AANA Journal Course

Optimizing Mechanical Ventilation During General Anesthesia

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Optimal mechanical ventilatory support is a vital component of intraoperative anesthesia care, lung protection, and minimizing postoperative pulmonary sequela. Although concepts surrounding ventilation can be multifaceted and ambiguous, a pragmatic approach coupled with contemporary evidence and skilled assessments will facilitate ideal intraoperative management. Effective mechanical ventilation is dependent on obtaining the best pulmonary mechanics, including compliance, resistance, and gas exchange. Optimally titrated positive end-expiratory pressure is the foundation for ideal pulmonary mechanics, preventing ventilator-induced lung injury, and minimizing postoperative pulmonary complications. A knowledgeable application of pressure support ventilation can offer additional advantages during general anesthesia and emergence, providing synchronized ventilation and augmenting the patient's own respiratory efforts. These concepts, coupled with clinical expertise, will offer insight into the methods, tools, and techniques available to modern anesthetists.

Keywords: Positive end-expiratory pressure, pressure support ventilation, pulmonary mechanics, ventilator-induced lung injury.

Objectives

Upon completion of this course, the reader will be able to:

1. Describe concepts of pulmonary mechanics including compliance, resistance, dead space, ventilation and perfusion mismatch, functional residual capacity, and alveolar recruitment.
2. Apply these concepts to intraoperative assessment and management of mechanical ventilation.
3. Describe best practices for preventing lung injury, maintaining functional residual capacity, alveolar recruitment, and gas exchange using optimal positive end-expiratory pressure (PEEP) and trials of PEEP.
4. Obtain a foundational understanding of pressure support ventilation, including characteristics, indications, application, pitfalls, and appropriate use.

Introduction

The ever-evolving nature of medicine and science requires healthcare practitioners to periodically reconsider our understanding of clinical concepts. Today, there is substantial evidence advocating lung protective techniques be used in patients with normal lung function.[1-5] In a 2006 multicenter study of tidal volume (V_T) during anesthesia, Jaber et al[6] noted that more than 80% of operating room patients were ventilated with no positive end-expiratory pressure (PEEP) and nonprotective settings. Similar findings were noted in a study of intensive care patients receiving protective ventilation and requiring surgery. Protective settings were continued intraoperatively in only 53% of patients.[7] Mechanical ventilation poses a known risk of injury and complications, with postoperative pulmonary sequela substantially contributing to mortality and morbidity.[4,8,9]

Contemporary anesthesia ventilators span a spectrum of capabilities. Irrelevant to variations in modes and models, a foundational understanding of pulmonary mechanics and physiology will allow confident and objective management in response to the dynamic needs of the patient. A knowledge of ventilator capabilities and response to patients is essential. At its core, mechanical ventilation should mimic natural breathing patterns. Bearing in mind the patient's own respiratory pattern, it is easy to see how settings can be nonphysiologic, altering ventilation and perfusion (V/Q) relationships. Humans

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Mechanics	Equation
Static compliance (Crs)	Crs = V_T/(Pplat − PEEP) in mL/cm H_2O Crs = 450/(15 − 5) = 450/10 = 45 mL/cm H_2O
Dynamic compliance (DyCrs)	DyCrs = V_T/(PIP − PEEP) in mL/cm H_2O DyCrs = 450/(17 − 5) = 450/12 = 37.5 mL/cm H_2O
Airway resistance (Raw)	Raw = (PIP – Pplat)/Flow in cm H_2O/L/s Raw = 17 – 15/L = 2 cm H_2O/L/s
Physiologic dead space (V_{DS}/V_T)	V_{DS}/V_T = ($PaCO_2$ – $PeCO_2$)/$PaCO_2$ V_{DS}/V_T = 49 – 41/49 = 8/49 = 16%
Time constant (TC)	TC = Raw × Crs TC = 0.045 L/cm H_2O × 2 cm H_2O/L/s = 0.09 s

Table 1. Pulmonary Mechanics: Equations and Examples

Abbreviations: PEEP, positive end-expiratory pressure; PIP, peak inspiratory pressure; Pplat, plateau pressure; Raw, airway resistance; V_T, tidal volume.

