REVIEW

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When to wean from a ventilator: An evidence-based strategy

ABSTRACT

It is often unclear when and how to wean patients from mechanical ventilation. We have devised an evidence-based protocol in which patients undergo a 30-minute trial of spontaneous breathing with a T tube or pressure support of 7 cm H_2O. Those who can tolerate the trial are extubated, while those who cannot are reconnected to mechanical ventilation but undergo another trial every day until they can be extubated. More study is needed to improve the criteria to predict successful spontaneous breathing and extubation, and to clarify the role of noninvasive ventilation to avoid reintubation.

KEY POINTS

Intensive care units should set up protocols for daily assessment by nurses and respiratory therapists to determine when patients are ready to start the weaning process.

Trials of spontaneous breathing can be conducted by T tube or pressure support and should last only 30 minutes.

If a patient fails the spontaneous breathing trial, wait 24 hours to try again.

Successful extubation is likeliest for patients with a strong cough and minimal endotracheal secretions.

HOW CAN WE BEST determine when a patient is ready to be weaned from mechanical ventilation, and what is the best weaning technique?

The questions are important, as about 30% of patients admitted to intensive care units require mechanical ventilation.[1] If weaning is delayed, costs are increased, as are the risks of nosocomial pneumonia, cardiac-associated morbidity, and death. On the other hand, weaning too soon often results in reintubation, which is associated with complications similar to those of prolonged ventilation.[2]

Yet, until recently, weaning has been done mostly on an empiric basis.

In the past few years, our group—the Spanish Lung Failure Collaborative Group—and others have been conducting clinical trials aimed at establishing an evidence-based approach to weaning. The findings are extensively reviewed in guidelines from the American College of Chest Physicians, the American Association for Respiratory Care, and the American College of Critical Care Medicine.[3]

This article discusses our algorithm (**FIGURE 1**) and issues for further research.

STEP 1: ASSESS READINESS FOR WEANING

Weaning begins when we recognize that the patient has recovered adequately from acute respiratory failure. Thereafter, clinical assessments are needed to determine the patient's readiness for discontinuation of ventilatory support and extubation.

Research suggests that the best way to know when weaning should start is to use a formal protocol managed by nurses, respiratory therapists, or both.[4–10] The studies used a vari-

