revised and 3rd extended Edition

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The Kronberg List of Ventilation Modes

Part 2: Measurement values, Indices

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Measurement Values and Indices

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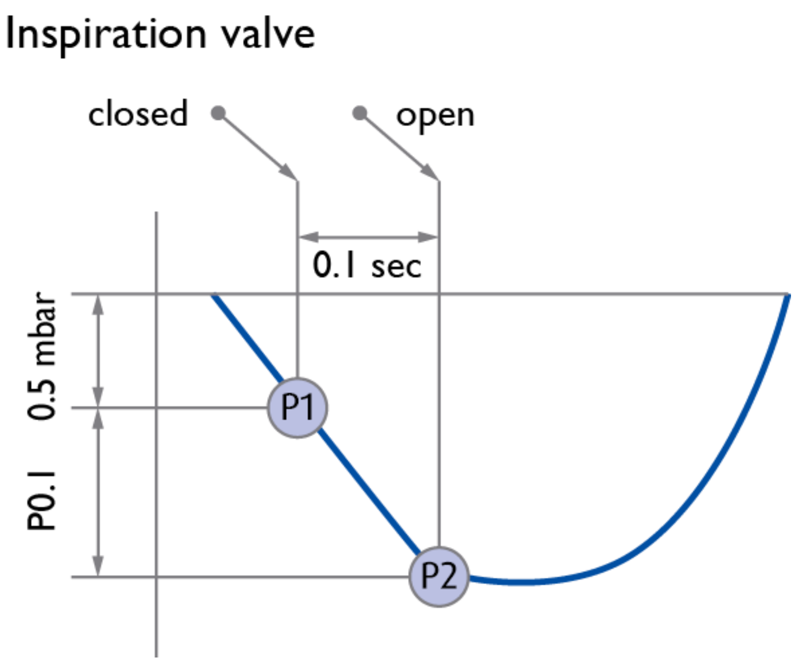
P.01: Occlusion Pressure Measurement



Airway occlusion pressure (P0.1) is regarded as a measure of the central ventilatory drive that controls spontaneous breathing.

Measurements are used to predict successful weaning, and in order to obtain an estimate of breathing effort. Often, P0.1 is used in addition to other para-meters to help determine the settings for pressure support in spontaneously breathing patients, and to determine the point at which a patient might require mandatory ventilatory support.

RSBI: Rapid Shallow Breathing Index

$$\frac{\text{Respiratory rate /min}}{\text{tidal volume (L)}}$$

The rapid shallow breathing index (RSBI) is considered a good weaning indicator with high predictive value of a successful outcome. The RSBI is calculated by dividing the patient's spontaneous respiratory rate per minute by the measured tidal volume (in litres).

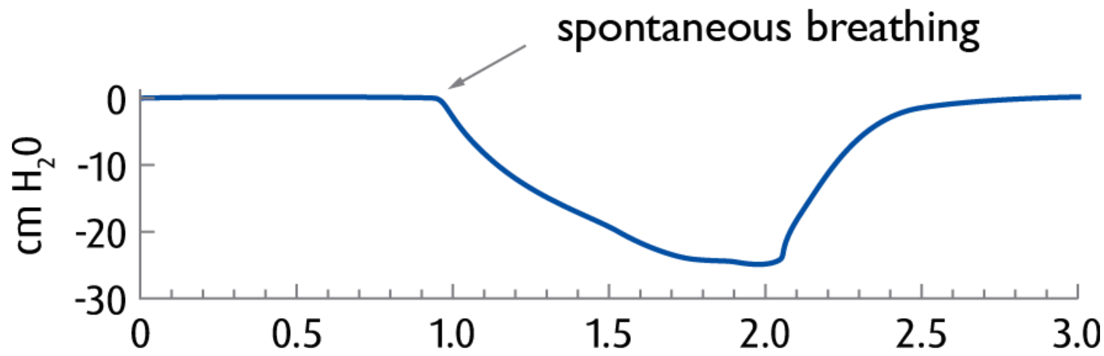
Examples:

