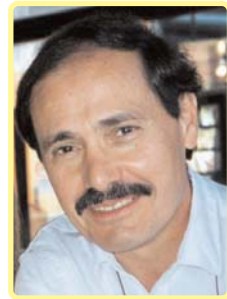


DO BREATHING PATTERNS PREDICT WEANABILITY?

by John Marini MD



The importance of timely ventilator withdrawal has been recognized in the widespread adoption of weaning protocols into Respiratory Care practice. The key elements of these are guided by quantitative indicators ("indices") of the muscle reloading process. By following such protocols, nurses and respiratory care practitioners often make important observations and are empowered to implement care decisions heretofore made only by the physician. In general, I support the concept of using protocols, but at the bedside I am sometimes disappointed with their recommendations and often override those that don't jibe with my gut feelings and prior experience. How reliable are the data we currently count on?

Patients may remain ventilator-dependent for a variety of reasons, including intolerable hypoxemia, cardiac instability or inability to protect the airway. Re-intubation may also be required for reasons quite unrelated to breathing demands and capacity to sustain them. Yet in an alert patient ventilated for an extended period, the commonest cause for weaning failure remains the presence of a demand for breathing power disproportionate to work capacity and endurance. Of the components "hard wired" into most weaning protocols, none is more pervasive than the rapid shallow breathing index (RSBI) calculated during spontaneous breathing or minimal (tube offsetting) pressure support. Certainly the RSBI is useful, and there is good reason for its favorable reception into daily practice. This simple index allows the patient to integrate respiratory stress and capability into a telltale

response that often - but not infallibly - predicts "weanability".

Despite substantial predictive utility, however, such "snapshot" indicators may be less reliable than measures that track the variation of breathing pattern over time. Although the literature in this area is not totally uniform in its implications, increased variability of frequency and tidal volume over a one hour period of unsupported breathing appears to be a favorable prognostic sign. At first glance, superiority of variation indices to the RSBI may appear surprising, but their predictive power is fully consistent with examples from scientific fields within and outside of medicine. Dynamism and variation of biorhythms are innate properties of human biology. For example, sinus rhythm normally varies through a wide range, and loss of this natural variation is a characteristic both of cardiac disease and of the normal cardio-respiratory system under high stress. In other words, robust homeostasis implies the existence of some baseline variation as well as the reserves to respond to a challenge.

Independent of any controlling mechanism geared to load adaptation, non-regulated variation may also occur in cycling systems with "feed forward" characteristics - the opposite of feedback. Familiar examples from our surrounding inanimate world include weather variations and the turbulence of running water. A few can be found in the field of critical care medicine, as well. Identification of such 'chaotic' behavior has made physical scientists aware that some complex dynamical systems are not easily described by traditional parameters and that accurate prediction of a system's behavior or characteristics only a short while into the future may not be possible from data sampling at a single point in time. It stands to reason, therefore, that it is hazardous to predict the overall response of a biological system to stress from any single observation of its regulated output (such as frequency, tidal volume or their quotient, RSBI).

The pattern of breathing provides valuable clues to how well the patient adapts to an increasing ventilation workload, be it due to an alteration of the mechanical properties of the respiratory system, impairment of the ventilatory pump, or a change in the midbrain's CO₂ set point. The human mechanism for breath control is a redundant system comprised of numerous complex elements. Although the metabolic demand and chemical set points (pH, PCO₂, PO₂) normally regulate the level of ventilation, the pattern selected to do so integrates many more inputs. Baseline variation of breathing pattern is characteristic of both healthy and diseased lungs. Under stress, minimizing the work of breathing assumes such a high priority that the integrated respiratory response will seldom if ever drive the system into muscular exhaustion, even under conditions of near catastrophic loading. To meet a changing ventilatory requirement, the subject may vary frequency, tidal volume, or alter one or more chemical set points. Characteristically, frequency rises disproportionately to tidal volume when approaching the limits of compensation.

