

Advanced pressure control modes of ventilation in cardiac surgery: Scanty evidence or unexplored terrain?

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Abstract

Lung atelectasis resulting after cardiopulmonary bypass (CPB) can result in increased intrapulmonary shunting and consequent hypoxemia. Advanced pressure control modes of ventilation might have at least a theoretical advantage over conventional modes by assuring a minimum target tidal volume delivery at reasonable pressures, thus having potential advantages while ventilating patients with pulmonary atelectasis postcardiac surgery. However, the utility of these modes in the post-CPB setting have not been widely investigated, and their role in cardiac intensive care, therefore, remains quite limited.

Keywords: Advanced pressure control modes, cardiac surgery, ventilation

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Introduction

Pulmonary complications are frequently encountered after cardiac surgery with cardiopulmonary bypass (CPB), and atelectasis is believed to be a major etiology.^[1,2] Atelectasis results in a decrease in lung compliance and adversely affects oxygenation.^[3] Significant lung collapse following cardiac surgery results in intrapulmonary shunting and hypoxemia.^[4,5] Conventional mechanical ventilation might have additional deleterious influence on these atelectatic lungs, particularly with employment of high tidal volumes and pressures resulting in pulmonary hyperinflation.^[6,7] However, if a patient is hypoxemic, he will require positive pressure ventilation to sustain oxygenation. Addition of continuous positive airway pressure in such patients, might improve functional residual capacity, and place the patient on a favorable part of the pressure-volume curve.^[8,9] If, however, this fails to improve oxygenation, then it becomes necessary to initiate positive pressure ventilation. The patient is, therefore, put on a conventional

mode of mechanical ventilation – volume control, pressure control, or pressure support. Most postcardiac surgery patients could be easily ventilated in this manner. But what if problems with oxygenation persist?

Optimal strategies for mechanical ventilation in cardiac surgical intensive care

Cyclical opening and closing of injured lung units damage them.^[10,11] It would be ideal, therefore, to ventilate patients at the top of the volume-pressure curve, at high lung volumes, but without accompanying phasic changes. In the absence of facilities for oscillatory ventilation, increasing mean airway pressure without increasing peak pressure can only be achieved by prolonged inspiratory time (Ti) in a pressure control mode. Prolonged Ti improves oxygenation. Conversely,

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when T_i exceeds the expiratory time, carbon dioxide removal is adversely affected leading to hypercarbia and respiratory acidosis. We know that generally patients tolerate respiratory acidosis very well, and we could allow this to happen as long as it does not affect the pulmonary vascular resistance significantly, which could be a factor in patients undergoing cardiac surgery. Pressure control ventilation (PCV) previously used to be the last resort in ventilating postcardiac surgery patients with very noncompliant lungs and significantly high airway pressures on synchronized intermittent mandatory ventilation (IMV). That has changed in most cardiac surgical Intensive Care Units, with PCV now viewed as a good primary ventilation mode in patients with poor lung compliance, especially when combined with longer inspiratory times (inverse ratio PCV, or "PCIRV"). Tidal volume of approximately 6 ml/kg ideal body weight is now standard of care in mechanical ventilation of patients with reduced lung compliance. There is increasing recognition of the fact that tidal volumes of 10 ml/kg or more predispose cardiac surgical patients to organ failure and increased ventilation days, even in patients who do not have acute respiratory distress syndrome.^[12] Especially, susceptibles are women and obese patients who tend to receive greater tidal volumes and have a greater incidence of consequent lung injury. Intraoperative ventilation with low tidal volumes has also been suggested to be protective in noncardiac surgery settings.^[13] Whether these benefits could also be translated to the cardiac surgical patient is however not clear. PCIRV should probably be instituted earlier rather than later in postcardiac surgery patients with pulmonary complications, despite a paucity of studies confirming a substantial benefit from this mode. This mode is extremely uncomfortable for patients, who generally need to be heavily sedated, and often paralyzed. Intensivists, however, prefer patients to be awake and interacting with the ventilator, leading to the development of newer modes to enable patients to breathe spontaneously even on PCIRV.