possess natural variability in breathing, sighing several times per hour to maintain recruitment and satisfy pulmonary stretch receptors.[10] Respiratory patterns adapt in response to $Paco_2$, Pao_2, pH, and baroreceptive signals. The more ventilatory parameters set by providers, the more likely respirations will run contrary to physiologic signals and lead to dyssynchrony.[11]

Pulmonary Mechanics

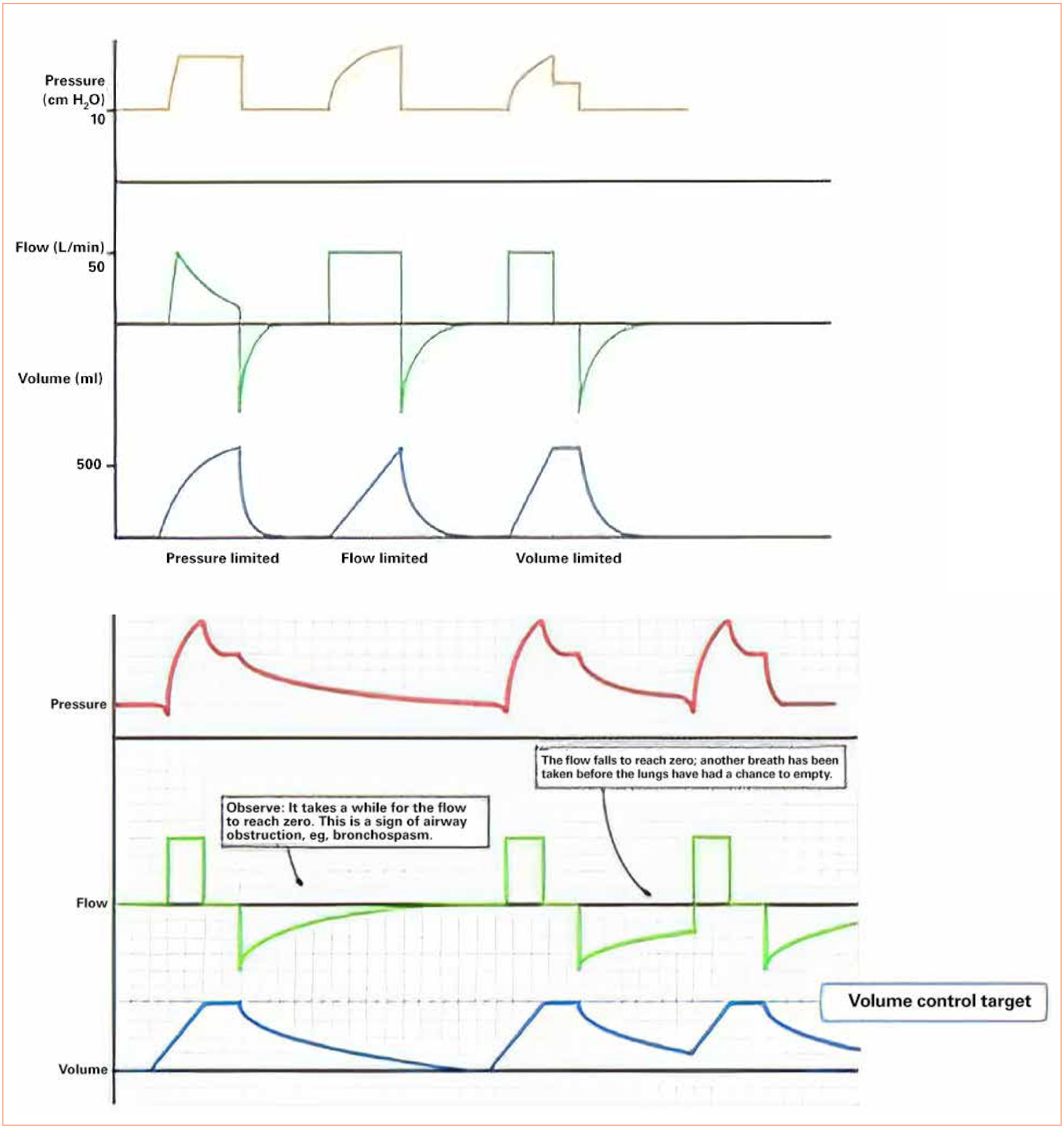
An understanding of pulmonary mechanics is vital to patient assessment during mechanical ventilation. Pulmonary mechanics include factors such as flow, volume, pressure, compliance, and resistance. These factors directly affect lung volumes and therefore functional residual capacity (FRC) and gas exchange. Goals during mechanical ventilation include optimizing the patient's pulmonary physiology, providing effective gas exchange, maintaining alveolar recruitment, reducing injury potential, and ensuring hemodynamic stability. Analyzing and incorporating measurements of pulmonary mechanics during your assessment will provide the information required for optimal intraoperative mechanical ventilation.

