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Partial ventilatory support in 1989

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Respiratory failure may be caused by either lung failure or pump failure or a combination of both. Even when the initial cause is lung failure the respiratory muscles, which are faced with a high work of breathing because of the altered mechanical characteristics of the lungs, are exposed to fatigue, i.e. inability to generate the required force. Most patients need mechanical ventilation because of an imbalance between the required work of breathing and ventilatory pump performance. Pump failure, however, is very seldom complete and in most instances, the patient's ventilatory potential can be used in a variety of partial ventilatory support modes.

In the 1980's the preservation of spontaneous breathing is relatively easily provided by modern ventilators, either by minute volume integration – IMV, SIMV, MMV, APRV – or by breath-by-breath integration – AMV, ACV, PSV – (see below for abbreviations). With some of these modes, such as PSV and APRV, ventilatory support is achieved by pressure control, whilst the other modes work by volume control.

Partial ventilatory support: minute volume integration

Intermittent mandatory ventilation (IMV) and synchronized IMV (SIMV)

These are the classical approaches to this type of integration. Initially proposed as a weaning mode [1], IMV has been widely used for the last 15 years as a basic mode of ventilation [2], used mainly on the basis of clinical empiricism rather than scientific assessment of its value. It has been the subject of many controversies and has proven and putative advantages and disadvantages [3]. Poor clinical tolerance has generally been ascribed to inadequate performance of the ventilator. Attempts have been made to solve the problem by manufacturers and by clinicians: ventilators have been improved and home-made solutions have been proposed [4, 5]. Other explanations for the poor clinical tolerance, which are linked to the intrinsic features of IMV, have recently been proposed. We showed that the coexistence of two completely different kinds of ventilation, mechanical and spontaneous, each with their own patterns, can decrease the efficiency of spontaneous respiration, because of the presence of an oscillating intrinsic PEEP acting as a variable inspiratory threshold-load which is maximum immediately after the mechanical inflation [6]. During SIMV patients perform substantial work even when the frequency of mechanical breaths is set at high values [7]. During IMV, acutely ill patients seem to be unable to adapt their inspiratory effort to both cyclic overloading due to intrinsic PEEP [6] and unloading due to mechanical inflation [7]. These data readdress an old question, whether IMV is better in assisting a failing ventilatory pump, and also create a new question, whether ventilatory assistance can be easily titrated by changing the frequency of mandatory breaths.

Mandatory minute volume ventilation (MMV)

This mode, first proposed in 1977 [8], has not met with success commensurate with attractive theoretical background. It represents a first gross attempt to close the patient-machine ventilatory loop. Even if several ventilators provide MMV with different technical solutions, none of them is completely satisfactory in clinical use. In its most classic form, MMV is SIMV with an automatic frequency setting of mechanical breaths and so it shares clinical and pathophysiological problems with IMV. Different controlled variables ($ETCO_2$, respiratory rate, tidal volume) and control

variables (pressure support level) for servo-controlled ventilation are currently under investigation. With these different approaches, better results might be achieved compared to MMV. The use of respiratory rate as a controlled variable is probably the most promising choice. This index is an expression of the respiratory drive and therefore integrates different information, as it is an end point of the quality of patient-machine interaction.

Airway pressure release ventilation (APRV)

The most recent ventilatory mode is quite unique because augmented ventilation is accomplished by a decrease in baseline positive airway pressure (not by an increase as with all other modes [9]). APRV is the only augmented mode of ventilation specially developed for lung failure and not derived from CMV. The latter indeed was originally conceived for pump failure. The idea is very attractive, although further investigations are necessary to assess its value in a clinical setting.

Partial ventilatory support: breath-by-breath integration

Assisted mechanical ventilation (AMV)

This is the oldest mode by which the patient interacts with the machine. When minimum back-up ventilation is warranted, it is called assist control ventilation (ACV). The only difference from CMV is that the patient can initiate a mechanical breath via a trigger. Once the trigger is activated, lung inflation is achieved with a preset fixed inspiratory flow and time. In order to achieve effective unloading of the inspiratory muscles, the flow delivered by the ventilator must overcome the inspiratory flow demand of the patient throughout inspiration [10, 11]. Consequences of the mismatching between the ventilator and the patient are useless muscle exertion and patient discomfort. These problems can be minimized if the operator is skilled and can set the ventilator to exactly fulfil the patient's requirements. Presently this goal can be reached with pressure support ventilation (PSV), a ventilation mode that is fully on demand. Compared to PSV, the only advantage of AMV is the delivery of a mandatory volume.

Pressure support ventilation (PSV)

This mode was introduced into modern ventilators in the early 1980s. Like IMV, it was initially introduced as a weaning method, and it rapidly gained in popularity as a mode of ventilation. PSV works as a supplement supporting muscle during inspiration and synchronized with the inspiratory muscles of the patient. In other words, it is demand-flow ventilation with inspiratory hyperpressurization and with demand expiration. The amount of ventilatory assistance can be titrated by adjustment of the pressure support level. A recent review provides further details of PSV [12]. Adequate levels of pressure support can greatly decrease the work of breathing [13] and favourably modify the breathing pattern, both by reducing respiratory rate and increasing tidal volume [14]. Increased patient comfort is also reported. Since volume is not controlled, there are on the other hand substantial risks of hypoventilation and hyperinflation. These can be avoided if the ventilator is provided with adequate safety systems. Although several advantages have been suggested, the exact clinical role of PSV remains unclear. We share the views that PSV can reduce the work of ventilation more effectively and more easily than IMV, nevertheless, the superiority of this mode is as yet unproven, both in the treatment of ventilatory failure, and in weaning from mechanical ventilation. The best way of providing PSV requires further evaluation. Marked differences between ventilators may be seen both in the shape of the pressure wave and in the sensitivity of the cycling mechanism [12].

Despite their widespread use, ventilatory modes such as ACV and IMV have been subject of controversy since their introduction into clinical practice. Poor clinical tolerance and patient discomfort are frequently reported, and technological advances (more sensitive triggers and synchronized IMV) have not produced significant improvements. This is probably due to the volume-control basis of these modes, in which both the inspiratory flow and time are preset by the ventilator operator. In this situation there is a greatly reduced opportunity for the patient to usefully interact with the ventilator. On the other hand good interaction can be achieved by pressure-control and breath-by-breath integration, i.e. by PSV. With good respiratory monitoring and use of ventilator alarms, PSV is, in our experience, as safe as volume-control modes, and it is more adaptable to the patient's needs. Despite the lack of clinical studies on PSV, we share the enthusiasm of many clinicians for this mode of partial ventilatory support.

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