Tracheal Reintubation: Caused by "Too Much of a Good Thing"?

William Shakespeare coined the phase when he wrote in *As You Like It*: "Can one desire too much of a good thing?" For many years now we have concentrated our efforts on liberating the patient from ventilatory support. The removal of the endotracheal tube (ETT) has been seen as a mere afterthought at the end of the liberation process. However, this approach results in an extubation failure rate (ie, the need for reintubation within 48–72 h) exceeding 30% in some studies.[1] Did we desire too much of a good thing? Liberation from the ventilator and liberation from the ETT are 2 different processes that should be separated. With a greater appreciation of the adverse outcomes, attention has now moved to refining liberation from the ETT, namely, the decision to extubate after having passed a spontaneous breathing trial (SBT). In this issue of Respiratory Care, Menon et al[2] add to our understanding of the incidence, patient characteristics, and consequences of tracheal reintubation among critically ill patients. In their retrospective cohort study, 11% of patients required reintubation within 48 hours of extubation. The patients requiring reintubation were older, more likely to be male, and had higher Simplified Acute Physiology Score II on admission. Reintubation was associated with 5-fold increase in mortality and 2-fold increase in median ICU stay, hospital stay, and institutional costs. Difficult intubation was also associated with increased mortality.

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The problem of reintubation is complicated by the fact that both delayed and premature discontinuations of mechanical ventilation have been associated with adverse outcomes. Delayed extubation is associated with increased risk of ventilator-associated pneumonia, ventilator-induced lung injury, laryngotracheal injury, and increased stay, while the need for early reintubation is associated with adverse outcomes, including increased mortality, higher costs, longer hospital stay, and greater need for tracheostomy.

The results of this study, together with the existing literature on the topic of extubation failure, raise some fundamental questions that deserve consideration in addressing this important problem.

Why Are We Unable to Better Predict Which Patients Will Fail Extubation?

There are multiple explanations for the low accuracy in prediction of extubation failure. First, previous studies have shown that the predictive power of weaning indices should be investigated separately for different patient populations, to improve accuracy, and this may apply to extubation success as well.[3] Second, previous studies of weaning prediction have been mostly limited to examination of static indices, which are measured on a one-time basis.[4,5] Dynamic measurements made of the weaning process, in which the physiologic variables are changing continuously, may improve the ability to predict extubation outcome.[6,7] Furthermore, since weaning failure is often due to multiple factors, it will not be reflected by the results of a single test.[8,9] Recently, the use of a decision-tree model, which included multiple indices as well as changes of these indices, has been shown to predict the extubation outcome more accurately.[7]

Since traditional weaning parameters have failed to predict extubation failure accurately, attention has turned to improvements in extubation decision-making through assessment of other elements that may contribute to extubation failure. These elements relate to inability to protect the airway or manage secretions, such as occurs with excessive respiratory secretions, inadequate cough, and depressed mental status. Salam et al examined 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. In their study the failure rate was 100% for patients with all 3 risk factors, compared to 3% for those with no risk factors.[10] However, it is unclear whether abnormal mental status per se increases the risk for extubation failure.[11] In addition to these parameters, loss of lung aeration evaluated by ultrasound at the end of an SBT may have a role in predicting post-extubation respiratory distress.[12]

Post-extubation laryngeal edema is another factor that may contribute to extubation failure. Extubation failure, as distinct from weaning failure, can occur secondary to upper-airway obstruction that might be recognized only after the ETT has been removed. Glottic or subglottic narrowing may result from laryngotracheal trauma, inflammation, granuloma formation, ulceration, or edema. The cuff leak test is widely used to identify patients with increased risk for laryngeal edema. However, it is controversial whether a cuff leak test per se can predict post-extubation stridor.[13,14] It is also important to note that the cuff leak has not been shown to predict the need for reintubation. In high risk patients it might be reasonable to use a cuff leak test combined with the presence of risk factors to identify patients with increased risk for laryngeal edema.[15] Laryngeal ultrasound may have a role in predicting post-extubation stridor, although work in the area is limited.[16] In addition, videolaryngoscopy has been proposed as a mechanism to evaluate the progression of laryngeal edema prior to extubation.[17]

