

## Blood Gases, Weaning, and Extubation

In this data-driven, evidence-based era of medicine, there remains a substantial portion of medical practice that lacks the 'definitive' clinical trial or other supporting science. This aspect of medicine is often referred to as the "art" of medicine and addresses that portion of disease management that is also referred to as clinical judgment or experience. There is probably an element of "art" in every medical decision. The timing of extubation or discontinuation of mechanical ventilation is no exception to this process.

In recent years there has been more science used to base management. Guidelines developed by the major health care professional groups involved in the management of these patients provide a framework for weaning from mechanical ventilation and extubation.<sup>1</sup> Recommendations include the control and elimination of factors that may contribute to ventilator dependence, early assessment after clinical stability for discontinuation of mechanical ventilation, as well as assessment for the potential discontinuation of mechanical ventilation during spontaneous breathing (as opposed to during supported breathing).

The physiologic variables and indexes that have been studied to date have been only moderately successful in predicting the likelihood of successful extubation. With patients on mechanical ventilation the variables/indexes with statistically significant likelihood ratios (for predicting extubation success) are minute ventilation, negative inspiratory pressure, maximum inspiratory pressure, occlusion pressure at 0.1 second, and the CROP index (which integrates compliance, respiratory rate, oxygenation, and maximum inspiratory pressure). During spontaneous breathing trials, the variables/indexes with statistically significant likelihood ratios are respiratory rate, tidal volume, and rapid shallow breathing index. The (commonly used) respiratory rate and rapid shallow breathing index were found to have positive likelihood ratios of only 1.50 (95% confidence interval 1.23–1.83) and 1.58 (95% confidence interval 1.30–1.90) in pooled analyses.<sup>2</sup>

Once a patient has met the threshold of these weaning criteria, a spontaneous breathing trial (SBT) is conducted. There can be great differences in the conduct of SBTs (unsupported, supported, level of support, duration), but irrespective of the methods, patients who successfully tolerate the SBT are considered ready for extubation. The SBT serves several purposes, providing a real-time assessment of a patient's respiratory mechanics, ability to oxy-

genate and ventilate, and comfort while breathing through a mechanical resistance that probably exceeds airway conditions when extubated. This strategy has been instrumental in reducing the duration of mechanical ventilation—by 2 days in the Ely et al study<sup>3</sup>—and has been the basis of other protocol-driven investigations,<sup>3–6</sup> with improvement in the efficiency and efficacy of patient management. Reintubation rates have been 5–15%, in contrast with failure rates over 30% among those not undergoing SBTs.<sup>7</sup> However, there are other causes of extubation failure that can not be identified with an SBT. Investigators have begun to focus on the possibility of post-extubation upper airway obstruction and the patient's ability to cough and clear secretions as other factors that contribute to post-extubation respiratory failure.<sup>8–9</sup> What other variables may contribute toward assessing these patients? What about arterial blood gas (ABG) values?

---

### SEE THE ORIGINAL STUDY ON PAGE 1033

---

In this issue of *RESPIRATORY CARE*, Salam et al<sup>10</sup> report their evaluation of the impact of ABG values on extubation decisions following SBTs. They collected data after 100 SBTs with 83 patients, and patients were extubated after 86 of these SBTs. Because of multiple SBTs, a total of 12 patients involved with 14 SBTs were not initially extubated. In 7 of the SBTs, there were enough changes in bedside-assessable variables to classify the SBT as failed. In the other 7 SBTs, the patients were not extubated, presumably because of their ABG values. The authors conclude that the ABG values affected the decision to extubate in only 7 SBTs.

