

# Standardized Vocabulary for Mechanical Ventilation

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**active exhalation valve** A mechanism for holding pressure in the breathing circuit by delivering the flow required to allow the patient breathe spontaneously. This feature is especially prominent in modes like Airway Pressure Release Ventilation that are intended to allow unrestricted spontaneous breathing during a prolonged mandatory (i.e., time triggered and time cycled) pressure controlled breath.

**asynchrony (dyssynchrony)** Regarding the timing of a breath, asynchrony means triggering or cycling of an assisted breath that either leads or lags the patient's inspiratory effort. Regarding the size of a breath, asynchrony means the inspiratory flow or tidal volume does not match the patient's demand. Also, some ventilators allow a patient to inhale freely during a pressure controlled mandatory breath but not to exhale, thus inducing asynchrony. Asynchrony may lead to increased work of breathing and discomfort.

**adaptive targeting scheme** A control system that allows the ventilator to automatically set some (or conceivably all) of the targets between breaths to achieve other preset targets. One common example is adaptive pressure targeting (e.g., Pressure Regulated Volume Control mode on the Maquet Servo-i ventilator) where a static inspiratory pressure is targeted within a breath (i.e., pressure controlled inspiration) but this target is automatically adjusted by the ventilator between breaths to achieve an operator set tidal volume target.

**airway pressure** The pressure at the airway opening measured relative to atmospheric pressure during mechanical ventilation.

**airway pressure release ventilation (APRV)** A form of pressure control intermittent mandatory ventilation that is designed to allow unrestricted spontaneous breathing throughout the breath cycle. APRV is applied using I:E ratios much greater than 1:1 and usually relying on short expiratory times and gas trapping to maintain end expiratory lung volume rather than a preset PEEP. This is in contrast to Bilevel Positive Airway Pressure (BIPAP) which is also pressure control intermittent mandatory ventilation but with I:E ratios closer to 1:1, expiratory times that do not create significant gas trapping and preset PEEP levels above zero.

**assisted breath** A breath during which all or part of inspiratory (or expiratory) flow is generated by the ventilator doing work on the patient. In simple terms, if the airway pressure rises above end expiratory pressure during inspiration, the breath is assisted (as in the Pressure Support mode). It is also possible to assist expiration by dropping airway pressure below end expiratory pressure (such as Automatic Tube Compensation on the Dräger Evita 4 ventilator). In contrast, spontaneous breaths during CPAP are unassisted because the ventilator attempts to maintain a constant airway pressure during inspiration.

**autoPEEP** The positive difference between end-expiratory *alveolar* pressure (total or intrinsic PEEP) and the end-expiratory *airway* pressure (set or extrinsic PEEP; Am J Respir Crit Care Med 2011;184:756-762). When autoPEEP exists, a positive pressure difference drives flow throughout exhalation until the subsequent breath interrupts deflation. AutoPEEP is caused when expiratory time (either set by the patient's brain or a ventilator) is short relative to the expiratory time constant of the respiratory system (possibly including the expiratory resistance of the breathing circuit).

**automatic tube compensation** A feature that allows the operator to enter the size of the patient's endotracheal tube and have the ventilator calculate the tube's resistance and then generate just enough pressure (in proportion to inspiratory or expiratory flow) to compensate for the added resistive load. (See servo control.)

**autotrigger** A condition in which the ventilator repeatedly triggers itself because the sensitivity is set too high (sometimes called "autocycling"). For pressure triggering, the ventilator may autotrigger due to a leak in the system dropping airway pressure below a pressure trigger threshold. When sensitivity is set too high, even the heartbeat can cause inadvertent triggering. Autotriggering is a form of patient-ventilator asynchrony.

**bio-variable targeting scheme** A control system that allows the ventilator to automatically set the inspiratory pressure or tidal volume randomly to mimic the variability observed during normal breathing. Currently this "biologically variable" targeting scheme is only available in one mode, Variable Pressure Support, on the Dräger V500 ventilator. The operator sets a target inspiratory pressure and a percent variability from 0% to 100%. A setting 0% means the preset inspiratory pressure will be delivered for every breath. A 100 % variability setting means that the actual inspiratory pressure varies randomly from PEEP/CPAP level to double the preset pressure support level.

**blower** A blower is a machine for generating relatively large flows of gas as the direct ventilator output with a relatively moderate increase of pressure (e.g., 2 psi). Blowers are used on home care and transport ventilators. (see compressor)

**breath** A positive change in airway flow (inspiration) paired with a negative change in airway flow (expiration), associated with ventilation of the lungs. This definition excludes flow changes caused by hiccups or cardiogenic oscillations. However, it allows the superimposition of, for example, a spontaneous breath on a mandatory breath or vice versa. The flows are paired by size, not necessarily by timing. For example, in Airway Pressure Release Ventilation there is a large inspiration (transition from low pressure to high pressure) possibly followed by a few small inspirations and expirations, followed finally by a large expiration (transition from high pressure to low pressure). These comprise several small spontaneous breaths superimposed on one large mandatory breath. In contrast, during High Frequency Oscillatory Ventilation, small mandatory breaths are superimposed on larger spontaneous breaths.

