# Non conventional modes of ventilation

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We use mechanical ventilation to support patients who cannot sustain ventilation unaided. We normally do this by inserting an endotracheal tube, actively blowing air into the chest, and then allowing the air to passively leave. In so doing, we create a multitude of problems, including:☐ Ventilator-associated pneumonia ("VAP");☐ Ventilator induced lung injury ("VILI");☐ Patient discomfort;☐ The potential for cardiovascular compromise;☐ The consequences of excessive patient sedation, and, particularly, over-enthusiastic paralysis.Ventilator terminology is confusing, especially as some authors have used the same words for different things! Kapadia has simplified ventilator terminology (Kapadia F, 1998). He uses three basic terms:1. The trigger - the signal that opens the inspiratory valve, allowing air to flow into the patient, either the patient initiates a breath, or the machine automatically does so at a given rate;2. The limit - the factor which limits the rate at which gas-flow into the lungs, many ventilators deliver gas at a constant flow rate ("flow-limited ventilation"), while others deliver gas up to a preset pressure ("pressure limited ventilation"). Combinations may be used.;3. Cycling - the signal which stops inspiration AND eventually opens the expiratory valve , Cycling may be triggered by:i. volume - inspiration stops once the target volume is delivered, and then (often after a time delay), expiration starts;ii. time - inspiration stops after a preset time interval (often set simply by dialling in, say, respiratory rate and and I:E ratio);Summary110iii. flow - when flow decreases to a given level, inspiration is shut off.iv. pressure (although this is not commonly used on its own);Technologic advances and computerized control of mechanical ventilators have made it possible to deliver ventilatory assistance in new modes. Driving these innovations is the desire to prevent ventilator-induced lung injury, improve patient comfort, and liberate the patient from mechanical ventilation as soon as possible. These include:Altered pressure profiles and use of feedbackMechanical ventilators are typically volume or pressure cycled; some newer models combine features of both. Because pressures and volumes are directly linked by the pressure-volume curve, any given volume will correspond to a specific pressure, and vice versa, regardless of whether the ventilator is pressure or volume cycled.APRVAirway pressure-release ventilation (APRV) was described in 1987 by Stock et al (Stock et al, 1987) as a mode for delivering ventilation in acute lung injury while avoiding high airway pressures. APRV combines high constant positive airway pressure (improving oxygenation and promoting alveolar recruitment) with intermittent releases (causing exhalation).Dual controlThe old-fashioned term "servo" (which just means feedback) is commonly used in ventilators that use feedback to alter settings

according to how the patient's lungs respond. These modes are dual control within a breath (intrabreath) or dual control breath-to-breath (interbreath). Dual control within a breath describes a mode in which the ventilator switches from pressure control to volume control during a single breath. Dual control breath-to-breath is simpler because the ventilator operates in either the pressure support or pressure controlSummary111mode. When the feedback loop is operative, the pressure limit is increased or decreased automatically to maintain a clinician-selected VT.Adaptive support ventilation (ASV)ASV automatically selects the appropriate tidal volume and frequency for mandatory breaths and the appropriate tidal volume for spontaneous breaths on the basis of the respiratory system mechanics and target minute alveolar ventilation.Described in 1994 by Laubscher et al, ASV became commercially available in 1998 in Europe and in 2007 in the United States (Hamilton Galileo ventilator, Hamilton Medical AG). This is the first commercially available ventilator that uses an "optimal" targeting scheme (Laubscher et al, 1994)Proportional Assist VentilationIn 1992, Younes and colleagues (Younes M, 1992) developed proportional assist ventilation (PAV) as an alternative in which the ventilator generates pressure in proportion to the patient's effort. PAV became commercially available in Europe in 1999 and was approved in the United States in 2006, available on the Puritan Bennett 840 ventilator (Puritan Bennett Co, Boulder, CO). PAV has also been used for noninvasive ventilation, but this is not available in the United States.Fast RatesHigh-frequency oscillatory ventilation (HFOV) was first described and patented in 1952 by Emerson and was clinically developed in the early 1970s by Lunkenheimer. Several modes of high-frequency ventilation have -been proposed, including high-frequency oscillatory ventilation (HFOV), and high frequency jet ventilation (HFJV). HFJV has been mainly used during short procedures such as bronchoscopies. It is not without complications, notably pressure "stacking", hypercarbia, and airway injury owing to difficulty with gas humidification. High-frequency ventilation can be considered ventilator-triggered, flow (HFJV) or pressure (HFOV) limited, and time-cycled. Some commercial machinesSummary112allow rates of up to about forty breaths per second (2400/min), although substantially slower rates are usually employed, in the range of 2-15 Hz.HFOV is interesting. It was first thought of as a ventilatory modality when someone noticed that dogs, when they pant , take breaths that are smaller than their dead space. (Dead space in all animals, even giraffes, is generally constant at about 1/3 of resting tidal volume). How, the researcher wondered, do panting dogs maintain oxygenation? To this day, we're still not sure of the answer - at least five different credible explanations have been proposed. Simplistically, the high frequency of panting (and HFOV) increases turbulence and thus mixing and diffusion of oxygen (Hess D, et al, 2001).The goal of HFOV is to minimize lung injury; its characteristics make it useful in patients with severe ARDS. The US Food and Drug Administration approved it for infants in 1991 and for children in 1995. The adult model has been available since 1993, but it was not approved until 2001 (SensorMedics 3100B, Cardinal Health, Inc).Non-invasive Ventilation and Negative PressuresThe first ventilators were tank ventilators such as the "iron lung" that relied on extracorporeal application of negative pressure, with a rubber seal around the patient's neck. These fell into disfavour for a variety of reasons including upper