Improper intraoperative ventilation may create overdistention, allow end-expiratory alveolar collapse, or induce lung injury.[1,9,12] Compliance measurements are a key to ventilator management in patients with and without lung disease. Respiratory system static compliance (Crs) is the pressure burden exerted on the lung for any volume change. It is calculated as change in volume over the change in pressure (Table 1) as follows: Crs = ΔV/ΔP = V_T/Plateau Pressure (Pplat) – PEEP. Dynamic compliance (DyCrs) is similar; however, it incorporates airway resistance (Raw) within the calculated value (Table 1).

Optimal compliance demonstrates ideal distending pressures, alveolar recruitment, V/Q matching, homogeneity, and prevention of ventilator-induced lung injury (VILI). In a randomized controlled trial of patients with acute respiratory distress syndrome, Pintado et al[13] demonstrated improvements in mortality, hemodynamics, pulmonary status, and multiorgan system dysfunction when adjusting PEEP to achieve an optimal compliance. Similar findings were demonstrated in several studies involving patients with normal lungs evaluating compliance, oxygenation, and dead space.[12,14,15] Static compliance values are relative to each patient and circumstance, often between 40 and 80 mL/cm H_2O. The crucial factor is ensuring each patient's best and optimal compliance. Recruited open lungs are compliant, whereas atelectatic or overinflated lungs are not. Consider this example; your patient is ventilated with a V_T of 450 mL, peak inspiratory pressure (PIP) of 17 cm H_2O, Pplat of 15 cm H_2O, and PEEP of 5 cm H_2O. This produces a driving pressure or ΔP of 10 cm H_2O (Pplat – PEEP) as shown in Table 1. Static compliance is measured at Crs = 45 mL/cm H_2O. Dynamic compliance calculations (PIP – PEEP) yield a ΔP of 12 cm H_2O and a DyCrs = 37.5 mL/cm H_2O, accounting for Raw proportional to the differential between PIP and Pplat (Table 1). Plateau pressure may also be trended as a surrogate of compliance when calculations are not expedient.

Corresponding with clinical assessment, measurements of Raw give objective data to consider during mechanical ventilation or in diagnosing airway compromise. Raw coincides with pulmonary time constants, a product of Raw and Crs, which demonstrates variability among lung units. Airway and lung units are rarely homogeneous, particularly in patients with underlying lung disease. Raw is divided between artificial and natural airways. Artificial airways have a fixed resistance, whereas natural airways are dynamic, responding to neuroendocrine and physiologic changes.

Raw is calculated as pressure per unit of flow, per unit of time: Raw = PIP – Pplat/Flow (inspiratory or expiratory in liters per second). An inspiratory flow of 60 L/min or 1 L/s would produce a Raw as follows (Table 1): 17 – 15/1 = 2 cm H_2O/L/s. Thus, inspiratory Raw is 2 cm H_2O/L/s with optimal Raw measuring less than 10 cm H_2O/L/s.



The flow falls to reach zero; another breath has been taken before the lungs have had a chance to empty.

Observe: It takes a while for the flow to reach zero. This is a sign of airway obstruction, eg, bronchospasm.

Figure 1. Normal Waveforms (top) Compared With Dynamic Hyperinflation, High Expiratory Resistance Often Secondary to Disease, Air Trapping, Auto-PEEP, Delayed Emptying, and Prolonged Expiration (bottom)

Abbreviation: PEEP, positive end-expiratory pressure.

