%) patients, according to the liberal and conservative definition, respectively. WiPO was not associated with CIRCI nor with inadequate adrenal reserve.

Conclusion: CIRCI was common during difficult weaning and was associated with its prolongation. We did not find a significant association between CIRCI and WiPO.

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RESEARCH Open Access

Role of sleep on respiratory failure after extubation in the ICU

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Background: Sleep had never been assessed immediately after extubation in patients still in the ICU. However, sleep deprivation may alter respiratory function and may promote respiratory failure. We hypothesized that sleep alterations after extubation could be associated with an increased risk of post-extubation respiratory failure and reintubation.

We conducted a prospective observational cohort study performed at the medical ICU of the university hospital of Poitiers in France. Patients at high-risk of extubation failure (> 65 years, with any underlying cardiac or lung disease, or intubated > 7 days) were included. Patients intubated less than 24 h, with central nervous or psychiatric disorders, continuous sedation, neuroleptic medication, or uncooperative were excluded. Sleep was assessed by complete polysomnography just following extubation including the night. The main objective was to compare sleep between patients who developed post-extubation respiratory failure or required reintubation and the others.

Results: Over a 3-year period, 52 patients had complete polysomnography among whom 12 (23%) developed post-extubation respiratory failure and 8 (15%) required reintubation. Among them, 10 (19%) had atypical sleep, 15 (29%) had no deep sleep, and 33 (63%) had no rapid eye movement (REM) sleep. Total sleep time was 3.2 h in median [interquartile range, 2.0–4.4] in patients who developed post-extubation respiratory failure vs. 2.0 [1.1–3.8] in those who were successfully extubated ($p = 0.34$). Total sleep time, and durations of deep and REM sleep stages did not differ between patients who required reintubation and the others. Reintubation rates were 21% (7/33) in patients with no REM sleep and 5% (1/19) in patients with REM sleep (difference, − 16% [95% CI − 33% to 6%]; $p = 0.23$).

Conclusions: Sleep assessment by polysomnography after extubation showed a dramatically low total, deep and REM sleep time. Sleep did not differ between patients who were successfully extubated and those who developed post-extubation respiratory failure or required reintubation.

PHYSICAL THERAPY I

- early mobilization/physical therapy in mechanically ventilated patients is supported by the American Thoracic Society and American College of Chest physicians as a preventive measure to promote liberation from mechanical ventilation
- **inspiratory respiratory muscle training**
- IMST is performed by adding a resistance device to the inspiratory limb of the ventilator circuit can be trained to improve strength and endurance so that fatigue occurs less easily However, whether IMST consistently results in earlier liberation from mechanical ventilation remains unproven. Consequently, it is not routinely used.

2

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Inspiratory Muscle Training With an Electronic Resistive Loading Device Improves Prolonged Weaning Outcomes in a Randomized Controlled Trial

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Objectives: To test if the use of an inspiratory muscle training program with an electronic resistive loading device is associated with benefits as to muscle strength, weaning, and survival in the ICU.
Design: Prospective randomized controlled trial.
Settings: Study conducted at the ICU of a Navy's hospital, Rio de Janeiro, Brazil, from January 2016 to September 2018.
Patients: Tracheostomized patients (18-86 yr) on prolonged weaning.
Interventions: Participants were assigned to inspiratory muscle training (intervention group) or a traditional T-piece protocol (control group). In the inspiratory muscle training group, participants underwent training with an electronic inspiratory training device (POWERbreathe K-5; Technologies Ltd, Birmingham, United Kingdom).
Measurements and main results: Changes in respiratory muscle strength and rates of ICU survival and weaning success were compared between groups. Forty-eight participants in the inspiratory muscle training group and 53 ones in the control group were included in the final analysis. The inspiratory muscle training was associated with a substantially higher gain on muscle strength as assessed by the maximal inspiratory pressure (70.5 [51.0-82.5] vs -48.0 cm H2O [36.0-72.0 cm H2O]; p = 0.003) and the timed inspiratory effort index (1.56 [1.25-2.08] vs 0.99 cm H2O/s [0.65-1.71 cm H2O/s]; p = 0.001). Outcomes at the 60th day of ICU were significantly better in the intervention group regarding both survival (71.1% vs 48.9%; p = 0.030) and weaning success (74.8% vs 44.5%; p = 0.001).
Conclusions: The use of an inspiratory muscle training program with an electronic resistive loading device was associated with substantial muscle strength gain and positive impacts in two very relevant clinical outcomes: the rates of ICU survival and successful weaning.