Is the patient ready to be weaned from the ventilator? An algorithm

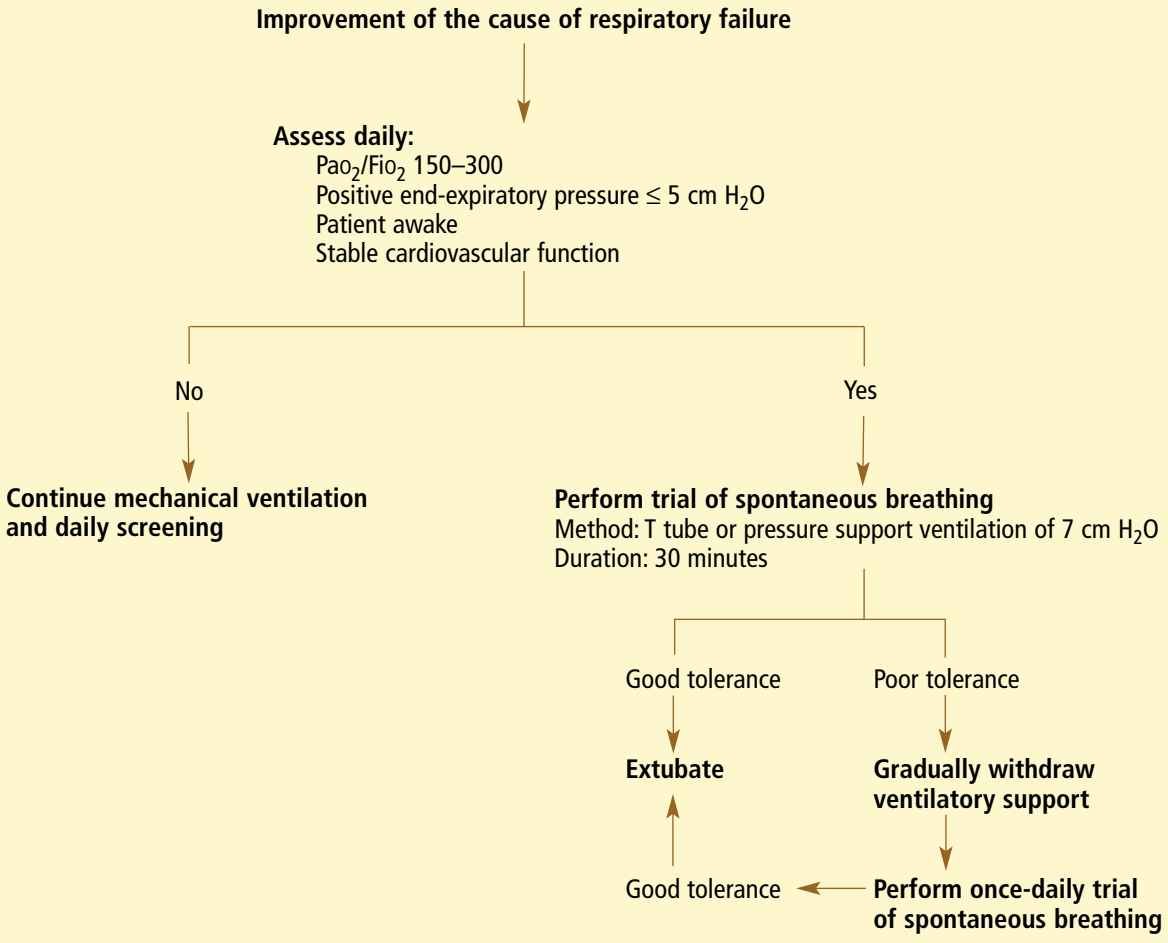

FIGURE 1

ety of clinical criteria for determining readiness for weaning, including oxygenation, hemodynamic stability, temperature, hemoglobin, and mental status (TABLE 1); a weakness of the studies was that the criteria were arbitrarily set by the researchers.

Unresolved issues about readiness for weaning

Questions remain about:

- **Oxygenation.** What is the Pao_2/Fio_2 threshold that best discriminates patients who are able to tolerate spontaneous breathing?[11] Should the level be the same for patients with chronic hypoxemia?
- **Hemoglobin level.** Is a hemoglobin level of 8 g/dL high enough, or is 10 g/dL necessary?[11]
- **Mental status.** Is it necessary to maintain ventilatory support until the patient is arousable? A recent descriptive study[12] observed that 10 (91%) of 11 patients with severe brain injury (Glasgow coma scale ≤ 4) could be successfully extubated. This finding needs to be confirmed in a randomized controlled study.

STEP 2: PERFORM A TRIAL OF SPONTANEOUS BREATHING

If the patient seems ready for weaning, the next step is to give him or her a short trial of spontaneous breathing.

T tube or pressure support?

Trials of spontaneous breathing are tradition-

TABLE 1

Criteria for starting weaning

Adequate oxygenation
$Pao_2 \geq 60$ mm Hg on $Fio_2 \leq 0.4$
($Pao_2/Fio_2 = 150–300$) with positive end-expiratory pressure ≤ 5 cm H_2O

Hemodynamic stability
No myocardial ischemia or significant hypotension

Temperature < 38°C

Hemoglobin ≥ 8–10 g/dL

Adequate mental status
Patient awake or easily aroused

TABLE 2

Criteria to determine success of a trial of spontaneous breathing

Objective criteria
$Sao_2 > 90\%$ or $Pao_2 > 60$ mm Hg on $Fio_2 < 0.4–0.5$
Increase in $Paco_2 < 10$ mm Hg or decrease in pH < 0.10
Respiratory rate < 35 breaths/minute
Heart rate < 140 or increased < 20% from baseline
Systolic blood pressure > 80–160 mm Hg or change < 20% from baseline

Subjective criteria
No signs of increased work of breathing, including thoracoabdominal paradox or excessive use of accessory respiratory muscles
No other signs of distress, such as diaphoresis or agitation

ally done with a T-tube system. However, one could argue that some patients fail this test because they must work harder to breathe through the endotracheal tube.

