Several “new” modes of mechanical ventilation have been carefully investigated mostly for ICU patients in the last decade [1,2]. Why did the same evolution not take place in anesthesia and why did we not use them in the operating room? Do we need new ventilation modes in anesthesia? In other words would it improve clinical outcome, safety or efficiency at a lower cost?

Some of these ICU ventilation modes became popular and widely used in the ICU, whereas others, despite encouraging preliminary results, often did not reach enough popularity to have a clinical role.

The main reason to admit a patient to the ICU is to provide him or her with ventilatory assistance. Anesthesia is given most frequently to patients with no respiratory insufficiency suggesting that the choice of ventilation mode is not important.

Mechanical ventilation is essentially instituted in the ICU to buy time in a patient to recover from the underlying disease causing respiratory failure. The recognition of previously neglected physiologic aspects and advancements in the knowledge of disease mechanisms did lead to the development of novel technologies aimed at improving the outcome of patients receiving ventilatory treatment. Does this also apply for anesthesia?

Let us focus first on the new modes developed for ICU. Thereafter we will analyze the needs in anesthesia and conclude what new modes could be useful or need further development in anesthesia.

The difference between modes is essentially the manner in which positive pressure is applied to the patient [3]. Controlled modes of mechanical ventilation are often needed in patients with severe hypoxemic respiratory failure and acute respiratory distress syndrome (ARDS). In this case, the principal purpose of a new mode is to improve oxygenation without further damaging the lung. When a controlled mode is not needed, partial ventilatory assistance is preferred, in which the delivery of support is triggered by the patient’s own breathing [4]. The main objective is here to
enhance the synchronization between the patient’s own spontaneous breathing and the mechanical assistance [4].

Three groups of modes get attention: First the ventilatory assist modes where attention is given to improve the matching of support with the patient demand: Proportional assist ventilation (PAV) [5] and neurally adjusted ventilatory assist (NAVA) [6] attempt to achieve this goal at the ICU.

Pressure support ventilation (PSV) is an older mode where pressure is delivered by the ventilator as a result of the patient’s respiratory effort. An increased patient demand however does not correspond to an increase in pressure support. Paradoxically, in volume-preset assist–control ventilation, the increased muscle effort results in a reduced amount of assistance delivered. A challenging approach to the improvement of patient–ventilator interaction would be to match ventilatory support with the neural output of the respiratory centers so that the patient receives more assistance when demand is high and less assistance when demand is low. Under anesthesia, due to the depression of the respiratory center this matching support is not useful. Neurally controlled support without demand matching might be useful when neuro muscular block prevents pressure support and the respiratory center is not depressed too much by the anesthetics.

During Proportional assist ventilation (PAV), the ventilator instantaneously delivers positive pressure throughout inspiration in proportion to patient-generated flow and volume. Consequently, with PAV, an augmented ventilatory output resulting from an increased effort would correspond to increased support applied by the ventilator: the more the patient requests, the more the ventilator delivers. Unlike other assistance techniques, flow, volume, and airway pressure are not preset. PAV has been shown to be effective in unloading the respiratory muscles [7] without imposing a fixed breathing pattern [8] and in enhancing patient comfort [9] and patient–ventilator interaction [10].

NAVA is developed to overcome the limitations of PAV while maintaining its potential advantages. The electrical activity of the inspiratory muscles is used as an index of the inspiratory neural drive. Detection and quantification of the electrical activity of the crural diaphragm (EAdi) by means of an esophageal array of bipolar electrodes has been validated in humans [11]. Because the ventilator is triggered directly by EAdi, the synchrony between neural and mechanical
inspiratory time is guaranteed both at the onset and at the end of inspiration, regardless of PEEPi, air leaks, and respiratory mechanics. As long as the respiratory center, phrenic nerves, and neuromuscular junctions are intact and not suppressed by drugs, the amount of support provided should instantaneously correspond to the ventilatory demand, irrespective of variations in contractility [6]. The use of neural control of mechanical ventilation has the capability to dramatically enhance the coordination between mechanical ventilation and respiratory muscle activity, thereby improving patient comfort.

Secondly the introduction of breath-to-breath variability during controlled mechanical ventilation improves oxygenation: biologically variable or fractal ventilation are modes used for patients with gas exchange impairment like in ARDS. Moreover it might reduce further lung damage. [12]. Biologically variable ventilation (BVV) or fractal ventilation (FV) is a new mode that mimics spontaneous breath-to-breath variability, incorporating natural variable noise into a volume-targeted, controlled mode. The ventilator is programmed to modulate respiratory rate and tidal volume while maintaining a fixed minute ventilation based on a previously generated data file.

Recruitment is a continuous and progressive phenomenon that depends not only on PEEP but also on the inflation volume [13]. The rationale behind BVV is based on the concept that the alveolar recruitment achieved by high volumes exceeds the derecruitment caused by small volumes, with the net result being an improvement in lung compliance and oxygenation without an increase in mean airway pressure [14].