Hemodynamic alterations and cardiac dysfunction can result from the change from assisted to spontaneous breathing. After removal of mechanical ventilation, negative intrathoracic pressures and sympathetic overstimulation may increase cardiac work load and result in weaning-induced myocardial ischemia and ventricular dysfunction. Combined with increased venous return, ventricular filling pressures may increase and precipitate pulmonary edema. A variety of hemodynamic and biochemical measures have been studied to predict and diagnose cardiac dysfunction during weaning.[18,19]Although the focus of the majority of these studies has been on prediction of success of SBT, recent work suggests that assessment of left ventricular diastolic dysfunction by echocardiography may have a role in predicting extubation failure as well.[20] In addition, biochemical markers have been assessed as weaning parameters; however, their role in prediction of extubation failure remains unknown.[21]

There is a need to determine what factors may be associated with extubation failure, since awareness of the risk factors may result in fewer incorrect decisions regarding extubation readiness. In a large multicenter population, among routinely measured clinical variables, rapid shallow breathing index, positive fluid balance 24 hours prior to extubation, and pneumonia at the initiation of ventilation were the best predictors of extubation failure.[22] Thille et al, in a medical population, found that age and chronic cardiac or respiratory disease were at high risk.[23] Studies that have focused on the association of extubation outcomes with variables that assess the ability to protect the airway have reported that the risk of extubation failure is increased with ineffective cough, a propensity for aspiration, and abundant secretions, while a decreased level of consciousness is not consistently identified as a risk factor for failure. Risk factors for post-extubation laryngeal edema include duration of intubation, overly large or excessively mobile ETT, excess cuff pressure, tracheal infection, and female sex.[15]

What Can Be Done to Reduce the Rate of Reintubation?

During the liberation process, application of noninvasive ventilation plays an important role in select patient populations, especially in patients with COPD. This important subject is discussed in detail in this issue of RESPIRATORY CARE.[24]

About 15% of all reintubations are performed because of post-extubation laryngeal edema.[15] Prophylactic methylprednisolone has been shown to reduce both the incidence of laryngeal edema and the rate of reintubation due to laryngeal edema.[25] However, this practice has not been universally adopted.

Based on current evidence there are no proven strategies to prevent adverse outcomes associated with reintubation. Therefore, the key is prevention of extubation failure through improved decision making. Since clinical decision making alone has failed, perhaps a protocol directed strategy approach using "best evidence" might be beneficial. Navalesi et al showed in a randomized controlled trial of neurologic and neurosurgical ICU patients that a systematic approach to weaning/extubation, one that arranged physiologic and clinical data in a written flow chart, reduced the incidence of extubation failure without affecting time spent on mechanical ventilation or in the ICU.[26] Other recent nonrandomized studies have reported reductions in reintubation rates using a protocolized approach.[27,28] The multiple steps required in assessment of readiness for extubation might lend themselves to an algorithm, an increasingly popular approach to solving difficult problems.

Since no single intervention alone is likely to solve the problem of extubation failure, a comprehensive algorithm that combines an SBT with a systematic risk assessment of extubation failure might be advantageous. Given the high stakes, a multidisciplinary team should be engaged in the decision making. This team should include respiratory therapists, nurses, and physicians. After passing an SBT, the patient is assessed for the risk of extubation, taking the difficulty of intubation into account. If the risk is low, the patient will be extubated. In contrast, if the risk for extubation failure is thought to be high, further optimization or tracheostomy should be considered (Fig. 1).

Pronovost et al demonstrated that applying quality improvement concepts and methods significantly reduced extubation failure rates in an academic surgical ICU.[29] The need for a ventilator and the need for an ETT are 2 different processes. It has been overwhelmingly shown that SBTs can be successfully performed in protocolized fashion by respiratory therapists and nurses.[30] However, the decision to extubate might benefit from an active multidisciplinary approach that includes physician input.

