RATIOCINATIVE VENTILATOR CONTROL ALGORITHMS

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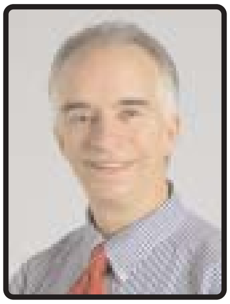

The current environment in the world of mechanical ventilation is exciting. We have, for our review, several systems that employ some level of ratiocinate control algorithm. These mechanical ventilation control systems fall into the Chatburn lexicon as Intelligent Control algorithms. They are; Adaptive, Optimal, Knowledge Based or Neural Networked.

Anyone charged with ventilator selection should become reasonably knowledgeable of these "closed-loop" systems prior to purchasing any new mechanical ventilation platform.

I agree with those who contend that some form of "closed-loop" ventilation system may be a future standard of patient care. These systems, as will be discussed, have the ability to monitor and asses the mechanically ventilated patient on a continuous basis. Manufacturer pre-selected set-points are analyzed on a breath by breath basis and these assessments are processed to create a "mindful" response from the ventilators ratiocinate control algorithm; which in turn creates the baseline data set for the subsequent breath and continued assessment. A "loop" is created wherein, the patient "communicates" physiologic parameters to the ventilator. These assessed values are then processed and an optimal ventilation strategy is employed and re-evaluated. Every system examines the patients breathing in a unique way and utilizes assessment-based information to adapt or adjust the subsequent level and method of ventilatory support to optimize the patient-ventilator concerto.

I am a proponent of the Chatburn lexicon of mechanical ventilation and will briefly review the classification of control algorithms.

Operational algorithms: the explicit instructions used by the ventilator's control circuit to generate the breathing pattern. These include a specification of phase variables, conditional variables, embedded system models and control logic and or artificial intelligence programs used.

Intelligent control: a class of ventilator control types that implement strategic control and/or tactical control using artificial intelligence programs.

Adaptive Control: one parameter of the ventilator is automatically adjusted to maintain another parameter in response to patient changes and based on patient needs.

Knowledge-based control: a type of ventilator control that attempts to capture the experience of human experts. It may use various artificial intelligence systems such as branching logic algorithms, lookup tables, or fuzzy logic.

Optimal control: a type of ventilator control that uses automatic adjustment of setpoints to optimize other variables as patient needs change. A measure of system performance is maximized or minimized. Each breath may be pressure limited and the pressure limit automatically adjusted between breaths. Adjustment is made in such a way that the work of breathing, (calculated and updated dynamically) is minimized and preset minute ventilation is maintained. (Hamilton Galileo ASV)

Neural network control: a ventilator control type that uses modeling tools called artificial neural networks to acquire and characterize intricate input-output interaction. A neural network learns by experience in a similar fashion to the human brain storing knowledge in the intensity of inter-node relations.

Adaptive support ventilation (ASV) is a construct of closed-loop ventilation. ASV designates programmed ventilator set-points based on assessments of patient lung mechanics and breathing effort. Adaptive support ventilation (ASV) provides for an optimal adaptation of ventilator settings in concert with the patient's passive and active respiratory mechanics.

ASV attempts to manage ventilator setpoints (mandatory breath rate, tidal volume, inspiratory pressure, inspiratory time, and I to E ratio) to sustain a designed favorable breathing pattern that assures the delivery of a clinician selected minute ventilation target while minimizing the work of breathing. ASV allows the ventilator to determine patient respiratory compliance and expiratory time-constants during an initial test of 5 breaths. The ASV algorithm delivers a pressure-controlled (PCV) breath while determining the most advantageous inspiratory pressure and respiratory rate according to the Otis´ equation. The Otis' equation predicts the respiratory rate / tidal volume relationship, associated with the minimal work of breathing.

ASV may be thought of as an Optimal / Adaptive ventilator control algorithm that may improve the safety and efficacy of mechanical ventilation. The ventilatory settings are, by design, mechanically adapted commensurate with assessed changes in respiratory mechanics. As the patient generates inspiratory

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effort, the algorithm adjusts by design from PCV to PSV. Therefore, the respiratory rate is controlled by the patient. The ventilator delivers a PCV breath if spontaneous respiratory rate decreases to less than the optimal value. The level of PSV is continuously adapted to deliver the desired minute volume. If rapid shallow breathing occurs, PSV levels are automatically increased. Conversely, ASV progressively decreases PSV if the patient's respiratory rate and tidal volume remain adequate; enhancing the extubation process.

One of the primary advantages of Optimal Control algorithms is that they free the Therapist to perform patient management rather than tactical duties. A weaning protocol based on ASV in fast-track cardiac surgery reduced human intervention related to respiratory management without delaying extubation. The clinician is freed of the minutia related to making small incremental changes. ASV decreases ventilatory support in patients passing a weaning trial and may improve patient ventilator interaction. The 24/7 adaptation to patient lung mechanics both mitigates ventilator induced lung injury, (VILI), and reduces 'tasks' associated with mechanical ventilation. This liberates the Respiratory Therapist to focus on increased 'situational awareness' vs. 'data overload".

As stated previously, the physiological and clinical knowledge needed to handle a defined clinical circumstance may be fixed within a computer program that directs the ventilator using artificial intelligence techniques, such as production rules, fuzzy logic or lookup tables. The rule-based control system is referred to as a Knowledge Based system which attempts to capture the experience of human experts using those same artificial intelligence techniques. The rules of these systems are based on "best evidence" or current thought in the world of mechanical ventilation.

The SmartCare system is an implanted rendering of the NeoGanesh system. The NeoGanesh system adjusts PSV levels to maintain a patient zone of "respiratory comfort" defined by respiratory parameters. Additionally, it is capable of undertaking an automated strategy for weaning. The NeoGanesh system is based on patterns of comprehension essential to perform mechanical ventilation in PSV.

The SmartCare mode on the Dräger Evita XL uses a rule-based expert system to keep the patient in a "comfort zone" based on ventilatory rate, tidal volume, and end-tidal carbon dioxide levels. Ventilator setpoints are automatically adjusted according to a rule based system. The pressure support level for spontaneous breaths is automatically adjusted to maintain appropriate frequency, tidal volume and end tidal CO_2. SmartCare employs a knowledge based control algorithm with a number of rules that ensure a lung protective strategy. According to the manufacturer SmartCare provides "Automatic Adaptation of Ventilatory Assistance" with an "Automatic Weaning Strategy".

Optimal and Knowledge base systems are in their relative infancy in term of clinical utilization however, the competent clinician will want to become familiar in more than a passing way with these two Cogent Control systems. They are both great leaps in the right direction. It is our responsibility to continually develop our knowledge and understanding of our patients and the clinical interventions we must provide for them. I trust the intellectually curios Focus reader will endeavor to learn more about these systems and evaluate them for themselves. Indeed, let me know your thoughts and experiences with these Optimal and Knowledge based systems.

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