Advanced modes of ventilation in cardiac surgical intensive care unit

Airway pressure release ventilation (APRV) was described in 1987 by Stock *et al.*^[14] as a mode for acute lung injury while limiting airway pressures. APRV combines high constant positive airway pressure with intermittent releases. Bilevel ventilation is a mode in which spontaneous ventilation could be achieved in both phases of the "high-low" positive airway pressure cycle [Figure 1]. The goal is to allow unrestricted spontaneous breathing so that need for excessive sedation or in some cases muscle relaxation can be avoided, thus

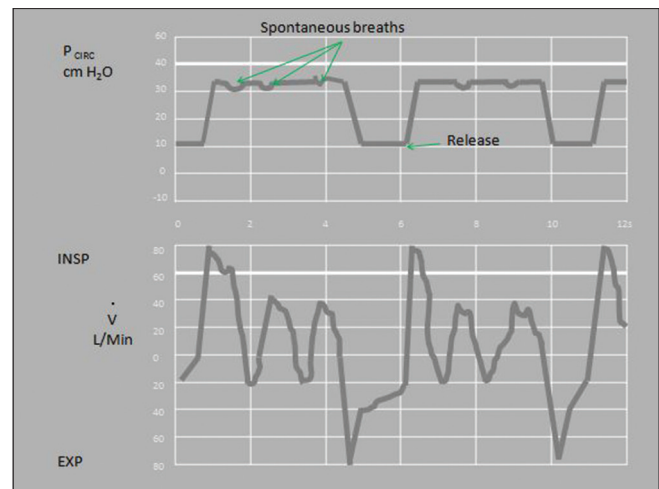


Figure 1: Bilevel ventilation

enabling faster separation from mechanical ventilation. A study by Rathgeber *et al.*^[15] compared duration of weaning between bilevel positive airway pressure (synonymous with Bilevel), volume controlled (VC) IMV, and VC continuous mandatory ventilation in patients undergoing cardiac surgery and demonstrated a marginal, yet significant decrease in weaning time. There appear to be no large published studies comparing APRV to conventional modes such as pressure support ventilation or T-piece, or to alternative modalities such as automatic tube compensation, proportional assist ventilation (PAV), adaptive support ventilation (ASV), or SmartCare. However, Putensen *et al.*^[16] have documented the benefits accrued from APRV, which include improvements in respiratory system compliance, PaO_2 , cardiac index, and delivery of oxygen, in comparison to patients subjected to conventional mechanical ventilation with muscle paralysis. The increase in cardiac output in patients breathing spontaneously might presumably be due to decreased pleural pressure and elevated abdominal pressure. This results in redistribution of splanchnic blood from abdominal viscera to inferior vena cava, resulting in enhanced venous return.^[17-19]

PAV purportedly reduces the work of breathing and patient-ventilator asynchrony. PAV allows automated modulation of airway pressure according to force generated by the patient. Unlike other modes in which the physician presets a specific tidal volume or pressure, PAV lets the patient determine the inspired volume and the flow rate. This mode mandates real-time estimation of resistance and compliance from which it determines the pressure to be generated. However, unlike the more commonly employed ASV mode which can be used both in passive as well as actively breathing patient, PAV can only be used in active patients. While to the best of our knowledge, there are no published studies

exploring the effects of PAV in patients undergoing cardiac surgery, in at least one randomized controlled study, ASV appreciably reduced the time spent on mechanical ventilation in a population of postcardiac surgery patients^[20] and also reduced the incidence of unnecessary alarms and ventilator resetting by clinicians, leading to better utilization of resources.^[21]

Paucity of evidence

Postoperative lung injury accounts for greater mortality after thoracic than following abdominal surgery.^[22] Slutsky and Ranieri indicate that the ventilator-induced lung injury may be reduced using lung protective mechanical ventilation.^[23] As research focuses on newer modes of mechanical ventilation that provide oxygenation and ventilation while reducing collateral pulmonary injury, there have evolved several advanced pressure control modes which seek to provide the benefits of both volume and pressure controlled ventilation. Like VC ventilation, delivery of a reasonable tidal volume is guaranteed, and at the same time, like pressure controlled ventilation, this is done with an adjustment of the flow rate to avoid deleterious increases in plateau pressure. Surprisingly, however, there are very few clinical trials related to their use in cardiac surgery, despite some evidence that some of them might limit the duration of postoperative mechanical ventilation and its attendant complications. While it is entirely possible to infer that unfamiliarity with many of these modes, as well as lack of substantial differences in tangible clinical end points from the noncardiac surgery settings might explain the reticence of researchers to explore these modes in the postcardiac surgery arena, larger studies are needed to clearly identify strategies that will result in improved survival, decreased duration of mechanical ventilation, earlier ICU discharge, earlier discharge from hospitals, and economic benefits. Clinically, relevant differences in these parameters are likely to be easier to identify in a subset of critically ill patients undergoing cardiac surgery who have a higher risk of requiring prolonged mechanical ventilation including those with extended CPB runs, undergoing complex cardiac repairs, and those with preexisting comorbidities affecting the lungs such as chronic obstructive pulmonary disease. It would be worthwhile pursuing work in these difficult patients in whom these modes might have clinically noteworthy benefits.

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Conflicts of interest

There are no conflicts of interest.

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