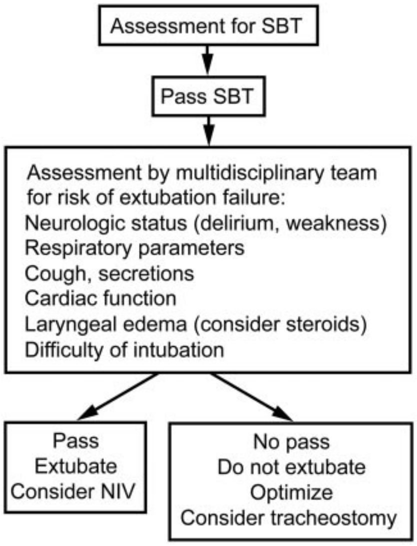

Fig. 1. Extubation algorithm. SBT = spontaneous breathing trial. NIV = noninvasive ventilation.

An "expert" multidisciplinary approach has proven beneficial in other high-risk areas, including emergency intubation and early mobilization in the ICU.[31,32] Finally, perhaps a lower threshold for early tracheostomy without a trial of extubation is warranted in patients with risk factors for extubation failure.

What Is the Optimal Rate of Reintubation?

In a recent review of the literature on failed extubation, Krinsley et al reported a mean rate of failed extubation of approximately 15% in observational and interventional studies.[1] The authors compared extubation failure rates to the surgical "negative appendix rate," in which an elevated rate suggests operating too frequently, and a rate approaching zero suggests not operating enough. The authors suggest an optimal rate of 5–10%. However, this suggestion has not undergone a rigorous review. It would seem reasonable that the optimal rate should be determined based on weighing the adverse outcomes and economic cost of extubation failure and those associated with delayed extubation. Certainly the optimal rate may vary across patient populations.

What Is the Reason for Adverse Outcomes Associated With Reintubation?

A number of hypotheses have been suggested for the adverse outcomes associated with extubation failure. The act of reintubation itself may be associated with increased complications, either due to life-threatening events that occur during reintubation (eg, cardiac arrest, aspiration, arrhythmias) or subsequent development of pneumonia. Clinical deterioration between SBT/extubation and reintubation may also contribute to worsened outcomes: a hypothesis that is supported by the increase in mortality with increasing duration of time between extubation and reintubation. Independent of the etiology of extubation failure, mortality increased 4-fold when reintubation occurred > 12 hours after extubation.[33] Extubation failure may serve as a surrogate for increased severity of illness. This derives from the fact that extubation failure remains a strong predictor of mortality, even after adjusting for markers of severity of illness, chronic comorbidities, age, and need for renal replacement therapy. Finally, the impact of total duration of mechanical ventilation may be a contributing factor. There is also some evidence that adverse outcomes associated with reintubation vary by etiology of respiratory failure. Epstein found a lower mortality rate for patients reintubated for upper-airway obstruction than for those reintubated for respiratory failure,[33] because the airway obstruction is immediately corrected with reintubation, while organ dysfunction due to other causes may not be as readily correctable.

Should Reintubation Rate Be a Quality Metric?

When determining the goals of quality improvement, it is important not only to determine appropriate measures, but also to determine what constitutes a meaningful change.[34] In other words, are zero defects possible or always desirable when measuring quality improvement? A zero reintubation rate can thus potentially reflect an unnecessarily long mechanical ventilation time or ICU stay, putting patients at increased risk of nosocomial infection and iatrogenic complications and creating a strain on hospital resources.

At this point, reintubation rate by itself seems not to be a good quality metric. Ventilator free days might be a more meaningful end point when trying to liberate the patient as early as possible while minimizing reintubation.

Considerable focus has been directed toward reducing complications associated with intubation in the critically ill. It appears that we should now place a similar focus on extubation. Given the poor outcomes associated with reintubation, clinicians should be more vigilant in identifying patients at risk for extubation failure. Increased awareness of the magnitude of consequences of failed extubation may help. A key question is how to identify patients at high risk of early extubation failure. Systematic evaluation of multiple domains of readiness for extubation is needed, and these domains might include traditional indicators of good performance on the ventilator, good overall medical status, and the ability to clear and defend the airway. Further study of protocolized extubation strategies are needed in different patient populations and within different clinical settings. This approach will help us to desire and achieve the "right amount" of a good thing.