airway obstruction (obstructive sleep apnoea, even in "normal patients"), claustrophobia, discomfort, lack of triggering in response to patient attempts to breathe, leaks, and sheer bulk (the "iron lung" weighed a ton, even modern cuirasses are bulky). Newer developments in this field have yet to be extensively tested.Non-invasive positive-pressure ventilation (NIPPV) has been around for ages, but earlier masks were uncomfortable, and patient selection was often poor. NIPPV appears to be particularly advantageous (with careful selection) in patients with chronic obstructive pulmonary disease. It has also been used in cystic fibrosis, -acute asthma, and patients awaiting lung transplantation. NIPPV may be life preserving in immune-compromised patients with Pneumocystis carinii or other pneumonias. The major advantage of NIPPV is probably the lack of anSummary113endotracheal tube - normal defence mechanisms that prevent entry of bacteria into the lung are preserved. There is now compelling evidence that early extubation to NIPPV lowers duration of mechanical ventilation, shortens ICU stay, lowers the incidence of nosocomial pneumonia and improves sixty-day survival (Nava S, et al, 1998).Liquid VentilationThere is a vast amount of experimental literature on liquid ventilation. Most commonly, this is a combination of airway instillation of oxygen-carrying fluorocarbons such as perflubron, with conventional ventilation (partial liquid ventilation, PLV). Unfortunately, clinical studies are few. There is a lot we still need to learn about PLV - for example, distribution of perflubron within the lung is far from homogeneous, tending to gravitate towards dependent areas. Initial improvements in oxygenation need not necessarily be maintained, and falsely high tidal volumes may occur. Claimed merits of PLV include improved oxygenation, wash-out of exudates and infectious material, decreased bacterial adhesion, and even (possibly) reduced lung injury.Altered Goals - O2, CO2 and pHOnly recently have we really begun to appreciate that "normality" is a far from reasonable goal in the critically ill. Everything in ICU is a trade-off, and previously we were probably far too enthusiastic in our attempts to reach a "normal" saturation of say 93(+)%, a "normal" PCO2 of say 40 mmHg, and a "normal" pH of 7.36 to 7.44. There is emerging evidence that we may be wrong on all three counts.PaO2 in the ARDSNET study (Brower RG, 2000) was allowed to DROP to 55mmHg (or an SaO2 of 88%) for protracted periods with quite the opposite of an adverse effect.For years now we have accepted a strategy of "permissive hypercapnia" in asthmatic patients (and more recently, in ARDS patients), with apparent benefit.Summary114pH is perhaps the most controversial of the lot, but many intensivists would be quite happy with a respiratory acidosis and pH of say, 7.20 or even less.Prone PositioningProne positioning does appear to benefit a proportion of patients with severe ARDS. The reason for this is not clear, but may be to do with the heterogeneous nature of the lung injury - "ARDS" seems to preferentially affect the dependent regions of the lungs, so a patient lying on their back may benefit from improved V/Q ratios when flipped over. The benefit of prone positioning may take several hours to become apparent. It makes sense to try this maneuver in ARDS patients with refractory arterial hypoxia, before indulging in more aggressive heroics.Low Dead Space and Tracheal Gas InsufflationOne problem with critically ill patients, especially those with severely diseased lungs, is high VD/VT ratios (large dead space: tidal volume). This may be a substantial

problem as we decrease tidal volume in an attempt to limit barotrauma, although most patients tolerate hypercapnia fairly well. Exceptions would be patients with severe associated metabolic acidosis, or those with raised intracranial pressure. Possible solutions are to use specially constructed endotracheal tubes with an internal second lumen to minimise dead space, or even to insufflate gas via a small cannula.Recruitment ManeuversA variety of approaches have been used to "recruit" collapsed air spaces in the lung. The general consensus seems to be that substantial pressures (+ 40 cmH 2 O) are needed to open up such air spaces - simply increasing the PEEP a few centimetres is not usually adequate, although such "mini-recruitment maneuvers" may cause mild improvements in oxygenation.