This occurs in health as well as disease. As the minute ventilation demand increases during exercise, tidal volume and frequency both rise, but beyond a certain level, tidal volume stabilizes and the respiratory rate should the burden of further work increases;

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Do Breathing Patterns... *Continued from page 52*

breath to breath variability of tidal volume all but disappears and breathing pattern becomes monotonous. This strategy, in fact, is energetically economical. Because the elastic inspiratory work of breathing is the product of volume above FRC and distending pressure, two small breaths of the same size are less energy costly than one twice as large. Furthermore, once up against the elastic boundaries of the respiratory system, further increases in tidal volume are pulled against declining compliance. It is not surprising that the frequency to tidal volume ratio (f/V_t) rises under stress and that both tidal volume and cycle length reduce their variability. In fact, it is adaptive to do so. Depending on the mechanical characteristics of the respiratory system, the minute ventilation requirement, and level of metabolic stress, therefore, a high f/V_t ratio does not always imply rapid shallow breathing and the RSBI may not always reflect muscle overload or predict weaning failure. At the bedside I have found it useful to ask the question: Did the total minute ventilation also go up in parallel with the RSBI? If so, the rising RSBI may simply reflect the rise in demand (e.g., secondary to agitation) - not fatigue.

Such reasoning may account for a rising "RSBI" and a declining variability of tidal volume as adaptive exercise responses. But for a given individual, what accounts for changing variability of the breathing pattern (or the lack thereof) in the muscular reloading that occurs during weaning? Does increased variation result from near exhaustion, as suggested by some older literature, or is it a marker of the reserve that the respiratory muscles have available? Likely the latter. In a variety of animal models and in selected clinical settings irregularity of tidal volume and frequency appear preferable to monotonous breathing in maintaining optimal gas exchange. Among the "weanability" criteria for judging the capacity for independent breathing, Sahn and Lakshminarayan suggested that the patient should demonstrate adequate breathing reserve by doubling

tidal volume and minute volume upon command. Experimentally, this makes good sense, as normal subject cannot indefinitely continue stressful breathing task when confronting a tidal pressure requirement more than approximately 40% of maximum isometric pressure. While regularization of the tidal volume may indicate sustainable adaptation to stress (consider high level exercise), more often it warns that the patient cannot efficiently encroach further on inspiratory reserve and is approaching the adaptive limit.

In daily management, difficult decisions to extubate must be often be made in patients who cannot effectively communicate with the caregiver. We depend on observations made of monitored variables, almost invariably those that are recorded from the devices at hand. Yet, analyses of variation, are not only noninvasive and risk-free, but the otherwise tedious process of tabulation, trending and analysis can now be conducted effortlessly by computer-aided tracking of the variables already measured by the ventilator. We need to look at these variation issues more carefully so as to automate those trended indicators of unusual value.

Which ones are they? For the moment, we remain unsure. Variation in the breathing pattern might reasonably be expected to arise from mental state and thoracic mechanics - factors quite apart from issues of endurance and fatigue. Variations in respiratory pattern having little to do with effort tolerance might originate from changes in agitation, comfort, medication, position, secretions, edema, muscular reflexes and state of alertness. How best to characterize variation must be addressed. The duration of pattern observation, the exact sampling period, the level of airway pressure support and the directional trends of the variation may also be important to consider. Clearly, some forms of pattern variation are not signs of relative health. If the interval is poorly chosen, monotonic declines in tidal volume, for example, would give rise to an ominous form of breathing variation, and the Cheyne Stokes pattern - although highly variable - is a marker for disease, not health. Dips of tidal volume below the normative baseline may not carry the same significance as bursts of deep breathing above that average. Because the cardiovascular system is often causative in weaning failure, perhaps physiologic variation should be assessed simultaneously along several dimensions - not just respiratory. The simultaneous behavior of other biological co-variates of respiration - heart rate, blood pressure and level of alertness - might be highly informative.

Protocols that depend on observation and feedback from trials of spontaneous breathing must be informed by reliable indicators. When first described 15 years ago, the RSBI was clearly a step forward in extracting information that reflects the demand/capability balance. But though very useful, experience has shown us the imperfection of its predictive power. In the present age of molecular biology and clinical trials some might argue that the great majority of bedside physiological observations necessary to implement quality respiratory care were made years ago - the discovery frontier has moved on. I respectfully disagree. Although the scientific frontier has clearly expanded, work at the caregiver-patient interface must not be abandoned. Aided by modern technology, numerous important and unsolved problems we confront in daily practice will yield to careful observations and insightful physiologic reasoning.

Dr. Marini, MD, Professor of Medicine at the University of Minnesota, is a clinician-scientist whose investigative work has concentrated in the cardiopulmonary physiology and management of acute respiratory failure. In the majority of his research, he has been positioned at the interface between basic physiology and clinical medicine so as to develop insights into advancing clinical practice.