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The PIP-Pplat differential can offer a surrogate indicator of inspiratory Raw during rapid assessment. Raw cannot be determined when using variable flow modes such as pressure control ventilation (PCV). Indeed, one indication for PCV is to overcome variable time constants and high Raw areas. Its descending flow pattern coupled with a fixed inspiratory time and pressure improve the distribution of ventilation and gas exchange.

Expiratory resistance is typically higher than inspiratory and more applicable for the care of patients with obstructive lung disease.[16] It can be evaluated using waveforms and peak expiratory flow rates as a convenient single numerical indicator, thereby enhancing your assessment. Flow/time, volume/time, and pressure/time waveforms may demonstrate a failure to reach baseline, indicating high expiratory Raw, air trapping, dynamic hyperinflation, and/or auto-PEEP (Figure 1). These characteristics are seen in obstructive disease, bronchospasm, airway edema, secretions, or small airway disease. The lowest Raw will often coincide with optimal compliance and PEEP. In the heterogeneous obstructive lung, optimal PEEP will splint airways, improve the distribution of ventilation, diminish air trapping, prevent auto-PEEP, and yield the lowest expiratory Raw.[17] Removing externally set PEEP to decrease air trapping in obstructive lung disease is an erroneous technique not in-line with current empiric data.[17] Raw may be minimized through optimal PEEP, treating airway abnormalities such as secretions or bronchospasm, and ensuring a patent airway. Lung disease is the hallmark indication for PEEP optimization, which will be reviewed in the next section.

Approximately 33% of each breath does not participate in gas exchange, termed dead space and averaging 2 mL/kg of ideal body weight (IBW).[18] Dead space is divided into 2 categories: anatomical and alveolar. Together the 2 encompass the physiologic (total) dead space (V_{DS}) and are measured in ratio to the V_T (V_{DS}/V_T). In addition to Crs, DyCrs, and Raw, lowering the V_{DS}/V_T will confirm ideal gas exchange. Although invasive, blood gas analysis is vital in the measurement of gas exchange. Applying the Enghoff modification of the Bohr equation, $V_{DS}/V_T = PaCO_2 - PeCO_2/PaCO_2$ (Table 1), values for dead space fraction may be estimated. Although not technically equivalent, the end-tidal carbon dioxide ($ETCO_2$) may act as a surrogate for $PeCO_2$. For example, an $ETCO_2$ of 41 mm Hg and $PaCO_2$ of 49 would yield a V_{DS}/V_T of 16% (Table 1). Trending V_{DS}/V_T allows ventilation titration for the best possible V/Q matching and gas exchange. Intrapulmonary shunt measurements can offer additional data on oxygenation and V/Q mismatch. Unfortunately, the shunt calculation is complex and pragmatically difficult. However, alveolar to arterial gradients from a blood gas analysis can act as a substitute indicator (A/a gradient = $PAO_2 - PaO_2$). Confirming optimal Crs, DyCrs, Raw, V_{DS}/V_T, and gas exchange are the key facets in providing optimal mechanical ventilation, which in turn minimizes the risk of postoperative pulmonary complications and VILI.

Positive End-Expiratory Pressure Optimization and Trials

The concept of PEEP was described as early as 1938. Unfortunately, optimal use and application elude many modern practitioners. The foundational setting in mechanical ventilation, PEEP should be individually set for each patient. All other parameters and settings rely on appropriate levels of PEEP to ensure adequate ventilation, FRC, and recruitment. General anesthesia creates major changes in pulmonary physiology, including alveolar collapse, absorption and compression atelectasis, a loss of respiratory muscle tone, FRC, and closing capacity.[18] These alterations in pulmonary physiology may last for several days, resulting in postoperative pulmonary complications and other sequelae.[18]

Providing PEEP levels sufficient to maintain alveolar recruitment is instrumental in protective ventilation. Therefore, what is optimal PEEP, and how is it determined? This must be individually determined for each patient. The distribution of ventilation changes with positive pressure ventilation (PPV) secondary to pulmonary heterogeneity, even in healthy patients. Ventilation is directed to low resistant areas while high resistant, low compliant areas receive inadequate gas exchange. Levels of PEEP may be insufficient to maintain recruitment in certain areas while others experience overdistention, risking VILI.