REFRACTORY PATIENTS

- **Tracheostomy**
- **Transfer to long-term acute care (LTAC)**
- First, the acute illness should be resolved.
- Second, the patient should not be dyspneic or hypoxemic during mechanical ventilation.
- Third, patients should have a stable airway and route to receive nutrition, which usually consists of a tracheostomy and enteral feeding tube
- LTAC facilities provide a site where weaning and rehabilitation are the primary focus of care. They foster involvement of the patient in decision-making and provide an environment that integrates the family and other caregivers into a supportive health care team. This team includes intensivists, internists, nurses, and respiratory therapists who identify weaning goals and coordinate the weaning process. In addition, there is daily patient-centered rehabilitation that includes physical exercise for regaining muscle strength and practice performing activities of daily living. Skilled therapists are also available to focus on issues such as speech and communication, nutrition support, physical and recreational activities, and counseling. Strategies for weaning patients who are in an LTAC facility for prolonged mechanical ventilation and their outcomes are described in detail separately.

- **Difficult intubation**

IT HAS BEEN DETERMINED THAT THE PATIENT'S MEDICAL CONDITION IS STABLE,

A WEANING TRIAL HAS BEEN SUCCESSFUL,

THE AIRWAY IS PATENT,

AND ANY POTENTIAL DIFFICULTIES IN REINTUBATION HAVE BEEN IDENTIFIED.

MOST PATIENTS ARE EXTUBATED DURING DAYTIME HOURS

SUCCESSFUL WEANING TRIAL. I

- most patients should not be extubated unless a successful weaning trial has been passed.

One study showed a decrease rate of reintubation at 48 hours when patients were rested back on the ventilator for an hour before extubation after the completion of a spontaneous breathing trial. This observation awaits further confirmation

Intensive Care Med. 2004 Jul;30(7):1334-9. doi: 10.1007/s00134-004-2231-7. Epub 2004 Mar 4.

2

Neurologic status, cough, secretions and extubation outcomes

Adil Salam [1], Lisa Tilluckdharry, Yaw Amoateng-Adjepong, Constantine A Manthous

Background: Spontaneous breathing trials (SBT) can be exhausting, but the preventive role of rest has never been studied. This study aimed to evaluate whether reconnection to mechanical ventilation (MV) for 1 h after the effort of a successful SBT could reduce the need for reintubation in critically ill patients.

Methods: Randomized multicenter trial conducted in 17 Spanish medical-surgical intensive care units (Oct 2013-Jan 2015). Patients under MV for longer than 12 h who fulfilled criteria for planned extubation were randomly allocated after a successful SBT to direct extubation (control group) or reconnection to the ventilator for a 1-h rest before extubation (rest group). The primary outcome was reintubation within 48 h. Analysis was by intention to treat.

Results: We recruited 243 patients randomized to the control group and 227 to the rest group. Median time from intubation to SBT did not differ between groups [5.5 (2.7, 9.6) days in the control group vs. 5.7 (2.7, 10.6) in the rest group; $p = 0.85$]. Reintubation within 48 h after extubation was more common in the control than in the rest group [35 (14%) vs. 12 (5%) patients; OR 0.33; 95% CI 0.16-0.65; $p < 0.001$]. A multivariable regression model demonstrated that the variables independently associated with reintubation were rest [OR 0.34 (95%CI 0.17-0.68)], APACHE II [OR 1.04 (1.002-1.077)], and days of MV before SBT [OR 1.04 (1.001-1.073)], whereas age, reason for admission, and type and duration of SBT were not.

Conclusion: One-hour rest after a successful SBT reduced the rates of reintubation within 48 h after extubation in critically ill patients.

ASSESS AIRWAY PROTECTION I

- **Assess airway protection** — Airway protection is the ability to guard against aspiration during spontaneous breathing. It requires
- sufficient cough strength and
- an adequate level of consciousness,
- The amount of secretions).
- Universally accepted threshold levels of cough strength, level of consciousness, and suctioning frequency that prohibit extubation have not been established.
- Extubation failure is highest when a combination of risk factors affecting airway patency is present. As an example, in one study when reduced cough peak expiratory flow rate (PEF ≤60 L/min), increased sputum volume (>2.5 mL/hour), and impaired neurologic function (inability to follow commands) were present, the incidence of extubation failure was 100 percent, compared with 3 percent when none of the risk factors were present

2

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JA Clinical Reports

CLINICAL RESEARCH ARTICLE Open Access

Frequent tracheal suctioning is associated with extubation failure in patients with successful spontaneous breathing trial: a single-center retrospective cohort study

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Objective: To determine the degree to which neurologic function, cough peak flows and quantity of endotracheal secretions affected the extubation outcomes of patients who had passed a trial of spontaneous breathing (SBT).

