GAS EXCHANGE MODELING FOR PREDICTING PULMONARY AIR EMBOLISM AND EDEMA IN REAL TIME

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Abstract

A four compartmental gas exchange model for predicting pulmonary air embolism and edema in real time on a mechanically ventilated patient was developed. The technique is fully automated, requires minimum input parameters and makes few assumptions. The model was based on Fick’s principle, shunt equations and well accepted, standard empirical equations obtained from the literature. The required input variables are – Inspired and Expired O2 and CO2, SaO2 and air flow rate measured at the mouth. The assumptions made were - end-capillary pressures of O2 and CO2 were same as the alveolar partial pressure of O2 and CO2, respectively. Also, the shunted blood has same O2 and CO2 concentrations as the mixed venous blood. An exhaustive search routine was applied to determine alveolar and arterial O2 and CO2 partial pressures. The shunt, physiological dead space and hence the V/Q mismatching can then be calculated from these variables. The embolism is known to increase physiological dead space (Vdead) and edema is known to increase physiological shunt (fs). But it was observed that both Vdead and fs change in embolism and edema. However, Vdead/Tidal volume normalized with paCO2 increases in case of embolism and decreases in case of edema. Also, RQ decreases in embolism and increases in edema. The effects of increasing dose of air emboli on various respiratory parameters were also studied.

Model

\[ Q(t) \times (1 - fs) = \frac{V_{CO2}}{C_{vCO2} - C_{c'CO2}} \]

\[ Q(t) \times (1 - fs) = \frac{V_{O2}}{C_{vO2} - C_{c'O2}} \]

Model Analysis

Using Fick’s Principle,

\[(1 - fs) \times C_{vCO2} + fs \times C_{vCO2} = C_{aCO2} \]

\[(1 - fs) \times C_{vO2} + fs \times C_{vO2} = C_{aO2} \]

Input parameters:

- Inspired and expired O2 and CO2
- SaO2
- Air flow rate at the mouth

Output parameters:

- Arterial and alveolar gases
- Shunt, dead space, V/Q, RQ

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ml/kg/hr. End tidal gases (CO₂, Forane and O₂) were continuously monitored. Inspired respiratory gases (O₂ and CO₂) were monitored.

**Pulmonary Embolism:** A serial IV injections of air (1, 1.5 and 2 ml/kg) was performed over 2 sec. The air was injected in superior vena cava. Acute pulmonary embolism lasted for about 10-20 min. Hence injections were given in 30-min intervals.

**Pulmonary Edema:** An iv dose of 0.2 ml/kg of Oleic acid was injected in superior vena cava of each animal via the pulmonary arterial catheter.

**Results**

**Effects of increasing air emboli dose**

**Conclusion**

A new method has been developed that can predict dead space and shunt noninvasively with minimum physiological monitoring. RQ and Vdead/VT/paCO2 have been identified as potential parameters to diagnose and separate embolism from edema. Vdead/VT and ventilation/perfusion fail to separate embolism from edema. The changes in shunt and dead space are linear with increasing embolism dose.

**References**