**breathing circuit** System of tubing connecting the patient to the ventilator.

**breath sequence** A particular pattern of spontaneous and/or mandatory breaths. The 3 possible breath sequences are: continuous mandatory ventilation, (CMV), intermittent mandatory ventilation (IMV), and continuous spontaneous ventilation (CSV).

**compliance** A mechanical property of a structure such as the respiratory system; a parameter of a lung model, or setting of a lung simulator; defined as the ratio of the change in volume to the associated change in the pressure difference across the system. Compliance is the reciprocal of elastance.

**compressor** A compressor is a machine for moving a relatively low flow of gas to a storage container at a higher level of pressure (e.g, 20 psi). Compressors are generally found on intensive care ventilators whereas blowers are used on home care and transport ventilators. Compressors are typically larger and consume more electrical power than blowers, hence the use of the latter on small, portable devices. (see blower)

**CMV** See continuous mandatory ventilation

**continuous mandatory ventilation** Commonly known as “Assist/Control”; CMV is a breath sequence for which spontaneous breaths are not possible between mandatory breaths because every patient trigger signal in the trigger window produces a machine cycled inspiration (ie, a mandatory breath). Machine triggered mandatory breaths may be delivered at a preset rate. Therefore, in contrast to IMV, the mandatory breath frequency may be higher than the set frequency but never below it. In some pressure controlled modes on ventilators with an active exhalation valve, spontaneous breaths may occur during mandatory breaths, but the defining characteristic of CMV is that spontaneous breaths are not permitted *between* mandatory breaths. See **mandatory breath, intermittent mandatory ventilation, trigger window**

**continuous spontaneous ventilation** A breath sequence for which all breaths are spontaneous.

**control variable** The variable (ie, pressure or volume in the equation of motion) that the ventilator uses as a feedback signal to manipulate inspiration. For simple set-point targeting, the control variable can be identified as follows: If the peak inspiratory pressure remains constant as the load experienced by the ventilator changes, then the control variable is pressure. If the peak pressure changes as the load changes but tidal volume remains constant, then the control variable is volume. Volume control implies flow control and vice versa, but it is possible to distinguish the two on the basis of which signal is used for feedback control. Some primitive ventilators cannot maintain either constant peak pressure or tidal volume and thus control only inspiratory and expiratory times (ie, they may be called time controllers).

**CPAP** Continuous positive airway pressure; the set or measured mean value of transrespiratory system pressure during unassisted breathing or between assisted breaths. While this term is sometimes used synonymously for PEEP, historically, PEEP came first. PEEP mechanisms originally required the patient to drop transrespiratory system pressure to below atmospheric pressure to inhale, imposing a load and causing an increased work of breathing. CPAP mechanisms were developed so that the patient only

had to drop pressure below the set CPAP level to inhale, thus decreasing the imposed load. See **PEEP**.

**CSV** See continuous spontaneous ventilation; all breaths are spontaneous. See **spontaneous breath**.

**cycle (cycling)** To end the inspiratory time (and begin expiratory flow)

**cycle variable** The variable (usually pressure, volume, flow, or time) that is used to end inspiratory time (and begin expiratory flow).

**driving pressure** The pressure causing delivery of the tidal volume during pressure control modes (ie the change in transrespiratory pressure associated with tidal volume delivery). Driving pressure may be estimated either from ventilator settings (ie, driving pressure = set inspiratory pressure above total PEEP) or from the airway pressure waveform (ie, driving pressure = end inspiratory pressure above total PEEP). See **airway pressure, inspiratory pressure, peak inspiratory pressure**

**dual targeting scheme** A control system that allows the ventilator to switch between volume control and pressure control during a single inspiration. Dual targeting is a more advanced version of set-point targeting. It gives the ventilator the decision of whether the breath will be volume or pressure controlled according to the operator set priorities. The breath may start out in pressure control and automatically switch to volume control, as in the Bird “VAPS” mode or, the reverse, as in the Dräger “Pressure Limited” mode feature. The Maquet Servo-i ventilator has a mode called “Volume Control” and the operator presets both inspiratory time and tidal volume as would be expected with any conventional volume control mode. However, if the patient makes an inspiratory effort that decreases inspiratory pressure by 3 cm H<sub>2</sub>O, the ventilator switches to pressure control and, if the effort lasts long enough, flow cycles the breath. Indeed, if the tidal volume and inspiratory time are set relatively low and the inspiratory effort is relatively large, the resultant breath delivery is indistinguishable from Pressure Support. As a result, the tidal volume may be much larger than the expected, preset value. This highlights the need to understand dual targeting. Because both pressure and volume are the control variables during dual targeting, we identify the control variable as the one with which the breath initiates. This is because the alternate control variable may never be implemented during the breath, depending on the other factors in the targeting scheme.