f = 25 Vt= 0.25 → RSBI = 100

f = 30 Vt= 0.35 → RSBI = 85.7

f = 30 Vt= 0.25 → RSBI = 120

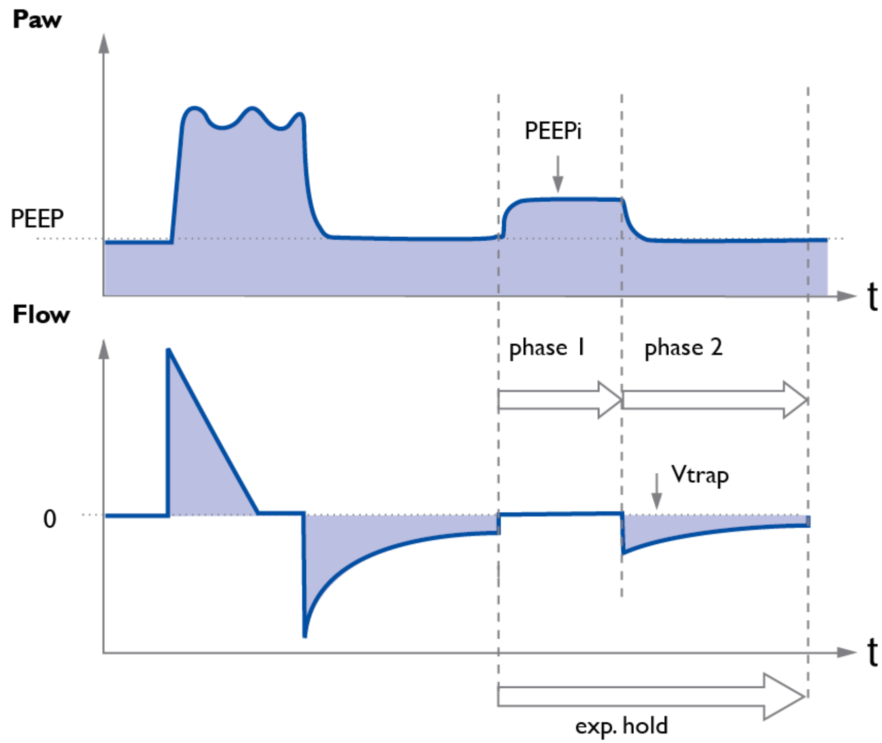
MIP: Maximum Inspiratory Pressure



Another weaning indicator used is maximum inspiratory pressure (MIP), which provides information on the patient's current maximum respiratory muscle strength. MIP is also often referred to as negative inspiratory force (NIF).

MIP measures the maximum inspiration effort produced after a prolonged expiratory phase (expiratory hold manoeuvre) and against an occlusion. Despite being considered controversial, this indicator value is used in clinical practice, particularly in patients with neuromuscular disorders.

PEEPi (intrinsic PEEP)



Irrespective of the adjustable PEEP level, a functional PEEP may be effective, which is generated by incomplete expiration. Reasons for this may be obstructions, short expiratory phases, or slowly ventilated areas of the lung, and this condition may also result from inverse ration ventilation (IRV). The functional PEEP, often referred to as Auto PEEP, can be measured in a multi-level PEEPi measurement and the trapped volume can be determined. The measurement is part of the expiratory hold manoeuvre.