Several indexes and physiologic factors require consideration when one is evaluating optimal PEEP or performing PEEP trials. In addition to pulmonary mechanics and gas exchange, consideration is required for hemodynamics, underlying pulmonary disease, surgical procedure, and positioning. Basic PEEP trial methods involve monitoring compliance and/or its surrogates (PIP, Pplat) with progressive changes in PEEP. During PEEP trials DyCrs has proved to be a particularly valuable indicator, accounting for changes in Raw in addition to Crs.[19] Alveolar to arterial gradient, oxygenation, and V_{DS}/V_T will generally improve in conjunction with compliance and resistance, indicating optimal settings. Suter et al[20] discovered that the best Crs coincided with maximum oxygen transport and the lowest V_{DS}/V_T. Maisch et al[21] found that a combination of best compliance and lowest V_{DS}/V_T in healthy anesthetized patients to be superior to other methods of optimization, both of which are easily employed intraoperatively. Results of several intraoperative studies concluded that moderate PEEP levels averaging approximately 10 cm H_2O were ideal in decreasing atelectasis, improving FRC, and providing the best gas exchange.[1,15,22] The best Crs, DyCrs, Raw, V_{DS}/V_T, and oxygenation are key indicators in demonstrating optimal settings that deliver dividends to patients both intraoperatively and postoperatively (Table 2).

A real-world example may help demonstrate these theories, realizing that a steady state is necessary, avoiding changes in position or other conditions that would alter pulmonary mechanics. Consider a patient receiving volume-controlled ventilation. After alveolar recruitment maneuvers, the anesthesia provider can increase PEEP while monitoring PIP/Pplat. This is often done in increments of 2 cm H_2O (ie, from 6 to 8 cm H_2O). If PIP/Pplat measurements fall, remain the same, or increase less than the change in PEEP, alveolar recruitment is occurring with an increasing FRC. If the initial PIP was 20 cm H_2O and if following an increase in PEEP of 2 cm H_2O for 15 minutes, the PIP falls to 19 cm H_2O, the FRC is improving with alveolar recruitment. Coinciding improvements

V_T	Approximately 6 mL/kg IBW IBW Males = 50 + [2.3 × (Height in inches – 60)] IBW Females = 45.5 + [2.3 × (Height in inches – 60)]
PEEP	5-7 cm H_2O; titrate for Crs or DynCrs and oxygenation
FIO_2	Normoxia, preferably ≤ 0.4 or SpO_2 ≥ 93%
Change in pressure (ΔP)	Minimize via PEEP and V_T adjustments
Pplat	Maintain ≤ 25-30 cm H_2O; the lower the better
ARMs	Every hour or when clinically indicated with your preferred technique

Table 2. Suggested Initial Ventilator Settings

Abbreviations: Crs, respiratory system static compliance; DynCrs, dynamic compliance; FIO_2, fraction of inspired oxygen; IBW, ideal body weight; PEEP, positive end-expiratory pressure; Pplat, plateau pressure; SpO_2, oxygen saturation measured by pulse oximetry; V_T, tidal volume.

in DyCrs, Crs, oxygenation, and V_{DS}/V_T would also be expected over a 10- to 20-minute trial period. The process may be repeated until the best Crs, DyCrs, V_{DS}/V_T, and oxygenation are achieved, indicating optimal settings. Conversely, an increase in PIP/Pplat greater than the change in PEEP would indicate a drop in compliance, overdistention, and increased risk of VILI. After confirming that the higher pressures do not stem from outside causes, returning the PEEP to its previous level would be indicated, with consideration for lower adjustments to achieve optimal Crs or DyCrs. For patients being ventilated with PCV, the anesthesia provider may use a similar extrapolation in DyCrs or Crs, noting changes in the delivered V_T for a set PIP and/or ΔP. Pressure is fixed; therefore, V_T changes are indicative of changes in compliance, recruitment, and FRC in contrast to PIP/Pplat changes during volume ventilation.