**dynamic compliance** The slope of the pressure-volume curve drawn between two points of zero flow (eg, at the start and end of inspiration).

**dynamic hyperinflation** The increase in lung volume that occurs whenever insufficient exhalation time prevents the respiratory system from returning to its normal resting end-expiratory equilibrium volume between breath cycles. Inappropriate operator set expiratory time may lead to dynamic hyperinflation, inability of the patient to trigger breaths, and an increased work of breathing.

**elastance** A mechanical property of a structure such as the respiratory system; a parameter of a lung model, or setting of a lung simulator; defined as the ratio of the change in the pressure difference across the system to the associated change in volume. Elastance is the reciprocal of compliance.

**elastic load** The pressure difference applied across a system (e.g., a container) that sustains the system's volume relative to some reference volume, and/or the amount of its compressible contents relative to some reference amount. (For a linear system: elastance  $\times$  volume, or, volume/compliance; for a container, the overall effective elastance (compliance) includes the elastances (compliances) of its structural components and the compressibility of the fluid [gas or liquid] within it.)

**equation of motion for the respiratory system** A relation among pressure difference, volume, and flow (as variable functions of time) that describes the mechanics of the respiratory system. The simplest and most useful form is a differential equation with constant coefficients describing the respiratory system as a single deformable compartment including the lungs and chest wall connected in series to a single flow conducting tube:

$$P_{TR}(t) + P_{mus}(t) = EV(t) + R\dot{V}(t) + autoPEEP$$

where

$P_{TR}(t)$  = the change in transrespiratory pressure difference (i.e., airway opening pressure minus body surface pressure) as a function of time (t), measured relative to end expiratory airway pressure. This is the pressure generated by a ventilator,  $P_{vent}(t)$ , during an assisted breath.

$P_{mus}(t)$  = ventilatory muscle pressure difference as a function of time (t); the theoretical chestwall transmural pressure difference that would produce movements identical to those produced by the ventilatory muscles during breathing maneuvers (positive during inspiratory effort, negative during expiratory effort)

$V(t)$  = volume change relative to end expiratory volume as a function of time (t)

$\dot{V}(t)$  = flow as a function of time (t), the first derivative of volume with respect to time

E = elastance (inverse of compliance;  $E = 1/C$ )

R = resistance

autoPEEP = end expiratory alveolar pressure above end expiratory airway pressure

For the purposes of classifying modes of mechanical ventilation the equation is often simplified to:

$$P_{vent} = EV + R\dot{V}$$

where

$P_{vent}$  = the transrespiratory pressure difference (ie, “airway pressure”) generated by the ventilator during an assisted breath

**expiratory flow time** The period from the start of expiratory flow to the instant when expiratory flow stops. By convention, expiratory flow is in the negative direction (below zero) in graphs.

**expiratory pause time** The period from cessation of expiratory flow to the start of inspiratory flow.

**expiratory time** The period from the start of expiratory flow to the start of inspiratory flow; expiratory time equals expiratory flow time plus expiratory pause time.

**feedback control** Closed loop control accomplished by using the output as a signal that is fed back (compared) to the operator-set input. The difference between the two is used to drive the system toward the desired output (ie, negative feedback control). For example, pressure controlled modes use airway pressure as the feedback signal to manipulate gas flow from the ventilator to maintain an inspiratory pressure setpoint.

**flow control** Maintenance of an invariant inspiratory flow waveform despite changing respiratory system mechanics

**flow triggering** The starting of inspiratory flow due to a patient inspiratory effort that generates inspiratory flow above a preset threshold (ie, the trigger sensitivity setting).

**flow target** Inspiratory flow reaches a preset value that may be maintained before inspiration cycles off.

**flow cycling** The ending of inspiratory time due to inspiratory flow decay below a preset threshold (aka, the cycle sensitivity).

**IMV** See intermittent mandatory ventilation.

**inspiratory flow** The flow into the airway opening during the inspiratory time. By convention, inspiratory flow is in the positive direction (above zero) in graphs.

**inspiratory flow time** The period from the start of inspiratory flow (into the airway opening) to the cessation of inspiratory flow.

**inspiratory hold** An intentional maneuver during mechanical ventilation whereby exhalation is delayed for a preset time (inspiratory hold time) after an assisted breath. This maneuver is used to assess static respiratory system mechanics and also to increase mean airway pressure during volume control ventilation in an attempt to improve gas exchange.