Therefore, some investigators advocate using pressure support to counteract this extra work.[13,14] The mean value of pressure support needed to compensate for the increased work of breathing caused by the ventilatory circuit and the endotracheal tube was found to be 7 cm H_2O (range 4–10).[15]

The Spanish Lung Failure Collaborative Group[2] conducted a study in adult patients to compare the use of a T tube vs pressure support (7 cm H_2O) in trials of spontaneous breathing. Although more patients in the T-tube group failed the trial (22% vs 14%; $P = .03$), there was no difference in the percentage of patients who remained extubated after 48 hours (63% in the T-tube group vs 70% in the pressure support group; $P = .14$).

Farias et al[16] performed a comparable study in children. The rates of successful extubation were similar after a first breathing trial performed with pressure support (10 cm H_2O) or a T tube.

30 Minutes are enough

Trials of spontaneous breathing usually last 2 hours, but patients who fail usually show signs of poor tolerance earlier.[2,17–20] The Spanish Lung Failure Collaborative Group[21] conducted a prospective, multicenter study in 526 ventilator-supported patients to compare trials of spontaneous breathing lasting 30 or 120 minutes. The percentage of patients who remained extubated for 48 hours did not differ between the two groups (75.9% vs 73.0%, $P = .43$).

Unresolved issues about spontaneous breathing trials

- **What constitutes 'success'?** The criteria for determining whether a trial of spontaneous breathing is a success or failure are similar to those for determining the patient's readiness for weaning (TABLE 2). However, the utility and accuracy of these criteria need to be assessed.
- **Are arterial blood gas measurements useful?** If a trial of spontaneous breathing is successful, can arterial blood gas measurements help in deciding whether to go to the next step of withdrawing the endotracheal tube?
- **Can CPAP help?** Patients with chronic obstructive pulmonary disease or asthma have auto-positive end-expiratory pressure (auto-PEEP). Can continuous positive airway pressure (CPAP) improve their tolerance to a spontaneous breathing trial?

Criteria for weaning have been arbitrary and must be validated

IF THE TRIAL FAILS

Gradual discontinuation of ventilatory support

Up to 35% of patients cannot tolerate their first trial of spontaneous breathing. For these patients we have different techniques to facilitate the gradual transition from mechanical

ventilation to spontaneous breathing, using a T tube, pressure support ventilation, or synchronized intermittent mandatory ventilation.

A systematic review[22] of four studies[23–26] that compared two or more of these techniques found none of them superior to the others, although synchronized intermittent mandatory ventilation may lead to a longer weaning process.

Wait 24 hours before another trial

We recommend waiting 24 hours before attempting a new trial of spontaneous breathing.

Jubran and Tobin[19] showed that failures are often due to persistent mechanical alterations in the respiratory system that are unlikely to rapidly reverse. A failed trial can precipitate respiratory muscle fatigue,[27] and studies in healthy subjects suggest that complete recovery from fatigue can take longer than 24 hours.[28]

In addition, Esteban et al[26] showed that multiple daily breathing trials offer no advantage over a once-daily trial.

Unresolved issues about gradual weaning

- **Is gradual weaning better?** New modes of weaning such as bilevel positive airway pressure and pressure support should be compared with once-daily trials of spontaneous breathing.
- **Can noninvasive ventilation help?** In two studies,[29,30] patients in whom a trial of spontaneous breathing failed were immediately extubated and managed with noninvasive ventilation (ie, using a mask); results were good, but perhaps not for all patients.
- **A role for computers?** Can a computerized algorithm reduce the patient's time on the respirator?

STEP 3: EXTUBATION

The decision to remove the endotracheal tube should be based on an assessment of airway patency and the ability of the patient to protect the airway.

No variable has yet been identified that predicts which patients will have to be reintubated. However, upper airway obstruction following extubation is associated with longer duration of mechanical ventilation, female gender, trauma, and repeated intubations.[31]

Cuff-leak test

Several studies evaluated the amount of air that leaks when the cuff of the endotracheal tube is deflated as a predictor of stridor after extubation. In one study, a cuff leak of less than 110 mL identified patients at risk for stridor.[32] However, a positive cuff-leak test, defined as no air leakage, did not predict extubation failure in another study.[33]

Cough strength and secretions

Most important for successful extubation is the patient's ability to protect the airway by coughing and clearing it of secretions.