Included in any discussion regarding PEEP is the concern over hemodynamic effects. Positive pressure ventilation alters hemodynamics via 3 main mechanisms: diminished venous return, diminished right ventricular output secondary to increased pulmonary vascular resistance, and reduced left ventricular preload.[23] Hypovolemic conditions compound these effects, particularly in patients without lung disease. Pulmonary vascular resistance may be increased when alveolar capillary beds are compressed, promoting increased V_{DS}/V_T and hypoxemia. Hypoxic pulmonary vasoconstriction in atelectatic, under recruited regions exacerbate the increased pulmonary vascular resistance. These effects are decreased or offset with appropriate PEEP and alveolar recruitment.[23]

The goals of PEEP include decreasing VILI as well as improving gas exchange and oxygen delivery to the tissues. Therefore, optimal PEEP promotes these goals without compromising hemodynamics; otherwise, oxygen delivery would be curtailed. These facts underscore the importance of achieving optimal, individual PEEP for each patient.[20,23] Neither continuous cardiac output nor hemodynamic measurements are available for most patients. Therefore, we must rely on pragmatic indicators of optimal PEEP. Suter et al[20] found the best Crs to be the strongest indicator for optimal PEEP, oxygen delivery, and thus optimal cardiopulmonary function. This conclusion was confirmed in several other studies.[12-15,21] When hemodynamic effects are noted, a thorough assessment to ascertain cause and idea settings should be completed, including best treatment for resolution.

Positive end-expiratory pressure is instrumental in preventing postoperative pulmonary complications.[1,24-27] Pulmonary complications occur in 5% to 10% of patients undergoing nonthoracic surgery and in 22% of thoracic surgeries or high-risk patients.[28] Atelectasis impedes surfactant production, catalyzing a vicious cycle that can persist for weeks after surgery and can lead to other sequelae. Pneumonia or bronchitis, hypoxemia, bronchospasm, acute lung injury, exacerbation of existing lung disease, and pulmonary emboli are all possibilities.[28] Retained secretions act as a nidus for infectious organisms, leading to pneumonia with hypoxemia, fever, and leukocytosis. Pulmonary complications are second only to cardiovascular events in degree of severity. The one all-encompassing characteristic of pulmonary complications is that all are modifiable, and most are preventable.

Pressure Support Ventilation

Since the advent of mechanical ventilation, medicine has struggled to create a ventilatory mode that could mimic a patient's own physiologic patterns. Pressure support ventilation was developed in the early 1980s with microprocessor-based ventilators that were sensitive to a patient's effort. Classified as a spontaneous mode, PSV only partially assists the patient and serves as one of the hallmark modes for weaning patients and promoting ventilator/patient synchrony. Despite a few shortcomings, PSV can be applied as a primary mode for patients under general anesthesia who are breathing spontaneously. One drawback includes the lack of a minimal V_T or minute ventilation setting with no automated backup for periods of apnea. Hybrid modes such as PSV-Protect were developed to allow a minimal minute ventilation to be set and maintained.