**inspiratory hold (pause) time** The period from the cessation of inspiratory flow (into the airway opening) to the start of expiratory flow during mechanical ventilation.

**inspiratory pressure** General term for the pressure at the patient connection during the inspiratory phase.

**inspiratory pressure change** The change in transrespiratory system pressure associated with delivery of the tidal volume as described in the equation of motion for the respiratory system. For pressure control modes, if inspiratory pressure is set relative to atmospheric pressure, the term “peak inspiratory pressure” is used to describe the setting. If inspiratory pressure is set relative to PEEP, the term “inspiratory pressure change” is used. See **equation of motion for the respiratory system, peak inspiratory pressure**

**inspiratory time** The period from the start of inspiratory flow to the start of expiratory flow. Inspiratory time equals inspiratory flow time plus inspiratory pause time.

**intelligent targeting scheme** A ventilator control system that uses artificial intelligence programs such as fuzzy logic, rule based expert systems, and artificial neural networks. Examples include the rule based system used by SmartCare (Dräger Evita XL ventilator) and IntelliVent-ASV (Hamilton S1 ventilator).

**intermittent mandatory ventilation** Breath sequence for which spontaneous breaths are permitted between mandatory breaths. For most ventilators, a short “window” is opened before the scheduled machine triggering of mandatory breaths to allow synchronization with any detected inspiratory effort on the part of the patient. This is referred to as synchronized IMV (or SIMV).

Three common variations of IMV are: (1) Mandatory breaths are always delivered at the set frequency; (2) Mandatory breaths are delivered only when the spontaneous breath frequency falls below the set frequency; (3) Mandatory breaths are delivered only when the spontaneous minute ventilation (ie, product of spontaneous breath frequency and spontaneous breath tidal volume) drops below a preset or computed threshold (aka Mandatory Minute Ventilation). Therefore, in contrast to CMV, with IMV the mandatory breath frequency can never be higher than the set rate but it may be lower.

For some modes (eg, Airway Pressure Release Ventilation), a short window is also opened at the end of the inspiratory time. Because spontaneous breaths are allowed during the mandatory pressure controlled breath, this window synchronizes the end of the mandatory inspiratory time with the start of spontaneous expiratory flow, if detected. With these technological developments, potential confusion arises as to whether inspiration that is synchronized (either start or stop) is considered patient triggered/cycled or machine triggered/cycled. If we say synchronized breaths are patient triggered and cycled, we have the awkward possibility of a spontaneous breath occurring during another spontaneous breath. This is avoided by distinguishing between a *trigger window* and a *synchronization window*.

There are some modes where the idea of IMV may be vague: With Airway Pressure Release Ventilation, relatively high frequency spontaneous breaths are superimposed on low frequency mandatory breaths. However, the expiratory time between mandatory breaths is often set so short that a spontaneous breath is unlikely to occur between them. Other ambiguous modes are High Frequency Oscillation, High Frequency Jet Ventilation, Intrapulmonary Percussive Ventilation and Volumetric Diffusive Respiration. With these modes, high frequency mandatory breaths are superimposed on low frequency spontaneous breaths and again, there is no possibility of a spontaneous breath actually occurring between mandatory breaths. Nevertheless, we classify all these modes as forms of IMV because spontaneous breaths can occur along with mandatory breaths and because spontaneous efforts do not affect the mandatory breath frequency. See **machine triggering, patient triggering, synchronization window, trigger window, continuous mandatory ventilation**

**load** The pressure required to generate inspiration (see elastic load and resistive load).

**machine cycling** Ending inspiratory time independent of signals representing the patient determined components of the equation of motion ( $P_{mus}$ , elastance, or resistance). Common examples are cycling due to a preset tidal volume or inspiratory time. If a patient signal (indicating expiration) occurs during an inspiratory time synchronization window, inspiration stops and is defined as a *machine cycled event* that ends a *mandatory breath*. See **machine triggering, patient triggering, synchronization window, trigger window, continuous mandatory ventilation, intermittent mandatory ventilation**

**machine triggering** Starting inspiratory flow based on a signal (usually time) from the ventilator, independent of a *patient trigger* signal. Examples include triggering based on a preset frequency (which sets the ventilatory period), or based on a preset minimum minute ventilation (determined by tidal volume divided by the ventilatory period). If a signal from the patient (indicating an inspiratory effort) occurs within a *synchronization window*, the start of inspiration is defined as a machine trigger event that begins a mandatory breath. See **machine cycling, patient triggering, synchronization window, trigger window, continuous mandatory ventilation, intermittent mandatory ventilation**

**mandatory breath** A breath for which the patient has lost control over timing. This means a breath for which the start or end of inspiration (or both) is determined by the ventilator, independent of the patient. That is, the machine triggers and/or cycles the breath. A mandatory breath can occur during a spontaneous breath (eg, High Frequency Jet Ventilation). A mandatory breath is, by definition, assisted. See **assisted breath, spontaneous breath**

**mandatory minute ventilation** A form of intermittent mandatory ventilation (IMV) in which the ventilator monitors the exhaled minute ventilation as a target variable. If the exhaled minute ventilation falls below the operator set value, the ventilator will trigger mandatory breaths or increase the inspiratory pressure until the target is reached.