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REFERENCES

1. Krinsley JS, Reddy PK, Iqbal A. What is the optimal rate of failed extubation? Crit Care 2012;16(1):111.
2. Menon N, Joffe AM, Deem S, Yanez ND, Grabinsky A, Dagal AH, Daniel S, Treggiari MM. Occurrence and complications of tracheal reintubation in critically ill adults. Respir Care 2012;57(10):1555-1563.
3. Krieger BP. Respiratory failure in the elderly. Clin Geriatr Med 1994;10(1):103-119.
4. Meade M, Guyatt G, Cook D, Griffith L, Sinuff T, Kergl C, et al. Predicting success in weaning from mechanical ventilation. Chest 2001;120(6 Suppl):400S-424S.
5. Yang KL, Tobin MJ. A prospective study of indexes predicting the outcome of trials of weaning from mechanical ventilation. N Engl J Med 1991;324(21):1445-1450.
6. Segal LN, Oei E, Oppenheimer BW, Goldring RM, Bustami RT, Ruggiero S, et al. Evolution of pattern of breathing during a spontaneous breathing trial predicts successful extubation. Intensive Care Med 2010;36(3):487-495.
7. Liu Y, Wei LQ, Li GQ, Lv FY, Wang H, Zhang YH, et al. A decision-tree model for predicting extubation outcome in elderly patients after a successful spontaneous breathing trial. Anesth Analg 2010;111(5):1211-1218.
8. MacIntyre NR, Cook DJ, Ely EW Jr, Epstein SK, Fink JB, Heffner JE, et al. Evidence-based guidelines for weaning and discontinuing ventilatory support: a collective task force facilitated by the American College of Chest Physicians; the American Association for Respiratory Care; and the American College of Critical Care Medicine. Chest 2001;120(6 Suppl):375S-395S. Also in: Respir Care 2002;47(2):69-90.
9. Epstein SK. Decision to extubate. Intensive Care Med 2002;28(5):535-546.
10. Salam A, Tilluckdharry L, Amoateng-Adjepong Y, Manthous CA. Neurologic status, cough, secretions and extubation outcomes. Intensive Care Med 2004;30(7):1334-1339.
11. King CS, Moores LK, Epstein SK. Should patients be able to follow commands prior to extubation? Respir Care 2010;55(1):56-65.