Thirdly the use of complex closed loop technologies allows the continuous measurement of the patient's respiratory mechanics and adaptation of the tidal volumes, peep, frequency and support levels. The adaptive support ventilation (ASV) is a ventilatory mode delivering assisted (pressure support ventilation-like) or controlled breathing cycles (pressure-controlled-like), related to a minute ventilation target set and on automated measurements of the patient's respiratory mechanics. ASV automatically adjusts according to measured lung mechanics at each breath. ASV provides safe and effective ventilation in patients with normal lungs, restrictive or obstructive diseases without need to change the settings. This mode might have more use during anesthesia as respiratory compliance can change rapidly during anesthesia. However due to the
open flow design today it is not available in the OR unless only TIVA is used.

Compared with the conventional modes, although intended for different aims, PAV, NAVA, BVV and ASV all move toward a more physiologic approach of mechanical ventilation.

Are these modes needed in anesthesia? Assist modes are hardly used in anesthesia. Respiratory failure due to muscle weakness and muscle fatigue do not occur immediately after anesthesia in someone who previously was breathing spontaneously without any support. Long and difficult weaning is not done post anesthesia in the operating room and if suspicious patients are kept ventilated and sedated while transferred to the ICU for weaning.

Hypoxemic respiratory failure is not frequent or only temporary like in one lung ventilation. Patient might come from the ICU and continuing his ventilation mode is then needed even for a short period.

Automatic parameter setting during anesthesia accelerates the adaptations now frequently not done or done too late, as gas monitoring although continuously done is not always continuously followed.

The indication for new anesthesia ventilation modes is different from the ICU and will be first requested in special situations or patients where it can make a difference in outcome, patient comfort and turnover time. The search however for these modes is never a straightforward process and would not happen if driven only by theoretical problems and analysis. On the contrary the open mind for new modes used at the ICU and being aware at the same time of practical problems in the operating room environment opens the possibilities to find and use new indications in anesthesia.

Synchronization with the patient demand seems to be impossible during deep anesthesia or deep muscle relaxation due to respiratory depression and blocked muscular activity. Deep muscle relaxation is important to provide sufficient workspace during laparoscopy, certainly in patients with a low abdominal compliance. Why would support ventilation then be ever possible?

In a recent study (15) we evaluated the depth of muscle relaxation at which pressure support ventilation would become impossible using non neurally support modes. To our surprise maximal muscle relaxation to a level of zero PTC at doses above 1,2 mg/kg rocuronium did never stop
the diaphragmatic activity. Up to a sensing resolution of 0,6 L/min the ventilator remains able to give pressure support under deep muscle relaxation given that respiratory depression by morphine is not high. The advantage of using pressure support during muscle relaxation was not clear in anesthesia. Several applications for it came forward in morbid obese patients during laparoscopic surgery. At the end of the laparoscopy pressure support ventilation can be started even during full muscle relaxation and pneumoperitoneum avoiding the risk of a patient breathing against the ventilator when muscle relaxation is ended and when hypercapnia is used to increase cardiac output and blood pressure. Awakening from inhalation anesthesia with sevoflurane or desflurane is much faster when patient is breathing already under hypercapnic pressure support than when normocapnic controlled ventilation is used. (16) Shortening turn over times and improving respiration is important in morbid obese patients. The use of pressure support allows too titrate the dose of morphinomimetics up to the maximum dose without respiratory depression at the end of surgery. (17) PSV improves pain management and avoid respiratory failure besides accelerating the turn over.

Variability in tidal volumes is not used explicitly in the OR yet, as the need isn’t explored. However we always use elevated oxygen concentrations per operative even in patients with normal lung function. This has been explained by the ventilation perfusion mismatch during mechanical ventilation. Spontaneous breathing patients during anesthesia might have less ventilation perfusion mismatch but have too small tidal volumes risking atelectasis. In morbid obese patients the use of pressure support also made a reduction in oxygen concentration possible. This is more due to the increased variation in tidal volume from breath to breath during PSV than the improved basal ventilation.

Using sufficient variability in tidal volume together with spontaneous breathing and support might make the use of high inspiratory oxygen concentration useless and breathing 21 % oxygen possible in the future.

The use of complex closed loop technologies might become very useful in selected patients like morbid obese patients undergoing laparoscopy. The question remains if the more physiologic ventilation will ever be measurable in its outcome.

These new ICU ventilation modes are not available in anesthesia ventilators today. However one should also not forget the more routine use of low and medium peep in every patient. Atelectasis is a major problem in morbid obese patients but happens in every intubated and ventilated patient from the first minute after intubation. CPAP is never used today in anesthesia, as it is not available on any anesthesia ventilator. Some think that closing the APL valve could imitate a CPAP
mode. But even with very high fresh gas flows the airway pressure will drop to zero during inspiration and rise to unpredictable pressures during expiration making this APL valve a dangerous tool. We foresee real CPAP modes coming available in next future.

Lung recruitment is still done in a non-professional manual way by inflating the lungs at an unknown pressure for an unknown time never followed by an immediate peep mode. First of all we react only to low saturations levels not originating from low cardiac output state. Measurement of FRC or atelectasis No anesthesia ventilator today is equipped with a lung recruitment mode. The ICU recruitments modes like 40/40 used for ARDS patients do not apply in the OR. Different new techniques are under evaluation to achieve sufficient lung recruitment without causing volutrauma during anesthesia and that might change our view in the future.

Attention to keep the lungs open from the induction to the end with PEEP is the simplest approach everyone should use today in every patient.

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