Deriving the full EOM

Equation of Motion

Airway pressure is predicted mathematically by the equation of motion:

$$P_{vent} + P_{mus} = \boxed{V_T/C_{RS}} + \boxed{R_{aw} \times \dot{V}_I} + \text{PEEP} + \text{PEEPi} + \text{inertance} \quad (1)$$

$$R_I = (\text{PIP} - \boxed{P_{plat}})/\dot{V}_I$$

$$R_E = \boxed{(P_{plat}} - \text{PEEP})/\dot{V}_{EXH}$$

$$P_{plat} = \frac{(V_T \times \text{PIP}) - (V_T \times \text{PEEP})}{V_T + (\boxed{\tau_E} \times \dot{V}_I)} \quad (2)$$

This approach has the advantage of being able to be used in spontaneous breathing modes such as pressure support, but has the disadvantage of requiring a computerized algorithm to make the necessary calculations.

τ_E = exhaled $V_T/\dot{V}_{EXH}$

Expiratory time constant for determinations of plateau pressure, respiratory system compliance, and total resistance

Hypothesis:

Expiratory time constant (T_E) can be usecd to determine Pplt, Crs and Rtot. Since T_E contains information regarding the mechanical properties of the respiratory system, namely elastance and resistance.

Material and Methods

T_E is expressed in seconds, and one T_E represents the time required for the lungs to reach 63% of its equilibrium value. T_E was measured 0.10 to 0.50 seconds after beginning of exhalation, using available Vt and flow measurements. Specifically, the slope of the least square fit between Vt and Flow constituted T_E. A straight line between the linear fit is necessary, as it ensures relacation of the patients respiratory muscles.

Derivation of equations

Rtot

For Rtot, we again start with the EOM, disregarding Pmus

$$\text{Paw} - \text{PEEP} = V_T / \text{Crs} + \text{Rtot} \times \text{Inhaled flow}$$

Multiply Vt/Crs by Rtot/Rtot:

$$\text{Paw} - \text{PEEP} = V_T \times \text{Rtot} / \text{Crs} \times \text{Rtot} + \text{Rtot} \times \text{Inhaled flow}$$

Substitute T_E for Rtot*Crs on the right side gives:

$$\text{Paw} - \text{PEEP} = V_T \times \text{Rtot} / T_E + \text{Rtot} \times \text{Inhaled flow}$$

Factoring the right side gives:

$$\text{Paw} - \text{PEEP} = R_{tot} (V_T / T_E + \text{Inhaled flow})$$

Divide both sides by Vt/T_E:

$$Rtot = \frac{Paw - PEEP}{\dfrac{V_T}{T_E} + Inhaled\ flow}$$

T_E is traditionally the product of Crs and Rtot.

Crs

Equation of Motion
(disregarding Pmus)

Paw - PEEP = (Vt/Crs)+Rtot*InspFlow

$\downarrow$ Multiply both sides by Crs

Crs(Paw-PEEP) =
Vt+(Rtot*inspFlow)Crs

$\downarrow$ Substitue Rtot*Crs for Te

Crs(Paw-PEEP) =
Vt+inspFlow*Te

$\downarrow$ Divide by (Paw-PEEP)

$$Crs = \frac{Vt+inspFlow*Te}{Paw-Peep}$$

Pplat

Plateau pressure = (tidal volume / static compliance) + PEEP

Pplat = Vt/Crs + PEEP

Substitute Crs by

Crs = (Vt+Te*Inhaled Flow)/
Paw-PEEP

Pplat = (Vt/Vt+Te*Inhaled
Flow/(Paw-PEEP)) + PEEP

Move (Paw-PEEP) up to
the numerator

Pplat = (Vt*Paw)-(Vt*PEEP)/
Vt+Te+Inhaled Flow