**mechanical ventilator** An automatic machine designed to provide all or part of the work required to generate enough breaths to satisfy the body's respiratory needs.

**mode of ventilation** A predetermined pattern of interaction between a patient and a ventilator, specified as a particular combination of control variable, breath sequence, and targeting schemes for primary and secondary breaths.

**negative pressure ventilation** A type of assisted breathing for which transrespiratory pressure difference is generated by keeping airway pressure equal to atmospheric pressure and making body surface pressure less than atmospheric pressure. Examples would be ventilation with an "iron lung" or "chest cuirass".

**Neurally Adjusted Ventilatory Assist** The name of a mode using a servo targeting scheme in which the controller sets airway pressure to be proportional to patient effort based on the voltage recorded from diaphragmatic activity from sensors embedded in an orogastric tube:

$$P(t) = KE_{di}(t)$$

where  $P(t)$  is inspiratory pressure relative to end expiratory pressure as a function of time,  $t$ ,  $K$  is the NAVA support level (an amplification factor),  $E_{di}(t)$  is the electrical signal from the diaphragm as a function of time. The operator inputs the constant of proportionality between voltage and pressure (gain). Then the controller sets airway pressure to equal the product of gain and the  $E_{di}$ .

**optimal targeting scheme** A ventilator control system that automatically adjusts the targets of the ventilatory pattern to either minimize or maximize some overall performance characteristic. One example is Adaptive Support Ventilation (Hamilton Medical G5 ventilator) in which the ventilator adjusts the mandatory tidal volume and frequency (for a passive patient) in such a way as to minimize the work rate of ventilation.

**partial ventilatory support** the ventilator and the respiratory muscles each provide some of the work of breathing; muscle pressure adds to ventilator pressure in the equation of motion.

**patient cycling** Ending inspiratory time based on signals representing the patient determined components of the equation of motion, ( $P_{mus}$ , elastance, or resistance). Common examples of cycling variables are peak inspiratory pressure and percent inspiratory flow. See **machine triggering, machine cycling, patient triggering, synchronization window, trigger window, continuous mandatory ventilation, intermittent mandatory ventilation**

**patient triggering** Starting inspiration based on a patient signal occurring in a *trigger window*, independent of a *machine trigger* signal. The signal is related to one of the patient determined components of the equation of motion ( $P_{mus}$ , elastance, or resistance). Common examples of patient trigger variables are airway pressure drop below baseline

and inspiratory flow due to patient effort. See **machine triggering, machine cycling, synchronization window, trigger window, continuous mandatory ventilation, intermittent mandatory ventilation**

**PC-CMV** Pressure controlled continuous mandatory ventilation.

**PC-IMV** Pressure controlled intermittent mandatory ventilation.

**PC-CSV** Pressure controlled continuous spontaneous ventilation.

**peak airway pressure** The maximum airway pressure during a mechanically assisted inspiration, measured relative to atmospheric pressure.

**peak inspiratory pressure** The inspiratory pressure change that is set relative to atmospheric pressure during pressure control modes. See **inspiratory pressure change**

**PEEP** Positive end expiratory pressure; the value of transrespiratory system pressure at end expiration. See **CPAP**

**positive pressure ventilation** A type of assisted breathing for which transrespiratory pressure difference is generated by raising airway pressure above body surface pressure (usually equal to atmospheric pressure). Examples would be ventilation with intensive care or transport ventilators.

**pressure** A measure of force per unit of area at a particular point in space.

**pressure change** The difference between pressure (or pressure gradient) measured at one point in time and the same pressure measured at a previous point in time.

**pressure gradient** The difference between pressure measured at one point in space and another point in space. Examples include the pressure difference across a cell membrane causing gas diffusion into the cell and the pressure difference across the respiratory system causing flow into the lungs. See **transairway pressure, transalveolar pressure, transthoracic pressure, transpulmonary pressure, transrespiratory pressure, transthoracic pressure**

**pressure control** A general category of ventilator modes for which pressure delivery is predetermined by a targeting scheme such that inspiratory pressure is either proportional to patient effort or has a particular waveform regardless of respiratory system mechanics. When inspiratory pressure is preset, we further specify that inspiration must start out with the preset pressure to avoid confusion with dual targeting that may switch from a preset flow to a preset pressure (eg, Pmax feature used with volume control modes on the Dräger Evita Infinity V500 ventilator). See **dual targeting scheme**. According to the equation of motion, pressure control means that inspiratory pressure is predetermined as the independent variable so that volume and flow become the dependent variables. See **volume control** and **equation of motion**.