How did the ABG values affect the decisions in those SBTs? Closer examination of the physiologic data for subjects 5, 6, and 7 may have led some to consider these unfavorable SBTs. All certainly had a heart rate increase of over 20 beats/min, and two of the three had a doubling of respiratory rate. Their ABG values demonstrated worsening hypercapnia and respiratory acidosis or worsening hypoxemia—information that would have either deferred extubation or further reinforced the decision not to extubate. The ABG values of the other patients who were not extubated are also notable for greater hypercapnia and respiratory acidosis than their pre-SBT values. Not all of the acidemia can be explained by respiratory changes alone,

and there must have been an element of metabolic (lactic) acidosis. In aggregate this group's pH declined from 7.39 to 7.32, and their  $P_{aCO_2}$  rose from 38 mm Hg to 47 mm Hg. What of the group that failed extubation? My analysis of the data in Table 1 in the Salam et al report indicates their pH declined from 7.47 to 7.43 and their  $P_{aCO_2}$  rose from 42 mm Hg to 46 mm Hg. Successfully extubated patients had similar changes, but not of the magnitude seen with those who were not extubated.

Why would this information be helpful in the management of these patients? The ABG values represent an aggregate of many events, involving cellular metabolism, muscle activity, oxygen consumption and carbon dioxide production, cardiac function, tissue perfusion, ventilation, and perfusion. As an aggregate measure, ABG values are relatively insensitive to minute changes in the system, but they also represent the global response to demands placed on the patient. In this case they represent the patient's response to the SBT and may provide insight to the response to extubation. Therefore, ABG abnormalities should be reviewed carefully, because they imply major changes in this complex system. In the cases described by Salam et al<sup>10</sup> the acidosis is telling. Of the 7 patients who were not extubated, five were acidemic, all had  $pH < 7.35$  at the end of the SBT, and three had  $pH < 7.30$ .

It is somewhat surprising that ABG values have not previously undergone more formal scrutiny of their impact on weaning and extubation. ABG analysis is a ubiquitous measurement and has long been part of the management of these patients. In the vast majority of investigations the ABG values are used to identify a patient's readiness for a weaning trial. Few investigators have addressed their impact *during* a weaning trial. ABG values were used in a study<sup>11</sup> involving postoperative patients and gradual reduction of intermittent mandatory ventilation. The intermittent mandatory ventilation rate was reduced as long as the patient was able to maintain a  $pH > 7.35$ , until the patient was breathing without intermittent mandatory ventilation support. Of note, they found that the pH was better than peak negative pressure or vital capacity for identifying patients able to tolerate unsupported respiration.<sup>11</sup> In a more recent report,<sup>12</sup> which compared noninvasive ventilation to conventional therapy, the authors identified the development of hypercapnia (defined as  $P_{aCO_2} > 45$  mm Hg) at the end of an SBT as an independent risk factor associated with lower 90-day survival. These data support the utility of ABG measurements in the weaning of mechanically ventilated patients.

The investigation by Salam et al<sup>10</sup> raises additional questions. What was it about the ABG values that led to the decision? Unfortunately, information on the rationale to forego extubation in these patients was not collected. Was it the acidosis, hypercapnia, oxygenation, or some combination of all of the above that led to the final decision?

There may have also been some additional bedside information that is not shown in the report. Certainly, we have all encountered patients who have similar laboratory data but very different clinical manifestations. It is interesting to note that of the clinicians in the Salam et al study,<sup>10</sup> the attending physicians had the greatest reservations about extubation (7 SBTs). There were fewer cases of concern among the residents (5), nurses (1), and respiratory therapists (4). What is the explanation for those differences? Experience? Insight? Chance?

Although Salam et al comment on the relative lack of impact of ABG values on the decision to extubate, one should not sell ABG values short; they have the potential to provide insight into a patient's condition, unlike any currently used variable or index. It is a test that is easily obtained and not subject to significant variations in acquisition and determination, as may be the case with other tests.<sup>13</sup> The importance of avoiding an inappropriate extubation based on ABG values should not be underestimated. Failed extubation means reintubation and increased risk of pneumonia, longer hospitalization, and increased mortality. In one medical center, patients who failed extubation were 7 times more likely to die, 31 times more likely to spend  $> 14$  days in the intensive care unit after extubation, and 6 times more likely to require transfer to a long-term-care facility (if they survived) than those successfully extubated.<sup>14</sup> Reintubation increases the risk of pneumonia over 8-fold.<sup>15</sup> The few days involved with a delayed extubation pale in comparison to these figures.