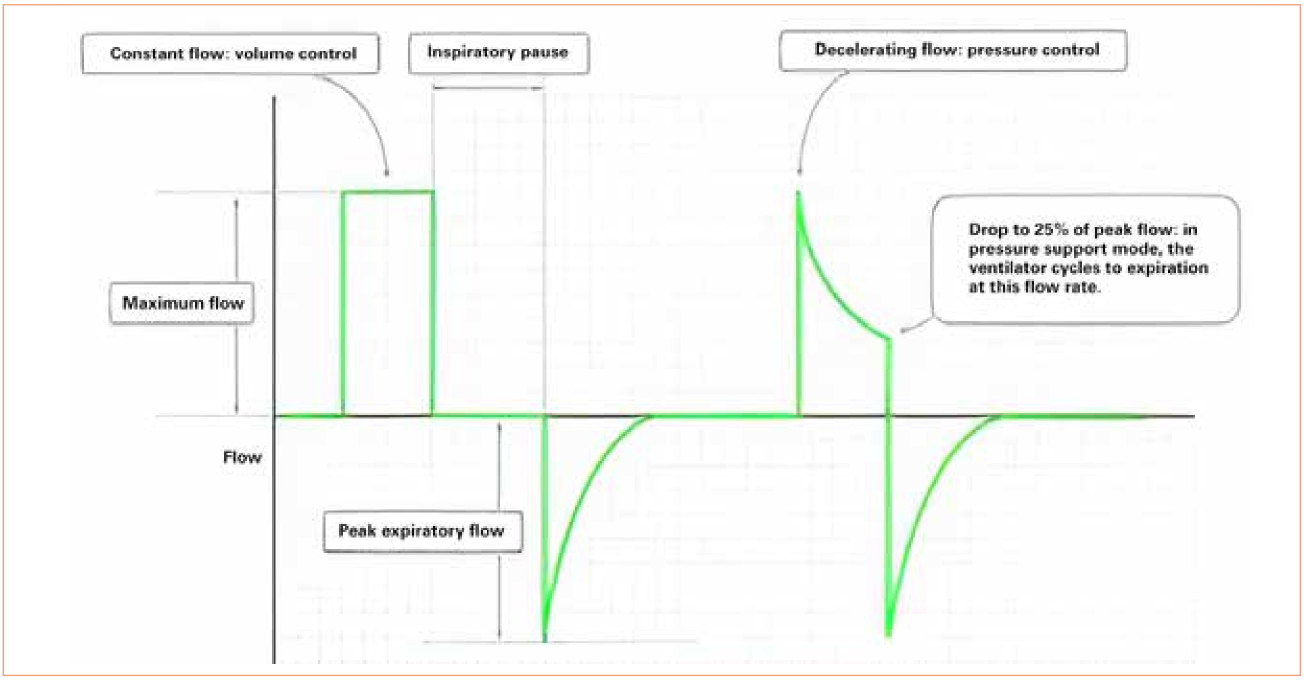

Figure 2. Flow Time Waveform Comparing a Constant Flow Breath and a Breath Delivered With Pressure Support[a]

[a] Note decelerating inspiratory pattern, cycling at 25% of peak flow.
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Pressure support ventilation has demonstrated effectiveness in all artificial airways, including endotracheal (ET) tubes and laryngeal mask airways (LMAs). Given an adequate fitting mask, PSV with PEEP can mimic noninvasive bilevel positive airway pressure (BiPAP). Pressure support has been effective at reducing the work of breathing associated with endotracheal intubation and mechanical ventilation. Consider the Poiseuille law concerning flow through a tube or cylinder. The law demonstrates that flow is directly proportional to the radius of the tube and the pressure differential, proximal to distal.[18] Smaller ET tubes are associated with significantly higher resistance and work of breathing indexes.[29] Pressure support delivers a driving pressure to the proximal airway, overcoming Raw and augmenting inspiratory flow across the length of the ET tube. Two studies with a limited number of patients yielded evidence suggestive of upper airway edema after extubation, contributing to an increased work of breathing equivalent to intubation, limiting the need for PSV.[30,31] Notwithstanding this hypothesis, providing adequate support, minimizing the work of breathing, augmenting pulmonary physiology, and optimizing patient comfort provide substantial benefit both intraoperatively and postoperatively.

Whenever modes like volume-controlled ventilation or PCV are employed, clinicians program most of the settings, including frequency, V_T, inspiratory flow, and inspiratory time. In using PSV, the provider only sets the pressure support level above PEEP and adjusted to deliver normal spontaneous V_T averaging 4 to 5 mL/kg IBW.[32] Support levels from 3 to 10 cm H_2O are commonplace. It is important to consider patient factors, including muscle strength, pulmonary pathology, comfort, surgical procedure, and work of breathing. Providers routinely err by setting PSV levels too high rather than too low. Inappropriately elevated pressure support levels are associated with ineffective efforts, periodic breathing, apnea, and dyssynchrony.[33,34] These findings are often identified during emergence when PSV levels are set inappropriately high.

Pressure support is delivered to the proximal airway after sensing the patient's inspiratory effort, providing the necessary flow and volume for the inspiratory time required by the patient. Sensitivity measures a differential change in circuit flow, traditionally 2 to 3 L/min, which is very responsive to patient efforts. Autotriggering has been reported with cardiac oscillations and chest wall rebound, which can be corrected with sensitivity adjustments and titration. Increasing the flow differential to 4 to 5 L/min will decrease responsiveness and eliminate any oversensitivity. Observing the patient's respiratory pattern, circuit pressures, waveforms, and $ETCO_2$ can confirm spontaneous efforts and synchrony, thus ensuring that sensitivity is set appropriately to prevent autotriggering yet responsive to patient efforts. Inspiratory flow progresses in a characteristic decelerating pattern (Figure 2).[35] As the patient's inspiratory needs are met, flow progressively declines until it reaches a predetermined level, usually 25% of the peak inspiratory flow, at which time the breath is terminated. Pressure support ventilation allows the patient to control their own respiratory pattern, including inspiratory flow, inspiratory time, V_T, respiratory rate, and pattern. Variability in respiratory patterns is essential with as little as 30% beneficial at improving V/Q relationships, particularly in patients with lung disease.[11,36] Because of these characteristics, PSV is considered one of the most comfortable and physiologic modes in mechanical ventilation.