**pressure cycling** Inspiration ends (ie, expiratory flow starts) when airway pressure reaches a preset threshold.

**Pressure Support:** The name of a mode using a set-point targeting scheme in which all breaths are pressure or flow triggered, pressure targeted, and flow cycled.

**pressure triggering** The starting of inspiratory flow due to a patient inspiratory effort that generates an airway pressure drop below end expiratory pressure larger than a preset threshold (ie, the trigger sensitivity setting).

**pressure target** Inspiratory pressure reaches a preset value before inspiration cycles off.

**primary breaths** Mandatory breaths during CMV or IMV or spontaneous breaths during CSV.

**Proportional Assist Ventilation (PAV)** The name of a mode using a servo targeting scheme based on the equation of motion for the respiratory system in the form:

$$P(t) = K_1V(t) + K_2\dot{V}(t)$$

where inspiratory pressure relative to end expiratory pressure as a function of time  $P(t)$  is the sum of two components. The first is the “volume assist” or the amount of elastic load supported, ie,  $K_1$  times volume as a function of time  $V(t)$ . The second component is the “flow assist” or the amount of resistive load supported, ie,  $K_2$ , times flow as a function of time,  $\dot{V}(t)$ . The values of  $K_1$  and  $K_2$  are preset by the operator and represent the supported elastance and resistance, respectively, whereas volume and flow are generated by the patient. Because volume and flow are initiated by the patient’s inspiratory effort created by muscle pressure,  $P_{\text{mus}}$ , the pressure generated by PAV can be thought of as an amplifier of  $P_{\text{mus}}$ .

**ramp** A mathematical function whose value rises or falls at a constant rate. Ascending (rising) or descending (falling) functions are sometimes used for inspiratory flow in volume control modes.

**resistance** A mechanical property of a structure such as the respiratory system; a parameter of a lung model, or setting of a lung simulator; defined as the ratio of the change in the pressure difference across the system to the associated change in flow.

**resistive load** The pressure difference applied across a system (e.g., a container) that is related to a rate of change of the system’s volume and/or the flow of fluid within or through the system. (For a linear system: resistance x flow, or, resistance x rate of change of volume; for a container, the effective resistance includes the mechanical (usually viscous) resistances of its structural components and the flow resistance of the fluid [gas or liquid] within it.)

**secondary breaths** Spontaneous breaths during IMV.

**sensitivity** The sensitivity setting of the ventilator is a threshold value for the trigger variable which, when met, starts inspiration. In other words, the sensitivity is the amount the trigger variable must change to start inspiratory flow. Sensitivity is sometimes used to refer to the cycle threshold.

**servo targeting** A control system for which the output of the ventilator automatically follows a varying input. For example, the Automatic Tube Compensation feature on the Dräger Evita 4 ventilator tracks flow and forces pressure to be equal to flow squared and multiplied by a constant (representing endotracheal tube resistance). Other examples include Proportional Assist Ventilation (Covidien PB 840 ventilator; pressure is proportional to spontaneous volume and flow) and Neurally Adjusted Ventilatory Assist (Maquet Servo-i ventilator; pressure is proportional to diaphragmatic electrical activity). For all three of these example modes airway pressure is effectively proportional to the patient's inspiratory effort.

**set-point targeting** A control system for which the operator sets all the parameters of the pressure waveform (pressure control modes) or volume and flow waveforms (volume control modes). Advanced volume control modes actually allow the ventilator to make small adjustments to the set inspiratory flow to compensate for such factors as patient circuit compliance. From an engineering point of view, this is adaptive feedback control, but from a ventilator mode taxonomy point of view, such adjustments are better seen as a way of implementing operator preset values, and thus classified as set-point targeting.

**sinusoid** A mathematical function having a magnitude that varies as the sine of an independent variable (eg time). A sinusoidal function is sometimes used for inspiratory flow in volume control modes.

**spontaneous breath** A breath for which the patient retains substantial control over timing. This means the start and end of inspiration may be determined by the patient, independent of any machine settings for inspiratory time and expiratory time. That is, the patient both triggers and cycles the breath. Note that use of this definition for determining the breath sequence (ie, CMV, IMV, CSV) assumes normal ventilator operation. For example, coughing during VC-CMV may result in patient cycling for a patient triggered breath due to the pressure alarm limit. While inspiration for that breath is both patient triggered and patient cycled, this is not normal operation and the sequence does not turn into IMV. A spontaneous breath may occur during a mandatory breath (eg Airway Pressure Release Ventilation). A spontaneous breath may be assisted or unassisted. See **assisted breath, mandatory breath**