RCexp: Expiratory Time Constant

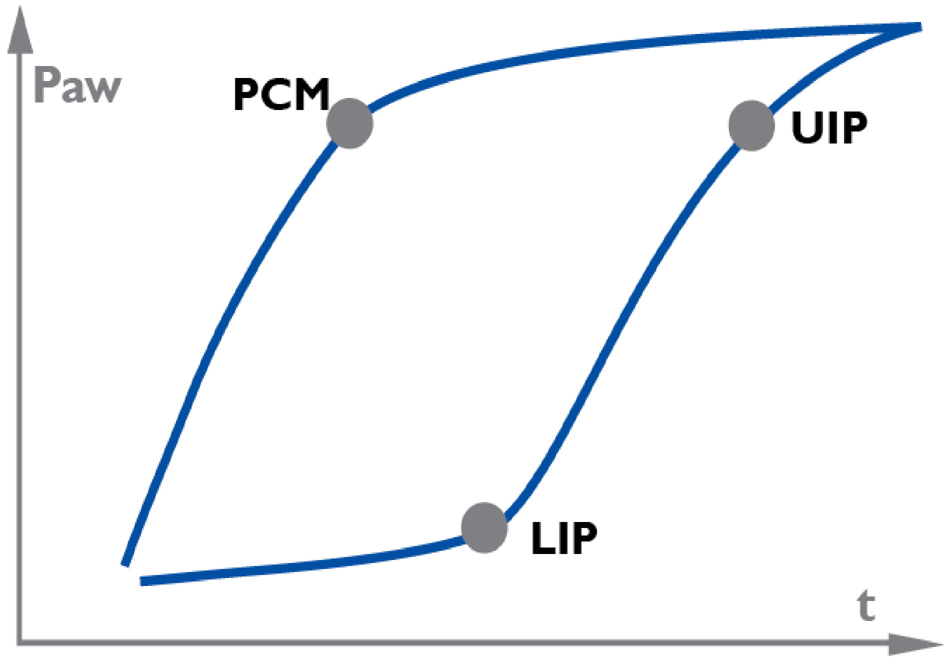
$$\frac{0.75 \times Vt}{\text{flow in ml/s}}$$

Aside from an evaluation of both pressure-flow curve and PEEPi measurements, this mode also offers the expiratory time constant (RCexp) as a method of detecting air-trapping (Auto-PEEP). Another option is to calculate the total expiratory time required. This involves calculating the ratio between the expiratory tidal volume and the expiratory flow rate, and expiratory time.

RCexp provides information on end-expiratory volume as a percentage of total lung volume:

- After RCexp x 1 approx. 63% of the lung volume has been emptied
- After RCexp x 2 approx. 86.5% of the lung volume has been emptied
- After RCexp x 3 approx. 95% of the lung volume has been emptied
- After RCexp x 4 approx. 98% of the lung volume has been emptied

Inflection Points: LIP / UIP / PMC (Part 1)



A manoeuvre can be performed to obtain a representation of the respiratory mechanics of the lung in the form of a pressure-volume curve. The following inflection points can be established in most cases:

Inflection Points: LIP / UIP / PMC (Part 2)

LIP: Lower Inflection Point:	First point of maximum curvature of the pressure-volume curve where the lungs' opening pressure is exceeded.
UIP: Upper Inflection Point:	Second point of maximum curvature of the pressure-volume curve where the limit of lung compliance is reached.
PMC: Point of maximum curvature	Point of maximum curvature prob-ably indicates required PEEP to maintain recruitment.

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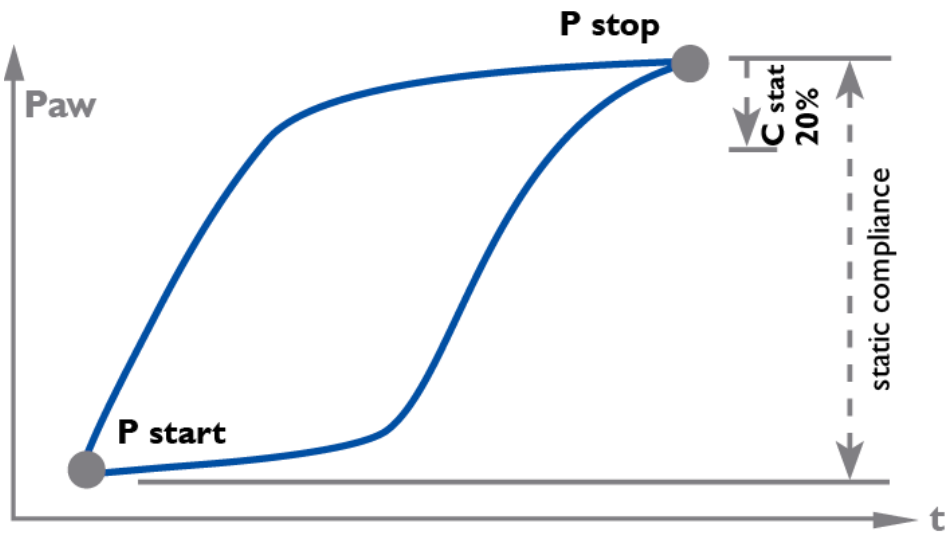
Possible applications:

Setting PEEP based on lower inflection point: LIP	**LIP** = required PEEP + (0 to 2 mbar)
Limiting plateau pressure and maximum volume based on the upper inflection point: UIP	**UIP** = maximum plateau pressureor maximum inspiratory pressure
Setting PEEP based on point of maximum cur-vature PMC	**PMC** = necessary PEEP

C20/C Index



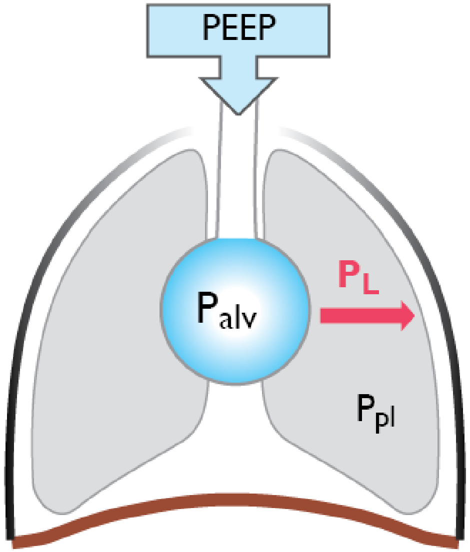
The stress index **C20/C** is calculated on the basis of the individual PEEPfinder measurements.

This 'overdistension index' is calculated during inspiration; it results from the compliance ratio of the final 20 % of the static compliance and the measured compliance between P start and P stop.
An index below 0.8 may be indicative of an overdistended lung.

TPP exp: end-expiratory transpulmonary pressure (Stress)

The oesophageal pressure can be measured by means of a modified gastric tube (PESO balloon catheter) and used to calculate the transpulmonary pressure.

The end-expiratory transpulmonary pressure TPP exp (alveolar pressure -– pleural pressure) can subsequently be adapted by titration of the applied PEEP because a correlation exists between the airway pressure and the applied PEEP. Titrating the applied PEEP to the end-expiratory transpulmonary pressure between 0 and 10 cmH2O or at least to a value in the positive range can reduce the cyclic occurrence of alveolar collapse.