Further questions need to be considered. First, can ABG values predict extubation failure? If so, what are the most important components and threshold values? Do ABG values provide any information that is not routinely collected during an SBT? Are there subgroups of patients with whom ABG values may be of greater utility? How many ABG measurements are needed to justify their benefit in extubating a patient? In this era of cost containment, a cost-benefit analysis seems in order. Salam et al have just touched on these areas with their investigation and more study is warranted. And finally, do their findings add to the art or the science of weaning and extubation? Given their focus on the "art"-terial blood gas, the answer is probably a little bit of both.

**Guy W Soo Hoo MD MPH**

Pulmonary and Critical Care Section  
West Los Angeles Healthcare Center  
Veterans Affairs Greater Los Angeles  
Healthcare System

Geffen School of Medicine at University of California  
Los Angeles, California

## REFERENCES

1. MacIntyre NR, Cook DJ, Ely EW Jr, Epstein SK, Fink JB, Heffner JE, et al; American College of Chest Physicians; American Association for Respiratory Care; American College of Critical Care Medicine. 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.
2. 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.
3. Ely EW, Baker AM, Dunagan DP, Burke HL, Smith AC, Kelly PT, et al. Effect on the duration of mechanical ventilation of identifying patients capable of breathing spontaneously. *N Engl J Med* 1996;335(25):1864–1869.
4. Esteban E, Alia I, Tobin MJ, Gil A, Gordo F, Vallverdu I, et al. Effect of spontaneous breathing trial duration on outcome of attempts to discontinue mechanical ventilation. Spanish Lung Failure Collaborative Group. *Am J Respir Crit Care Med* 1999;159(2):512–518.
5. Vallverdu 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(6):1855–1862.
6. 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: effect on weaning time and incidence of ventilator-associated pneumonia. *Chest* 2000;118(2):459–467.
7. Zeggwagh AA, Abouqal R, Madani N, Zekraoui A, Kerkeb O. Weaning from mechanical ventilation: a model for extubation. *Intensive Care Med* 1999;25(10):1077–1083.
8. Miller R, Cole RP. Association between reduced cuff leak volume and postextubation stridor. *Chest* 1996;110(4):1035–1040.
9. 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(5):1530–1536.
10. Salam A, Smina M, Gada P, Tilluckdharry L, Upadya A, Amoateng-Adjepong Y, Manthous CA. The effect of arterial blood gas values on extubation decisions. *Respir Care* 2003;48(11):1033–1037.
11. Millbern SM, Downs JB, Jumper LC, Modell JH. Evaluation of criteria for discontinuing mechanical ventilatory support. *Arch Surg* 1978;113(12):1441–1443.
12. Ferrer M, Esquinas A, Arancibia F, Bauer TT, Gonzalez G, Carrillo A, et al. Noninvasive ventilation during persistent weaning failure: a randomized controlled trial. *Am J Respir Crit Care Med* 2003;168(1):70–76.
13. Soo Hoo GW, Park L. Variations in the measurement of weaning parameters: a survey of respiratory therapists. *Chest* 2002;121(6):1947–1955.
14. Epstein SK, Ciubotaru RL, Wong JB. Effect of failed extubation on the outcome of mechanical ventilation. *Chest* 1997;112(1):186–192.
15. Torres A, Gatell JM, Aznar E, el-Ebiary M, Puig de la Bellacasa J, Gonzalez J, et al. Re-intubation increases the risk of nosocomial pneumonia in patients needing mechanical ventilation. *Am J Respir Crit Care Med* 1995;152(1):137–141.

---

Correspondence: Guy W Soo Hoo MD MPH, Pulmonary and Critical Care Section, West Los Angeles Healthcare Center, 11301 Wilshire Boulevard, Los Angeles CA 90073. E-mail: guy.soo@med.va.gov.