Design: Prospective observational study.

Setting: The medical intensive care unit of a 325-bed teaching hospital.

Measurements and main results: Cough peak flow (CPF), endotracheal secretions and ability to complete four simple tasks were measured just before extubation in patients who had passed a SBT. Eighty-eight patients were studied; 14 failed their first trials of extubation. The CPF of patients who failed was lower than that of those who had a successful extubation (58.1+/-4.6 l/min vs 79.7+/-4.1 l/min, p=0.03) and those with CPF 60 l/min or less were nearly five times as likely to fail extubation compared to those with CPF higher than 60 l/min (risk ratio [RR]=4.8; 95% CI=1.4-16.2). Patients with secretions of more than 2.5 ml/h were three times as likely to fail (RR=3.0; 95% CI=1.0-8.8) as those with fewer secretions. Patients who were unable to complete four simple tasks (i.e. open eyes, follow with eyes, grasp hand, stick out tongue) were more than four times as likely to fail as those who completed the four commands (RR=4.3; 95% CI=1.8-10.4). There was synergistic interaction between these risk factors. The failure rate was 100% for patients with all three risk factors compared to 3% for those with no risk factors (RR=23.2; 95% CI=3.2-167.2). The presence of any two of the above risk factors had a sensitivity of 71 and specificity of 81% in predicting extubation failure. Patients who failed a trial of extubation were 3.8 times as likely to have any two risk factors compared to those who were successful.

Conclusions: These simple, reproducible methods may provide a clinically useful approach to guiding the extubation of patients who have passed a SBT.

I

- **Secretions**–Although the volume of secretions can be measured at the bedside(via the suction canister), most clinicians assess secretion clearance by the frequency of
- suctioning. In general, those who require suctioning more than every two to three hours should not be extubated. The nature of secretions (eg, thick or thin) can also be examined bedside but thick secretions on their own is not a contraindication to extubation unless the cough is borderline or weak.

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Predictors of successful extubation in neurosurgical patients

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Background: Extubation failure, i.e., reintubation in ventilated patients, is a well-known risk factor for mortality and prolonged stay in the intensive care unit (ICU). Although sputum volume is a risk factor, the frequency of tracheal suc- tioning has not been validated as a predictor of reintubation. We conducted this study to examine whether frequent tracheal suctioning is a risk factor for reintubation.

Patients and methods: We included adult patients who were intubated for > 72 h in the ICU and extubated after completion of spontaneous breathing trial (SBT). We compared the characteristics and weaning-related variables, including the frequency of tracheal suctioning between patients who required reintubation within 24 h after extuba- tion and those who did not, and examined the factors responsible for reintubation.

Results: Of the 400 patients enrolled, reintubation was required in 51 (12.8%). The most common cause of reintuba- tion was difficulty in sputum excretion (66.7%). There were significant differences in sex, proportion of patients with chronic kidney disease, pneumonia, ICU admission type, the length of mechanical ventilation, and ICU stay between patients requiring reintubation and those who did not. Multivariate analysis showed frequent tracheal suction (> once every 2 h) and the length of mechanical ventilation were independent factors for predicting reintubation.

Conclusion: We should examine the frequency of tracheal suctioning > once every 2 h in addition to the length of mechanical ventilation before deciding to extubate after completion of SBT in patients intubated for > 72 h in the ICU

2

- **Cough**–In most patients, cough strength is assessed formally during deep (endotracheal) suctioning at the bedside with or without gag reflex evaluation. However, a formal assessment may be useful in patients noted to have a weak cough on endotracheal suctioning or patients with neuromuscular disorders (eg, Parkinson disease, critical care myopathy). Several tests are available:
- Spirometry – A spirometer (specifically designed for mechanical ventilators) is inserted into the ventilator circuit and the patient is then instructed to cough. The PEF during the cough is measured. Most experts use a cutoff of PEF ≤60 L/min since this indicates a high likelihood of failure. Patients with a PEF ≤60 L/min are five times more likely to require reintubation than patients with a PEF >60 L/min
- Index card – The endotracheal tube (ETT) is detached from the ventilator circuit and a card (eg, an index card) is held approximately 1 to 2 cm from the proximal end of the ETT. The patient is then instructed to cough. A patient who is unable to moisten the card with 3 to 4 coughs is three times more likely to fail extubation than a patient who can moisten the card

