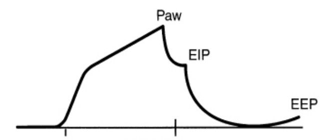
pulmonary mechanics

general

- Assessment of pulmonary mechanics is crucial to monitoring pulmonary function during artificial ventilation.
- It requires the measurement of VT, peak inspiratory flow rate, peak airway pressure, end-inspiratory plateau pressure, end-expiratory pressure in the circuit, and any occult end-expiratory pressure measured during an end-expiratory pause maneuver.
- From these variables, the compliance and resistance of the respiratory system are determined.

compliance



Depiction of a scalar (time) waveform of peak airway pressure (Paw) during constant volume mechanical ventilation with a square wave of inspiratory flow. As inspiration commences, the abrupt increase in flow against the resistance of the patient-ventilator circuit results in an immediate pressure step that is proportional to both the flow rate and the resistance. The slope in the pressure-time curve reflects the rate rise in alveolar pressure and provides qualitative information about the dynamic compliance of the respiratory system (lungs and chest wall). The introduction of an end-inspiratory pause-hold results in dissipation of Paw down to a stable end-inspiratory plateau pressure (EIP), which reflects the elastic recoil pressure of the respiratory system. Release of the pause-hold expels the tidal volume (V_T), and pressure is released down to the baseline end-expiratory pressure (EEP). Dividing V_T by EIP - EEP yields the quasi-static compliance of the respiratory system, whereas dividing the inspiratory flow rate by Paw - EIP yields the resistance of the respiratory system.

- Under conditions of passive mechanical ventilation, peak airway pressure denotes the total force necessary to overcome the resistive and elastic recoil properties of the respiratory system (i.e., both lungs and chest wall).

- Distinguishing the resistive from the elastic recoil-related pressures requires introduction of an end-inspiratory circuit occlusion after VT delivery. During the end-inspiratory pause, peak airway pressure dissipates down to a stable plateau pressure. After a 3-second pause-hold, "quasi-static" conditions usually exist, so that the corresponding plateau pressure represents the elastic recoil pressure. Dividing the VT by the plateau pressure (Pplat) minus the PEEP yields the "quasi-static" compliance of the respiratory system (Crs-stat)
- During patient-triggered ventilation, the assessment of pulmonary mechanics becomes uncertain. Clinically, the pause time is decreased to 0.5 to 1 second, to limit any potential artifact from spontaneous breathing efforts that may falsely raise or lower the plateau pressure.

$$\text{Crs-stat} = \frac{V_T}{\text{Pplat} - \text{PEEPtot}}$$

resistance

- Respiratory system resistance (Rrs) is the ratio of driving pressure to flow and is calculated as the difference between the peak airway pressure (Paw) and the end-inspiratory plateau pressure (Pplat) divided by the preocclusion peak inspiratory flow rate ([Vdot] I) and expressed as cm H2O/L per second:

$$\text{Rrs} = \frac{\text{Paw} - \text{Pplat}}{\dot{V}_I}$$

- Resistance is flow dependent, because the driving pressure necessary to overcome resistance increases disproportionately to changes in [Vdot]I (due to increased turbulence). Therefore, respiratory system resistance can be accurately determined only with a constant inspiratory flow (square wave) pattern. Because resistance is expressed as cm H2/L per second, a [Vdot]I of 60 L/min (1 L/sec) is a convenient setting to measure resistance, and it also happens to be a standard setting for patient comfort.

intrinsic PEEP

- At end-expiration, if the respiratory system remains above its relaxed position, the elastic recoil pressure in the lung is positive. This is referred to as intrinsic PEEP.
- Intrinsic PEEP is measured by an end-expiratory circuit occlusion whereby, after a normal expiratory time elapses, both the inspiratory and expiratory ventilator valves close for 3 to 5 seconds, allowing alveolar pressure to equilibrate with airway pressure

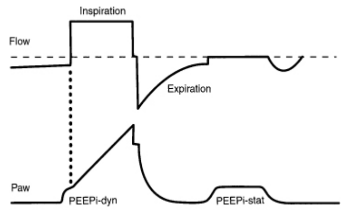


Figure 60-3 Simultaneous scalar waveforms of flow and peak airway pressure (Paw) illustrate the clinical measurement and separation of dynamic from static measurements of intrinsic positive end-expiratory pressure (PEEPi). Dynamic measurements reflect the lowest level of PEEPi in the respiratory system and are measured as the positive Paw just before inspiratory flow begins. The maximal level of PEEPi is the pressure plateau measured during an end-expiratory pause-hold.

- Intrinsic PEEP is common in mechanically ventilated patients with various lung diseases. Patients with ARDS or cardiogenic pulmonary edema tend to have markedly lower levels of intrinsic PEEP (3 to 4 cm H2O) compared with patients with chronic obstructive lung diseases (14 cm H2O).

pressure - volume curves

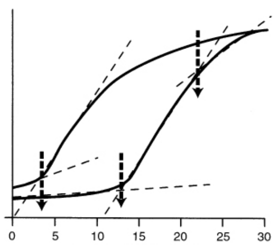


Figure 60-5 Graphic technique for determining the lower and upper inflection points of the pressure-volume curve. Tangents are drawn, extending the slopes of the various compliance segments of the curve. Where the tangents intersect, a third tangent is dropped down to the horizontal axis *(arrows)*.

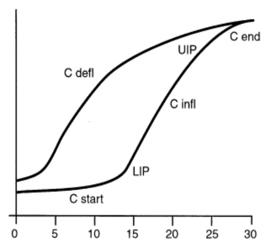


Figure 60-4 Static pressure-volume relationship (curve) of the respiratory system depicted from below functional residual capacity to total lung capacity. Cdefl, deflation compliance; Cend, end compliance; Cinfl, inflation compliance; Cstart, starting compliance; LIP, lower inflection point; UIP, upper inflection point.

- The static pressure-volume relationship is used to analyze the elastic properties of the respiratory system

- There are two general approaches for measuring the P-V curve: the step method and the pulse method.
(i) the step method:
- In the step method, the chest is passively inflated (and then deflated) in small-volume steps with a calibrated supersyringe over a volume range of 1.5 to 2 L. Volume steps are plotted against the corresponding static pressure points on graph paper to obtain the curve.
- Measurements require a short-acting neuromuscular blocking agent and sedation to ensure complete passive ventilation
(ii) The pulse method:
- based on the principle that when a low, constant flow of gas is injected into the lungs, volume change is proportional to time, so that direct volume measurement is unnecessary.

- Typically, PEEP is set 2 cm H2O above the lower inflection point to ensure optimal lung recruitment, and VT is set below the upper inflection point to prevent lung injury from excessive stretch.

compliance & resistance in normal & pathological states

- In mechanically ventilated, normal patients, compliance is 57 to 85 mL/cm H2O, and resistance is 1 to 8 cm H2O/L per second.
- Patients with ARDS or cardiogenic pulmonary edema tend to have a low compliance (35 or 44 mL/cm H2O, respectively) and an elevated resistance (12 or 15 cm H2O/L per second, respectively).
- In contrast, patients with chronic airway obstruction tend to have both a higher compliance (66 mL/cm H2O) and a higher resistance (26 cm H2O/L per second).