In a recent study,[11] the probability of successful extubation was highly positively correlated with cough strength and inversely correlated with the amount of secretions in the airway. Patients with moderate to strong coughs were four times more likely to be extubated successfully than those with weak coughs, and those with no or mild secretions were more than eight times as likely to be extubated successfully than those with moderate to abundant secretions. Poor cough strength and greater secretions were synergistic in predicting extubation failure.

Risk for airway obstruction:
- **Longer ventilation**
- **Female**
- **Trauma**
- **Repeated intubation**

Unresolved issues in extubation

- What variables best predict extubation success?
- Can the value of the cuff-leak test be confirmed?
- What is the role of noninvasive ventilation to avoid reintubation?

REFERENCES

1. **Esteban A, Anzueto A, Frutos F, et al.** Characteristics and outcomes in adult patients receiving mechanical ventilation: a 28-day international study. JAMA 2002; 287:345–355.
2. **Esteban A, Alía I, Gordo F, et al.** Extubation outcome after spontaneous breathing trials with T-tube or pressure support ventilation. The Spanish Lung Failure Collaborative Group. Am J Respir Crit Care Med 1997; 156:459–465.
3. **Task Force by the American College of Chest Physicians; American Association for Respiratory Care and the American College of Critical Care Medicine.** Evidence-based guidelines for weaning and discontinuing ventilatory support. Chest 2001; 120:375S–395S.
4. **Cohen IL, Bari N, Strosberg MA, et al.** Reduction of duration and cost of mechanical ventilation in an intensive care unit by use of a ventilatory management team. Crit Care Med 1991; 19:1278–1284.
5. **Wood G, MacLeod B, Moffatt S.** Weaning from mechanical ventila-