Pressure support ventilation allows for the preservation of several physiologic functions that are beneficial to patients under general anesthesia. A balance between the negative effects of PPV and the advantages of spontaneous respirations can be appreciated with PSV. Active inspiratory efforts promote improved distribution of ventilation, augmented venous return, V/Q matching, and several other benefits seen in spontaneous respiratory physiology. A 2012 randomized controlled trial found that PSV prevented ventral redistribution of ventilation compared with PCV.[37] Similarly, PSV was found to improve minute ventilation and gas exchange while preserving hemodynamic function during inhaled anesthesia.[32] In 2013, Capdevila et al[38] compared patients undergoing knee arthroscopy, using LMAs, and randomly assigned patients to controlled mandatory ventilation, spontaneous breathing, or PSV. Patients receiving PSV experienced the lowest propofol and fentanyl requirements, decreased emergence times, and fastest LMA removal times compared with controlled mandatory ventilation and spontaneous breathing, with no untoward side effects.[38] Another randomized controlled trial of 34 pediatric patients undergoing adenotonsillectomy found lower intraoperative sevoflurane requirements, lower anesthesia times, decreased extubation times, and lower pain scores in the postanesthesia care unit in patients ventilated with pressure support vs spontaneous ventilation.[39] Furthermore, intraoperative use of PSV in moderately obese patients has demonstrated improved perioperative lung function, oxygenation, an improved distribution of ventilation to the dorsal regions of the lung, and positive effects that persisted into the postoperative period.[40]

Pressure support ventilation has numerous promising characteristics that skilled clinicians may employ; however, as with any tool, it must be used appropriately. Anesthetic and opioid levels can be titrated in patients breathing spontaneously with appropriate levels of pressure support. Pressure support ventilation may be used in overcoming the depressive effects of anesthetics and muscle relaxants, providing support during emergence, augmenting V/Q matching and gas exchange, preventing atelectasis, eliminating potent inhalational agents, and providing a synchronized mode of ventilation. Assessment of muscle strength and the effectiveness of respirations on PSV can be confounding, however, proving to be a barrier to its use during emergence. Support levels set inappropriately potentially mask muscle weakness, create respiratory alkalosis, alter neuroreflexive controls of respiration, produce periodic irregular respirations, and lead to dyssynchrony. In setting pressure support, few factors require consideration outside achieving a V_T approximately 4 to 5 mL/kg IBW, which may be accomplished with levels between 3 and 6 cm H_2O. Other patients may require little to no pressure support, indicative of recovery. The required level of support may be used as an indicator akin to spontaneous respirations with an open adjustable pressure-limiting valve. Patients with residual anesthesia or persistent muscle weakness may require higher PSV levels. Work of breathing, respiratory rate, pattern, and effort are all assessed. Body habitus, comorbidities, position, and surgical procedure are also considered in support requirements. When patient parameters are favorable and extubation is imminent, PEEP and pressure support levels can remain intact up to extubation.

Conclusion

Management of mechanical ventilation, like anesthesia, is an art supported by science. Contemporary theories and practices have evolved to ensure efficiency and prevent iatrogenic injury, learning from the mistakes of our past. Advances in computer microprocessor and other technology offer high-bred modes and functions that meet the needs of an array of patients. In applying concepts of pulmonary physiology and mechanics, anesthetists possess the ability to tailor ventilator settings according to the patient's physiologic requirements. Optimally applied PEEP can ensure a patient's cardiopulmonary homeostasis while preventing VILI and postoperative sequelae. Additionally, PSV employed effectively offers anesthetists a spontaneous mode with clear physiologic advantages.

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