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12. Soummer A, Perbet S, Brisson H, Arbelot C, Constantin JM, Lu Q, et al. Ultrasound assessment of lung aeration loss during a successful weaning trial predicts postextubation distress. Crit Care Med 2012;40(7):2064-2072.
13. Kriner EJ, Shafazand S, Colice GL. The endotracheal tube cuff-leak test as a predictor for postextubation stridor. Respir Care 2005;50(12):1632-1638.
14. Gros A, Holzapfel L, Marqué S, Perard L, Demingeon G, Piralla B, et al. Intra-individual variation of the cuff-leak test as a predictor of post-extubation stridor. Respir Care 2012 [ePub ahead of print].
15. Wittekamp BH, van Mook WN, Tjan DH, Zwaveling JH, Bergmans DC. Clinical review: post-extubation laryngeal edema and extubation failure in critically ill adult patients. Crit Care 2009;13(6):233.
16. Ding LW, Wang HC, Wu HD, Chang CJ, Yang PC. Laryngeal ultrasound: a useful method in predicting post-extubation stridor. A pilot study. Eur Respir J 2006;27(2):384-389.
17. Newmark JL, Ahn YK, Adams MC, Bittner EA, Wilcox SR. Use of video laryngoscopy and camera phones to communicate progression of laryngeal edema in assessing for extubation: a case series. J Intensive Care Med 2012 [ePub ahead of print].
18. Teboul JL, Monnet X, Richard C. Weaning failure of cardiac origin: recent advances. Crit Care 2010;14(2):211.
19. Moschietto S, Doyen D, Grech L, Dellamonica J, Hyvernat H, Bernardin G. Transthoracic echocardiography with doppler tissue imaging predicts weaning failure from mechanical ventilation: evolution of the left ventricle relaxation rate during a spontaneous breathing trial is the key factor in weaning outcome. Crit Care 2012;16(3):R81.
20. Papanikolaou J, Makris D, Saranteas T, Karakitsos D, Zintzaras E, Karabinis A, et al. New insights into weaning from mechanical ventilation: left ventricular diastolic dysfunction is a key player. Intensive Care Med 2011 [ePub ahead of print].
21. Grasso S, Leone A, De Michele M, Anaclerio R, Cafarelli A, Ancona G, et al. Use of N-terminal pro-brain natriuretic peptide to detect acute cardiac dysfunction during weaning failure in difficult-to-wean patients with chronic obstructive pulmonary disease. Crit Care Med 2007;35(1):96-105.
22. Frutos-Vivar F, Ferguson ND, Esteban A, Epstein SK, Arabi Y, Apezteguia C, et al. Risk factors for extubation failure in patients following a successful spontaneous breathing trial. Chest 2006;130(6):1664-1671.
23. Thille AW, Harrois A, Schortgen F, Brun-Buisson C, Brochard L. Outcomes of extubation failure in medical intensive care unit patients. Crit Care Med 2011;39(12):2612-2618.
24. Hess DR. The role of noninvasive ventilation in the ventilator discontinuation process. Respir Care 2012;57(10):1619-1625.
25. Francois B, Bellissant E, Gissot V, Desachy A, Normand S, Boulain T, et al. 12-h pretreatment with methylprednisolone versus placebo for prevention of postextubation laryngeal oedema: a randomised double-blind trial. Lancet 2007;369(9567):1083-1089.
26. Navalesi P, Frigerio P, Moretti MP, Sommariva M, Vesconi S, Baiardi P, et al. Rate of reintubation in mechanically ventilated neurosurgical and neurologic patients: evaluation of a systematic approach to weaning and extubation. Crit Care Med 2008;36(11):2986-2992.
27. Dries DJ, McGonigal MD, Malian MS, Bor BJ, Sullivan C. Protocol-driven ventilator weaning reduces use of mechanical ventilation, rate of early reintubation, and ventilator-associated pneumonia. J Trauma 2004;56(5):943-951; discussion 951-942.
28. McLean SE, Jensen LA, Schroeder DG, Gibney NR, Skjodt NM. Improving adherence to a mechanical ventilation weaning protocol

for critically ill adults: outcomes after an implementation program. Am J Crit Care 2006;15(3):299-309.
29. Pronovost PJ, Jenckes M, To M, Dorman T, Lipsett PA, Berenholtz S, et al. Reducing failed extubations in the intensive care unit. Jt Comm J Qual Improv 2002;28(11):595-604.
30. Tonnelier JM, Prat G, Le Gal G, Gut-Gobert C, Renault A, Boles JM, et al. Impact of a nurses' protocol-directed weaning procedure on outcomes in patients undergoing mechanical ventilation for longer than 48 hours: a prospective cohort study with a matched historical control group. Crit Care 2005;9(2):R83-R89.
31. Wilcox SR, Bittner EA, Elmer J, Seigel TA, Nguyen NT, Dhillon A, et al. Neuromuscular blocking agent administration for emergent tracheal intubation is associated with decreased prevalence of procedure-related complications. Crit Care Med 2012;40(6):1808-1813.
32. Kasotakis G, Schmidt U, Perry D, Grosse-Sundrup M, Benjamin J, Ryan C, et al. The surgical intensive care unit optimal mobility score predicts mortality and length of stay. Crit Care Med 2012;40(4):1122-1128.
33. 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(2):489-493.
34. McMillan TR, Hyzy RC. Bringing quality improvement into the intensive care unit. Crit Care Med 2007;35(2 Suppl):S59-S65.