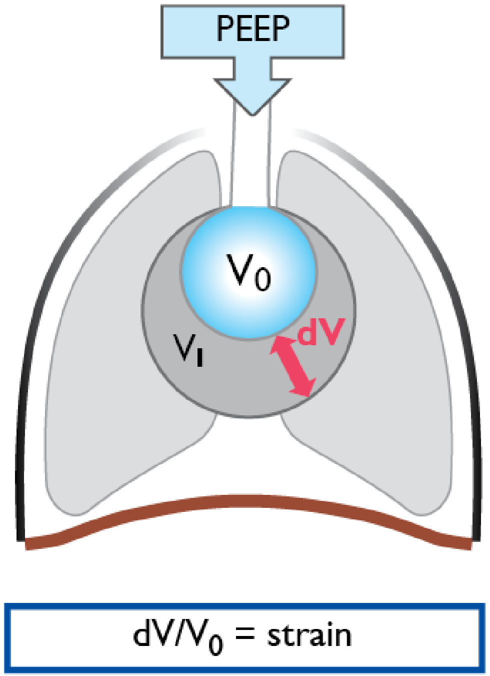


$$P_{transpulm}\ (P_L) = P_{alv} - P_{pl}$$

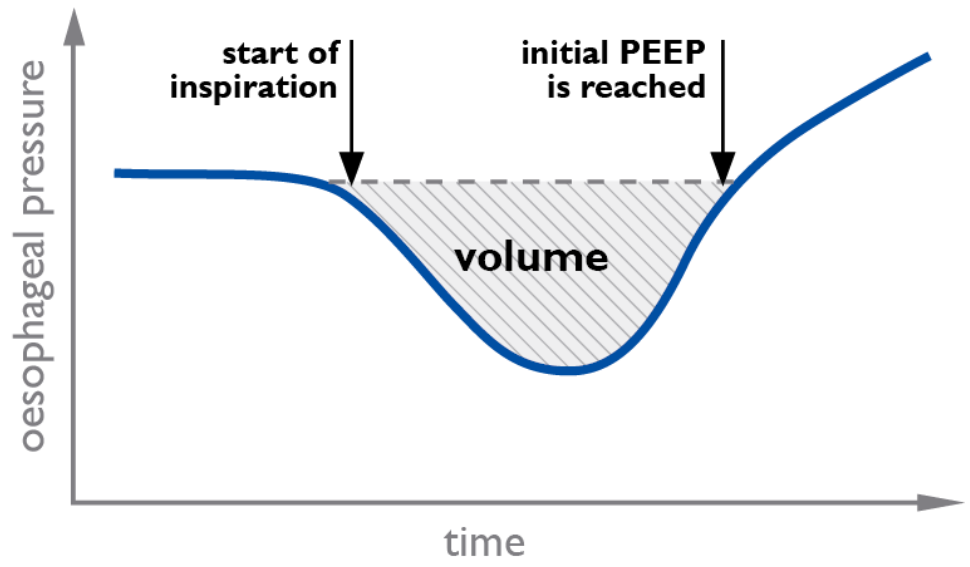
$P_L \approx$ stress

TPP insp: end-inspiratory transpulmonary pressure (Strain)

The end-inspiratory transpulmonary pressure TPP insp (plateau pressure – pleural pressure) can reduce alveolar overdistension and thus help to set the ideal tidal volume or inspiratory pressure. Depending on the clinical status, the target range is between 12 and 20 cmH2O.



WOB: Work of Breathing



The work of breathing (WOB) is the amount of energy (∫ pressure x volume) necessary to accomplish the act of breathing and, eventually, the energy required to overcome the mechanical resistance, which is basically the resistance to flow and the airway resistance.
In spontaneously breathing patients, it is possible to measure the work of breathing on the basis of the oesophageal pressure, a surrogate for pleural pressure, breath by breath.

Characteristics of the Chatburn Taxonomy (Part 1)

In 2015, Robert L. Chatburn published a comprehensive taxonomy that facilitates the classification of ventilation modes. Ten fundamental maxims were established allowing users to compare the different modes, select the most suitable mode and assess the efficiency of the control algorithm with respect to the goal of the therapy.

(1) A breath is one cycle of positive flow (inspiration) and negative flow (expiration) defined in terms of the flow vs time curve.
(2) A breath is assisted if the ventilator provides some or all of the work of breathing within a time window.
(3) A ventilator assists breathing using either pressure control or volume control.
(4) Breaths are classified according to the criteria that trigger (start) and cycle (stop) inspiration.

Characteristics of the Chatburn Taxonomy (Part 2)

(5) Trigger and cycle events can be either patient-initiated (triggered) or ventilator-initiated (e.g., time-cycled).

(6) Breaths are classified as spontaneous or mandatory based on both the trigger and cycle events.

(7) Ventilation modes are based on three basic breath sequences: CMV, IMV and CSV.

(8) The basic breath sequences can be delivered in the form of five basic ventilatory patterns: VC-CMV, VC-IMV, PC-CMV, PC-IMV and PC-CSV.

(9) Within each ventilatory pattern, there are several types that can be distinguished by their targeting schemes.

(10) A mode of ventilation is classified according to its control variable, breath sequence and targeting schemes.