ASSESS RISK FOR POSTEXTUBATION. I STRIDOR

- occurs in less than 10 percent of critically ill patients and is associated with increased rates of reintubation,
- Most cases are due to vocal cord edema related to the ETT; others include laryngeal injury, secretions, vocal cord dysfunction, and rarely tracheal stenosis or lesions

RISK I-2

1. Prolonged intubation(variably defined as≥36hours to≥6days)
2. Age greater than80years)
- A ratio of ETT to laryngeal diameter greater than 45 percent on computed tomography
- A small ratio ofpatient height(inmm) toETT diameter(inmm)
- An elevated acute physiology and chronic health evaluation(APACHE) IIscore
- A GCS score <8
- Traumatic intubation
- Female gender
- A history of asthma
- Excessive tube mobility due toi nsufficient fixation
- Insufficient or lack of sedation
- Aspiration

APROACH 1-3

- **Patients not at risk**
- Patients who have no risk factors for postextubation stridor should be extubated in the same manner as other patients and no assessment of the cuff leak test is necessary.

- **Patients at risk**
- Patients who have one or more risk factors for postextubation stridor should undergo a cuff leak test.
- **Cuff leak :**qualitatively qualitatively
- **Other tests :**
- Laryngeal ultrasonography is asimple,rapid,and noninvasive way to evaluate the width of the laryngeal air column during cuff deflation, thereby assessing the likelihood of postextubation stridor
- Simultaneous assessment of both cough and cuffleak may improve prediction of postextubation stridor. After the cuff is deflated, the ETT is occluded and the patient is instructed to cough. The absence of both an audible cough and a cuff leak indicates the patient is 10 times more likely to develop postextubation stridor

COUGH LEAK TEST. 1-4

THE ABSENCE OF A LEAK SUGGESTS THERE IS REDUCED SPACE BETWEEN THE ETT AND THE LARYNX. THIS MAY BE DUE TO LARYNGEAL EDEMA, LARYNGEAL INJURY, SECRETIONS, STENOSIS, OR A LARGE ETT WITHIN A RELATIVELY SMALL LARYNX. PATIENTS **WITHOUT** A CUFF LEAK ARE AT INCREASED RISK FOR POSTEXTUBATION STRIDOR.

- Qualitativ
- Performed by deflating the cuff and then listening for air movement around the ETT using a stethoscope placed over the upper trachea. Air movement indicates that a cuff leak is present while no air movement suggests that it is absent and may indicate laryngeal obstruction

- Quantitative
- Performed by deflating the ETTcuff and measuring the difference between the inspired and expired tidal volumes of ventilator-delivered breaths during **volume**-cycled mechanical ventilation. The lowest three expired tidal volumes obtained over six breaths are averaged and then subtracted from the inspired tidal volume to give the cuff leak volume .Although ill-defined, we and other experts consider cuff leak volumes less than 110 mL or less than 12 to 24 percent of the delivered tidal volume as thresholds for determining diminished airway patency and risk for postextubation stridor from laryngeal edema (ie, "reduced" or "absent" cuff leak) . Cuff leak volumes greater than or equal to 110 mL or greater than 24 percent of the delivered tidal volume is considered a normal cuff leak test.

GLUCOCORTICOIDS

- patients who are assessed to be at high risk of postextubation stridor and who have a reduced or absent cuff leak and to patients who have failed extubation due to postextubation stridor.
- Methylprednisolone (20 mg) administered intravenously every four hours for a total of 4 dose
- regimen. Alternatively, a single dose of 40 mg of methylprednisolone administered four hours prior to extubation may be used. Choosing one over the other should be at the discretion of the physician and depends upon the assessed risk of postextubation stridor in a given patient.

PATIENTS WHO FAIL DUE TO POSTEXTUBATION STRIDOR

- prompt reintubation is warranted (sometimes with a smaller-sized ETT).
- ● Treat with a short course of glucocorticoids for presumed or observed laryngeal edema.
- ● Perform a cuff leak test following treatment,provided the patient meets all other extubation criteria again
- • If an appropriate cuff leak is detected, bedside extubation is generally safe.
- • If a cuff leak is reduced or absent despite a course of glucocorticoid therapy, extubation over an airway exchange catheter (AEC; eg, a Cook catheter) may facilitate successful reintubation without delay, if necessary