**synchronized IMV (SIMV)** A form of IMV in which mandatory breath delivery is coordinated with patient effort. A synchronized breath is considered to be machine triggered. See **intermittent mandatory ventilation**

**synchronization window** A short period, at the end of a preset expiratory time or at the end of a preset inspiratory time, during which a patient signal may be used to synchronize a mandatory breath trigger or cycle event to a spontaneous breath. If the patient signal occurs during an expiratory time synchronization window, inspiration starts

and is defined as a *machine triggered* event. This is because the mandatory breath would have been time triggered regardless of whether the patient signal had appeared or not and because the distinction is necessary to avoid logical inconsistencies in defining mandatory and spontaneous breaths which are the foundation of the mode taxonomy. If inspiration is triggered in a synchronization window, the actual ventilatory period for the previous breath will be shorter than the set ventilatory period (determined by the set mandatory breath frequency). Some ventilators add the lost time to the next mandatory breath period to maintain the set frequency. Sometimes a synchronization window is used at the end of the inspiratory time of a pressure controlled, time cycled breath. If the patient signal occurs during such an inspiratory time synchronization window, expiration starts and is defined as a *machine cycled* event. Some ventilators offer the mode called Airway Pressure Release Ventilation (or something similar with a different name) that makes use of both expiratory and inspiratory synchronization windows. See **intermittent mandatory ventilation, machine triggering, patient triggering, trigger window.**

**tag** A mode classification. A tag can be an acronym. For example the mode named Volume A/C is classified as volume control (VC) continuous mandatory ventilation (CMV) with set-point targeting (s) and can be represented as VC-CMV<sub>s</sub>. Another example (using both primary and secondary breaths) would be PRVC SIMV classified as PC-IMV<sub>a,s</sub>, where the primary breath uses adaptive targeting (a) and the secondary breath uses set-point targeting (s). The mode named Adaptive Support Ventilation has multiple targeting for each type of breath (ie, both optimal, o, and intelligent, i). It is classified as PC-IMV<sub>oi,oi</sub>.

**target** A predetermined goal of ventilator output. Targets can be viewed as the goals of the targeting scheme. *Within-breath targets* are the parameters of the pressure, volume, or flow waveform. Examples of within-breath targets include inspiratory flow or pressure and rise time (set-point targeting), tidal volume (dual targeting) and constant of proportionality between inspiratory pressure and patient effort (servo targeting). Note that preset values *within a breath* that end inspiration, such as tidal volume, inspiratory time, or percent of peak flow, are also cycle variables. *Between-breath targets* serve to modify the within-breath targets and/or the overall ventilatory pattern. Between-breath targets are used with more advanced targeting schemes, where targets act over multiple breaths. Examples of between-breath targets and targeting schemes include average tidal volume (for adaptive targeting), percent minute ventilation (for optimal targeting) and combined PCO<sub>2</sub>, volume, and frequency values describing a “zone of comfort” (for intelligent targeting).

**targeting scheme** A model of the relationship between operator inputs and ventilator outputs to achieve a specific ventilatory pattern, usually in the form of a feedback control system. The targeting scheme is a key component of a mode description.

**taxonomy** A hierarchical classification system. A taxonomy for modes of ventilation has four levels: 1) the control variable, 2) the breath sequence; 3) the targeting scheme for primary breaths and ; 4) the targeting scheme for secondary breaths. These levels

correspond to the levels of Family, Class, Genus, and Species of the Linnaean taxonomy used in biology.

**TC-IMV** Time controlled intermittent mandatory ventilation (eg, High Frequency Oscillatory Ventilation or Intrapulmonary Percussive Ventilation).

**tidal volume** The volume of gas, either inhaled or exhaled, during a breath. The maximum value of the volume vs time waveform.

**time cycling** Inspiratory time ends after a preset time interval has elapsed. The most common examples are a preset inspiratory time or a preset inspiratory pause time.

**time constant** The time at which an exponential function attains 63% of its steady state value in response to a step input; the time necessary for inflated lungs to passively empty by 63%; the time necessary for the lungs to passively fill 63% during pressure controlled ventilation with a rectangular pressure waveform. The time constant for a passive mechanical system is calculated as the product of resistance and compliance and has units of time (usually expressed in seconds). Passive inhalation or exhalation is virtually complete after 5 time constants.

**time control** A general category of ventilator modes for which inspiratory flow, inspiratory volume, and inspiratory pressure are all dependent on respiratory system mechanics. As no parameters of the pressure or flow waveform are preset, the only control of the breath is the timing, ie, inspiratory and expiratory times. Examples of this are high frequency oscillatory ventilation (CareFusion 3100 ventilator) and Volumetric Diffusive Respiration (Percussionaire).