Characteristics of the Chatburn Taxonomy (Part 3)

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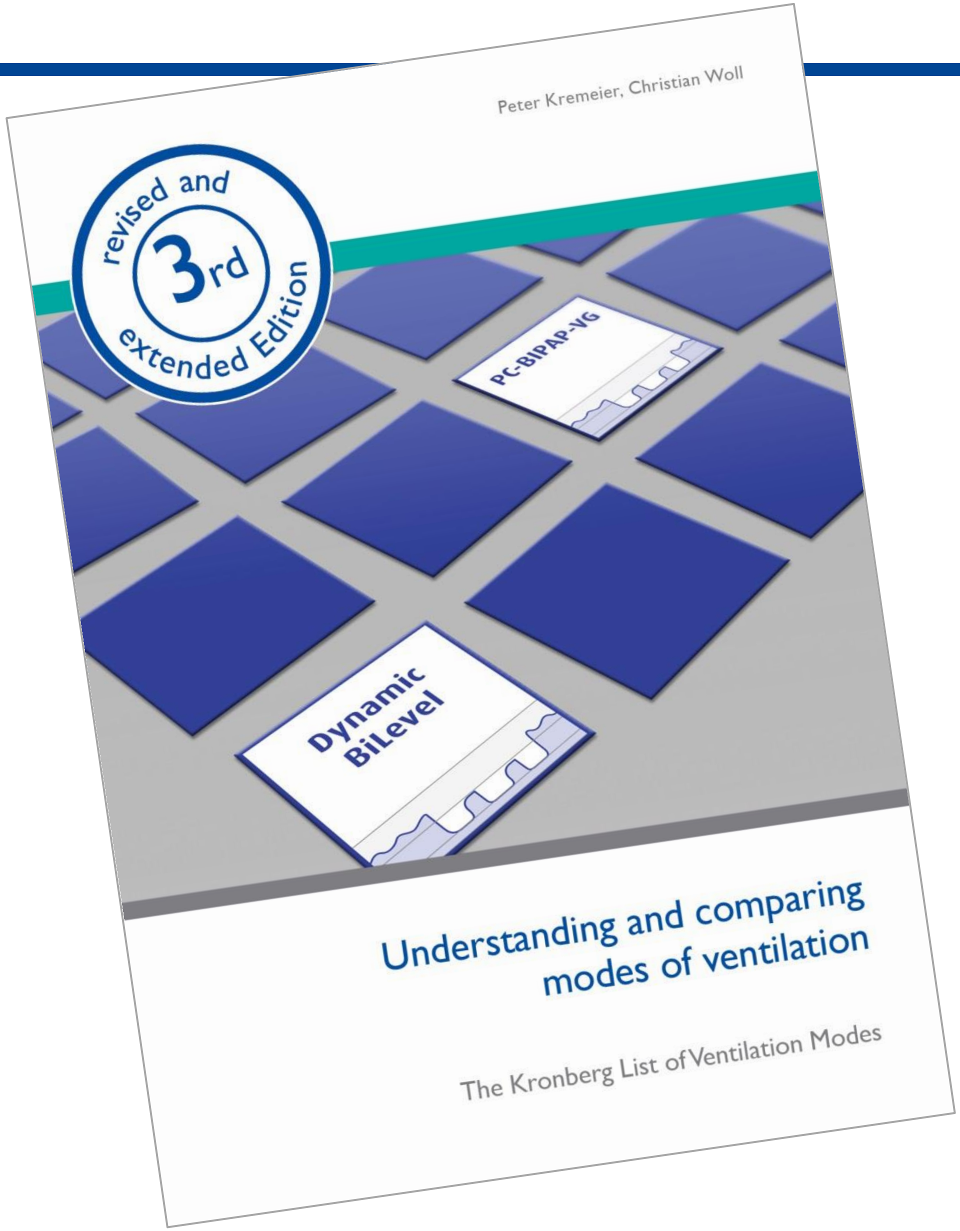
Targeting schemes:

set-point	s	The pressure ramp (pressure-controlled modes) or the flow pattern (volume-controlled modes) is set.
dual	d	The ventilator switches automatically between volume control and pressure control.
servo	r	The pressure support is proportional to the inspiratory effort.
adaptive	a	In response to the changing patient status, the ventilator automatically adapts one target or more between two breaths.
bio-variable	b	The ventilator sets the inspiratory pressure or the tidal volume randomly to mimic the variability observed during normal breathing.
optimal	o	The ventilator adjusts the targets of the ventilatory pattern to achieve an overall performance characteristic (e.g., optimising the work of breathing).
intelligent	i	The control algorithms include artificial intelligence programs, such as rule-based expert systems or artificial neural networks.



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Any questions?

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