AT-RISK PATIENTS
REINTUBATION

- It is estimated that 12 to 14 percent of patients who undergo planned extubation require reintubation within 48 to 72 hours, most within the first 24 hours
- ● A weak cough(cough peak expiratoryflow rate≤60L/min
- ● Frequent suctioning(eg,every one to two hours,sputum volume>2.5mL/hour)
- ● Glasgow Coma Score <8
- ● A positive fluid balance during the24 hours preceding extubation
- ● Pneumonia as thereason for the initial intubation
- ● Patients who are≥65years old with severe chronic cardiacorrespirator ydisease
- ● A reduced or absent cuff leak,

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Critical Care

RESEARCH Open Access

Role of ICU-acquired weakness on extubation outcome among patients at high risk of reintubation

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Objective: To derive and validate a multivariate risk score for the prediction of respiratory failure after extubation.

Patients and methods: We performed a retrospective cohort study of adult patients admitted to the intensive care unit from January 1, 2006, to December 31, 2015, who received mechanical ventilation for ≥48 h. Extubation failure was defined as the need for reintubation within 72 h after extubation. Multivariate logistic regression model coefficient estimates generated the **R**e-**I**ntubation **S**ummation **C**alculation (RISC) score.

Results: The 6,161 included patients were randomly divided into 2 sets: derivation (n = 3,080) and validation (n = 3,081). Predictors of extubation failure in the derivation set included body mass index <18.5 kg/m2 [odds ratio (OR), 1.91; 95% CI, 1.12–3.26; P = 0.02], threshold of Glasgow Coma Scale of at least 10 (OR, 1.68; 95% CI, 1.31–2.16; P < 0.001), mean airway pressure at 1 min of spontaneous breathing trial <10 cmH2O (OR, 2.11; 95% CI, 1.68–2.66; P < 0.001), fluid balance ≥1,500 mL 24 h preceding extubation (OR, 2.36; 95% CI, 1.87–2.96; P < 0.001), and total mechanical ventilation days ≥5 (OR, 3.94; 95% CI 3.04–5.11; P < 0.001). The C-index for the derivation and validation sets were 0.72 (95% CI, 0.70–0.75) and 0.72 (95% CI, 0.69–0.75). Multivariate logistic regression demonstrated that an increase of 1 in RISC score increased odds of extubation failure 1.6-fold (OR, 1.58; 95% CI, 1.47–1.69; P < 0.001).

Conclusion: RISC predicts extubation failure in mechanically ventilated patients in the intensive care unit using several clinically relevant variables available in the electronic medical record but requires a larger validation cohort before widespread clinical implementation.

PATIENTS WITH UNPLANNED EXTUBATION

- Unplanned extubation occurs in 3 to 12 percent of intubated patients .
- It is more common in patients who are orally intubated than those who are nasally intubated
- .It is also more frequent in patients whose ETT is not well secured or who are agitated,
- have low levels of sedation,
- Most unplanned extubations occur within one day of planned extubation and are deliberate maneuvers by the patients rather than accidental
- Most patients who undergo unplanned extubation should be promptly assessed with a low threshold to reintubate immediately. This strategy is based upon reports which suggest that delayed reintubation is associated with increased mortality .Increased mortality may be due to the technical difficulty associated with reintubation in this setting .and that unplanned extubation is associated with a longer duration of mechanical ventilation, ICU stay, and hospitalization
- In support, approximately 50 percent of patients who have undergone unplanned extubation require reintubation, often within 12 hours .
- Reintubation is more common following accidental unplanned extubation and among patients who require full ventilatory support, have higher sedation scores, and have a significant oxygen requirement (ie, FiO2 >50 percent)

NUTRITION

- –Following extubation,clinicians should assess the safety of refeeding.The timing of refeeding is individualized and depends upon factors including duration of intubation, mental status,and underlying comorbidities (eg, neuromuscular disorders, critical care myopathy, poor level of consciousness).Typically, most patients intubated for short periods (eg, less than one week) can generally eat within a few hours after extubation under direct supervision, while those who have been intubated for more prolonged periods or with comorbidities that increase the risk of aspiration may need formal assessment within 24 to 48 hours before feeding.

PATIENTS WITH ESTABLISHED I POSTEXTUBATION RESPIRATORY FAILURE

- patients who undergo planned extubation require reintubation, mostly within the first 24 hours. Similarly, over half of patients who undergo unplanned extubation require immediate reintubation
- The most common etiologies are atelectasis from poor secretion clearance, heart failure, aspiration, bronchospasm, and laryngeal edema
- **NIV**
- **HFNC**

با تشکر از توجه شما