The history and potential of 'intelligent ventilation'

I define an 'intelligent ventilator' as a dynamic and responsive machine that provides every patient with safe, efficient, synchronised, comfortable and appropriate ventilatory support through a continuous interactive process utilising four basic elements: on-line non-invasive respiratory function monitoring; initialisation of the most ideal ventilatory pattern for the current lung condition; automated closed-loop controlled adjustment of the ventilatory support in response to any change in the lung condition; and timely weaning from the ventilatory support in a safe and controlled fashion, without inducing any clinical deterioration of lung function.[1]

I further define 'intelligent ventilation' as appropriate application of the most suitable mode of ventilation in every clinical situation with on-line, automated adjustment of the mode and level of support as required whenever the individual patient's respiratory needs alter, with automated weaning as soon as possible to reduce the time needed for mechanical ventilatory support and days in the ICU.[2-4]

Many forms of closed-loop, automatically applied partial support protocols have been developed on many different ventilators; I have reviewed and tried all of them, including mandatory minute ventilation (MMV), pressure-support ventilation (PSV), proportional assist ventilation (PAV), SmartCare/PS, AutoMode and NAVA (Neurally Adjusted Ventilatory Assist).[4-6]

The most well-known, basic and effective form of closed-loop control ventilation which is widely used today is PSV. The clinician sets a target pressure (the pressure support setting), and flow is automatically adjusted to maintain that pressure throughout inspiration. As the ventilator monitors airway pressure (the target), the control algorithm continuously modulates the flow (the output) to achieve the desired pressure.[7]

My earliest experience with 'closed-loop' ventilation started some 25 years ago (in 1988), when I started studying the clinical use of mandatory minute volume ventilation using an Ohmeda CPU 1 electronic ventilator with my colleagues Peter Potgieter and Stan Davis in the respiratory intensive care unit at Groote Schuur Hospital, Cape Town.[8] Thereafter, together with our chief clinical technologist, Anton Fourie, we started working on intelligent closed-loop automatic ventilation utilising an adaptive lung ventilation controller applied by a Mackintosh Computer mounted on an Amadeus Ventilator with a PC-based analyser for on-line lung function analysis in collaboration with Dr Josef Brunner of the R&D division of Hamilton Medical AG, Bonaduz, Switzerland.

One of the aims driving our collaboration, generously funded by the Hamilton family from Reno, Nevada, was to develop an intelligent 'ventilator for Africa'. The dream was to build an automatic ventilator that could safely ventilate and wean patients automatically in remote areas, where resources of skilled intensive care manpower were lacking.

It was a pleasure and an honour for us to be part of this research and to play a part in the development of the world's first production-model, automated, closed-loop, mechanical ventilator in scientific collaboration with many other international researchers funded and co-ordinated by the Hamilton Company in Switzerland.

Of interest to readers of *SAJCC* is that many of the original refinements in the theory of the algorithms used in optimising ventilation of patients with asthma and chronic obstructive pulmonary disease and the weaning protocols came out of the academic work done by my colleagues and myself at Groote Schuur in the early 1990s.[9]

My colleagues and I, at Groote Schuur in those early days and more recently at the Hadassah-Hebrew University Medical Center in Jerusalem, made no personal financial investment, and did not receive any personal financial benefit from these products. However, for many years we have been associated with the research team in the clinical introduction of this technology to our patients.

An amazing discovery for all who played a part in the development of this technology was the realisation that most patients could be automatically ventilated optimally according to the 'least work of breathing' fit of the measured mechanics of the lungs and chest wall. Simply by providing the maximal alveolar ventilation, for the lowest minute ventilation, and the least dead-space ventilation, the resulting blood gases would be the best possible for the state of the lungs.[10] We recognised the importance of preventing the development of intrinsic (auto) positive end-expiratory pressure (PEEP) while maximising alveolar ventilation.

The development of adaptive support ventilation (ASV) machines without the need for end-tidal carbon dioxide or oxygen saturation in the closed loop proved the reality of the 'least work of breathing' philosophy in the optimal mechanics of ventilation of most patients.[1,11] Severe forms of restrictive lung disease with severely reduced pulmonary compliance necessitated the development of the fractional inspired oxygen (FiO_2), PEEP and the end-tidal CO_2 controllers to create the IntelliVent concept now in production.[12] The advances in the technology of intelligent automated ventilators during my ICU career over the past 3 decades have made all our wildest dreams a reality.

The increasing number of patients on mechanical ventilation all over the world, and the shortage of intensive care-trained nurses and physicians to optimally manage and wean patients on mechanical ventilation, indicate that advanced closed-loop mechanical ventilation systems will be needed to reduce ICU staff workload and shorten the duration of mechanical ventilation.

So, before it is too late and I retire from academic ICU medicine, I am happy to be able to share my experiences using ASV in Hadassah with the readers of the *SAJCC*.[13]

With my very best wishes to all you wonderful intensive care nurses and physicians who save lives every day in South African ICUs.

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S Afr J Crit Care 2012;28(1):2-3. DOI:10.7196/SAJCC.138