**tidal pressure** the change in trans-alveolar pressure (i.e., pressure in the alveolar region minus pressure in the pleural space, equivalent to elastance times volume in the equation of motion) associated with the inhalation or exhalation of a tidal volume.

**total cycle time** Same as ventilatory period, the sum of inspiratory time and expiratory time.

**total PEEP** The sum of autoPEEP and intentionally applied PEEP or CPAP. Synonymous with intrinsic PEEP.

**time triggering** The starting of inspiratory flow due to a preset time interval. The most common example is a preset ventilatory frequency.

**total ventilatory support** The ventilator provides all the work of breathing; muscle pressure in the equation of motion is zero. This is normally only possible if the patient is paralyzed or heavily sedated.

**transairway pressure** Pressure at the airway opening minus pressure in the lungs (i.e., alveolar pressure).

**transalveolar pressure** Pressure in the lungs minus pressure in the pleural space. Equal to transpulmonary pressure only under static conditions.

**transchestwall pressure** Pressure in the pleural space minus pressure on the body surface.

**transpulmonary pressure** Pressure at the airway opening minus pressure in the pleural space.

**transrespiratory pressure** Pressure at the airway opening minus pressure on the body surface; equal to the sum of transairway pressure plus transalveolar pressure plus transchestwall pressure.

**transthoracic pressure** Pressure in the lungs minus pressure on the body surface; equal to the sum of transalveolar pressure plus transchestwall pressure

**trigger (triggering)** To start the inspiratory time. See **machine triggering, patient triggering**

**trigger variable** The variable (usually pressure, volume, flow, or time) that is used to start the inspiratory time.

**trigger window** The period comprised of the *entire expiratory time* minus a short “refractory” period required to reduce the risk of triggering a breath before exhalation is complete. If a signal from the patient (indicating an inspiratory effort) occurs within this trigger window, inspiration starts and is defined as a *patient triggered* event. See **intermittent mandatory ventilation, machine triggering, patient triggering, synchronization window**

**ventilatory pattern** A sequence of breaths (CMV, IMV, or CSV) with a designated control variable (volume or pressure) for the mandatory breaths (or the spontaneous breaths for CSV).

**ventilatory period** The time from the start of inspiratory flow of one breath to the start of inspiratory flow of the next breath; inspiratory time plus expiratory time; the reciprocal of ventilatory frequency. Also called total cycle time or total breath cycle.

**volume control** A general category of ventilator modes for which *both* inspiratory flow and tidal volume are predetermined by a targeting scheme to have particular waveforms independent of respiratory system mechanics. Usually, flow and tidal volume may be set directly by the operator. Alternatively, the ventilator may determine tidal volume based on operator preset values for frequency and minute ventilation or the ventilator may determine inspiratory flow based on operator set tidal volume and inspiratory time. When inspiratory volume and flow are preset, we further specify that inspiration must start out with the preset flow to avoid confusion with dual targeting that may switch from a preset pressure to a preset flow and volume (eg. Volume Assured Pressure Support). See **dual targeting scheme**. Note that setting tidal volume is a necessary but not sufficient criterion for volume control. The reason is that some ventilators use pressure control with

adaptive targeting and allow the operator to set a tidal volume but not an inspiratory flow. In this case, the tidal volume setting refers to the between-breath tidal volume target, not a within-breath target. See **adaptive targeting scheme**. Likewise, setting inspiratory flow is also a necessary but not sufficient criterion for volume control. For example, the Bird Mark 7 ventilator requires an inspiratory flow setting but has no tidal volume setting. Instead the operator sets the inspiratory pressure, which is also the cycle variable. Hence, breaths are pressure controlled, and changing lung mechanics change the rate of pressure rise, the inspiratory time, and hence the delivered tidal volume as in other examples of pressure control. According to the equation of motion, volume control means that both volume and flow are predetermined as the independent variables and pressure is thus the dependent variable. See **pressure control** and **equation of motion**.

**volume cycling** Inspiratory time ends when inspiratory volume reaches a preset threshold (ie, tidal volume).

**VC-CMV** Volume controlled continuous mandatory ventilation.

**VC-IMV** Volume controlled intermittent mandatory ventilation.

**volume target** A preset value for tidal volume that the ventilator is set to attain either within a breath or as an average over multiple breaths.

**volume triggering** The starting of inspiratory flow due to a patient inspiratory effort that generates an inspiratory volume signal larger than a preset threshold (ie, the trigger sensitivity setting).

**work of breathing** The general definition of work is the integral of pressure with respect to volume during an assisted inspiration. There are two general components of work related to mechanical ventilation. One kind is the work performed by the ventilator on the patient, which is reflected by a positive change in airway pressure above baseline during inspiration. The second component is the work the patient does on the ventilator to (eg, to trigger inspiration), which is reflected by a negative change in airway pressure below baseline during inspiration.