Proportional assist ventilation

Acute respiratory failure is most often characterized by gas exchange disturbances as well as an impairment of the mechanical properties of the respiratory system leading to an increase in breathing workload. Therefore, the classical goals of mechanical ventilation are to restore gas exchange and to relieve the patient of the work of breathing. During controlled mechanical ventilation, all of the work of breathing is taken over by the machine, whereas during partial ventilatory support, the ventilator as well as the patient contribute to a variable extent to the total work necessary for ventilation.

Proportional assist ventilation (PAV) is a new mode of partial ventilatory support which is designed selectively to relieve the resistive and elastic burden of the respiratory system in proportion to the patient’s breathing effort. Unlike all other forms of assisted ventilation, there is no preset pressure or volume target during PAV. Instead, the ventilator applies pressure as a function of patient effort: the more effort the patient puts out the more assistance the machine will provide. Therefore, PAV might be viewed as an additional set of respiratory muscles which will take over a certain proportion of the workload for each instantaneous breathing effort. The relation between effort and ventilation, which is usually decreased during acute respiratory failure, might thereby be shifted back to normal. PAV is a positive feedback regulation system needing a proper input signal. Since ventilatory effort cannot be readily measured, flow rate and/or volume are taken as the input signal for the guiding algorithm during PAV. Airway pressure applied by the machine might therefore develop as a function of volume (elastic unloading) or a function of flow (resistive unloading). Theoretically, when the patient’s respiratory mechanics are known, PAV can be used selectively to relieve the patient of increased elastance or resistance, allowing the machine to assist according to the underlying lung pathology. PAV was introduced into the literature in 1992 and has been under experimental and clinical investigation since then. It is the purpose of this article to review briefly some of the most recent investigations on this interesting new ventilatory mode.


In this paper the implementation of the theoretical approach of PAV into a prototype ventilator was tested in a laboratory setup. A bellows-in-a-box lung model driven by a sine wave generator was used to simulate spontaneous breathing at different “ventilatory drives”, i.e., tidal volumes ranging from 0.2 to 1.2 l. All measurements were repeated for three different settings of the mechanical properties of the model lung: (1) normal mechanics, (2) high elastance, normal resistance, (3) high resistance, normal elastance. The primary parameter measured during the different situations was the breathing workload. PAV was set to unload the lung mechanics by 30, 50, and 70%. These settings were compared to pressure support ventilation (PSV) set at 6 mbar. For a tidal volume of 0.7 l, PSV and PAV resulted in a comparable amount of unloading of the work of breathing. With PAV, the level of unloading remained stable for all tested tidal volumes except for PAV set at 30% and a tidal...
volume of 0.4 l, when the measured unloading was somewhat lower than predicted. In contrast, PSV consistently oversupported low tidal volumes, whereas for higher tidal volumes lower assistance was observed. For all the different mechanical properties of the lung model, increasing percentages of unloading with PAV resulted in a stepwise decrease of the work of breathing performed by the model. The most important finding of this work is that PAV implemented in the tested prototype might be sufficient to unload a defined percentage of the work of breathing for different ventilatory drives. In contrast, PSV resulted in insufficient unloading for a given breathing effort, but it was not useful when breathing effort changed. For tidal volumes below 0.5 l, the prototype ventilator reacted less predictably during PAV.


The authors investigated eight patients who were mechanically ventilated for acute respiratory failure. After the respiratory system mechanics were determined using the occlusion technique during a period of hyperventilation, the patients were connected to a prototype ventilator capable of providing PAV. After a 5-min period of spontaneous breathing through the ventilator circuit, volume assist (VA) was subsequently added at four levels to unload 20, 40, 60, and 80% of the measured elastance, respectively. For each level of VA a flow assist (FA) was added at a level to unload 50% of the measured resistance. It was found that increasing levels of VA resulted in increased tidal volumes (V_T), whereas the respiratory rate (RR) was hardly affected. The addition of FA produced a further increase in V_T and a reduction in RR, so that minute ventilation remained stable. VA at each level produced a dose-dependent decrease in elastic workload, whereas the resistive work tended to increase. Therefore, the decrease in the total inspiratory work was not so pronounced. In combination with FA, a decrease in resistive work was achieved so that the combined application of VA and FA was found most effective for unloading the patient. It was concluded that VA and FA should be used together when PAV is used in acute respiratory failure patients.


In this paper, the results for eight patients with chronic obstructive pulmonary disease (COPD), breathing with various settings for PAV, were reported. After determination of the baseline respiratory mechanics using the occlusion method, the patients were connected to a prototype PAV ventilator. The following conditions were subsequently tested: spontaneous breathing through the circuit (SB), SB with continuous positive airway pressure (CPAP) adjusted to a level of 80% of the previously measured intrinsic-positive end-expiratory pressure (PEEPi), FA at a level to unload any elastance above normal (15 mbar x 1^3 x s^{-1}), FA plus PEEP of 80% of PEEPi, VA adjusted to unload any elastance greater than normal (15 mbar x 1^3), VA + PEEP amounting to 80% of PEEPi, FA + VA, and FA + VA + PEEP amounting to 80% of PEEPi. It was found that FA + PEEP resulted in the most favorable increase in minute ventilation and relief of dyspnea. During VA as well as during FA, an increased V_T was reported without significant changes in RR, whereas when the two were combined a 144 ± 3% increase in V_T was associated with a clear decrease in RR. Furthermore, the most effective reduction of breathing workload was found during FA + PEEP. When VA was added to this setting, a further reduction in RR and work indices was found. On the other hand, a prolonged inspiratory time was observed during VA + FA + PEEP and, hence, a significant amount of patient-ventilator asynchrony resulted. Interestingly, the application of CPAP, FA, and VA alone produced a decrease in the oxygen cost of breathing. From these data the authors concluded that the application of external PEEP to counterbalance PEEP and flow assist to unload the resistive work of breathing are most effective when using PAV in COPD patients. In those patients the application of any further volume assist resulted in patient-ventilator desynchronization due to ventilator overassistance.


Fifteen patients with preexisting stable COPD and chronic hypercapnia were enrolled in this study. In these patients, an exercise test using a bicycle ergometer with incremental load was performed until the patient was breathless, exhausted, or electrocardiographic abnormalities occurred. Exercise tolerance was expressed as the endurance time during an exercise test at 80% of the maximal performance the patients were able to achieve. This exercise test was performed during different ventilatory conditions: PAV was delivered via a face mask with FA adjusted to compensate for 80% of the resistance and VA adjusted to compensate for 80%