tion: physician-directed vs a respiratory-therapist-directed protocol. Respir Care 1995; 40:219–224.
6. **Saura P, Blanch L, Mestre J, Valles J, Artigas A, Fernandez R.** Clinical consequences of the implementation of a weaning protocol. Intensive Care Med 1996; 22:1052–1056.
7. **Horst HM, Mouro D, Hall-Jenssens RA, Pamukov N.** Decrease in ventilation time with a standardized weaning process. Arch Surg 1998; 133:483–489.
8. **Ely EW, Baker AM, Dunagan DP, et al.** Effect on the duration of mechanical ventilation of identifying patients capable of breathing spontaneously. N Engl J Med 1996; 335:1864–1869.
9. **Kollef MH, Shapiro SD, Silver P, et al.** A randomized, controlled trial of protocol-directed versus physician-directed weaning from mechanical ventilation. Crit Care Med 1997; 25:567–574.
10. **Marelich GP, Murin S, Battistella F, Inciardi J, Vierra T, Roby M.** Protocol weaning of mechanical ventilation in medical and surgical patients by respiratory care practitioners and nurses. Chest 2000; 118:459–467.
11. **Khamiees M, Raju P, DeGirolamo A, Amoateng-Adjepong Y, Manthous CA.** Predictors of extubation outcome in patients who have successfully completed a spontaneous breathing trial. Chest 2001; 120:1262–1270.
12. **Coplin WM, Pierson DJ, Cooley KD, Newell DW, Rubenfeld GD.** Implications of extubation delay in brain-injured patients meeting standard weaning criteria. Am J Respir Crit Care Med 2000; 161:1530–1536.
13. **Fiastro JF, Habib MP, Quan SF.** Pressure support compensation for inspiratory work due to endotracheal tubes and demand continuous positive airway pressure. Chest 1988; 93:499–505.
14. **Brochard L, Rua F, Lorino H, Lemaire F, Harf A.** Inspiratory pressure support compensates for the additional work of breathing caused by the endotracheal tube. Anesthesiology 1991; 75:739–745.
15. **Nathan SD, Ishaaya AM, Koerner SK, Belman MJ.** Prediction of minimal pressure support during weaning from mechanical ventilation. Chest 1993; 103:1215–1219.
16. **Farias JA, Retta A, Alía I, et al.** A comparison of two methods to perform a breathing trial before extubation in pediatric intensive care patients. Intensive Care Med 2001; 27:1649–1654.
17. **Vallverdú I, Calaf N, Subirana M, Net A, Benito S, Mancebo J.** Clinical characteristics, respiratory functional parameters, and outcome of a two-hour T-piece trial in patients weaning from mechanical ventilation. Am J Respir Crit Care Med 1998; 158:1855–1862.
18. **Frutos F, Alía I, Esteban A, et al.** Comportamiento clínico durante un test de prueba de ventilación espontánea con tubo en T. Med Intensiva 1995; 19:343–348.
19. **Jubran A, Tobin MJ.** Pathophysiologic basis of acute respiratory distress in patients who fail a trial of weaning from mechanical ventilation. Am J Respir Crit Care Med 1997; 155:906–915.
20. **Tobin MJ, Pérez W, Guenther SM, et al.** The pattern of breathing during unsuccessful trials of weaning from mechanical ventilation. Am Rev Respir Dis 1986; 134:1111–1118.
21. **Esteban A, Alía I, Tobin MJ, et al, for the Spanish Lung Failure Collaborative Group.** Effect of spontaneous breathing trial duration on outcome of attempts to discontinue mechanical ventilation. Am J Respir Crit Care Med 1999; 159:512–518.
22. **Butler R, Keenan SP, Inman KJ, Sibbald WJ, Block G.** Is there a preferred technique for weaning the difficult-to wean patient? A systematic review of the literature. Crit Care Med 1999; 27:2331–2336.
23. **Tomlinson JR, Miller KS, Lorch DG, Smith L, Reines HD, Sahn SA.** A prospective comparison of IMV and T-piece weaning from mechanical ventilation. Chest 1989; 96:348–352.
24. **Esen F, Denkel T, Telci L, et al.** Comparison of pressure support ventilation (PSV) and intermittent mandatory ventilation (IMV) during weaning in patients with acute respiratory failure. Adv Exp Med Biol 1992; 317:371–376.
25. **Brochard L, Rauss A, Benito S, et al.** Comparison of three methods of gradual withdrawal from ventilatory support during weaning from mechanical ventilation. Am J Respir Crit Care Med 1994; 150:896–903.
26. **Esteban A, Frutos F, Tobin MJ, et al.** A comparison of four methods of weaning patients from mechanical ventilation. Spanish Lung Failure Collaborative Group. N Engl J Med 1995; 332:345–350.
27. **Vassilakopoulos T, Zakynthinos S, Roussos C.** The tension-time index and the frequency/tidal volume ratio are the major pathophysiologic determinants of weaning failure and success. Am J Respir Crit Care Med 1998; 158:378–385.
28. **Laghi F, D'Alfonso N, Tobin MJ.** Pattern of recovery from diaphragmatic fatigue over 24 hours. J Apply Physiol 1995; 79:539–546.
29. **Nava S, Ambrosino N, Clini E, et al.** Noninvasive mechanical ventilation in the weaning of patients with respiratory failure due to chronic obstructive pulmonary disease. A randomized, controlled trial. Ann Intern Med 1998; 128:721–728.
30. **Girault C, Daudenthun I, Chevron V, Tamion F, Leroy J, Bonmarchand G.** Noninvasive ventilation as a systematic extubation and weaning technique in acute-on-chronic respiratory failure: a prospective, randomized controlled study. Am J Respir Crit Care Med 1999; 160:86–92.
31. **Epstein SK, Ciubotaru RL.** Independent effects of etiology of failure and time to reintubation on outcome for patients failing extubation. Am J Respir Crit Care Med 1998; 158:489–493.
32. **Miller RL, Cole RP.** Association between reduced cuff-leak volume and postextubation stridor. Chest 1996; 110:1035–1040.
33. **Engoren M.** Evaluation of the cuff-leak test in a cardiac surgery population. Chest 1999; 116:1029–1031.

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