Quick Review: Oxygen Transport
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Citation

Abstract
This is a brief review on Oxygen Transport.

“The first concern in any life-threatening illness is to maintain an adequate supply of oxygen to sustain oxidative metabolism”

...Marino

OXYGEN TRANSPORT
The Oxygen Transport Variables:

OXYGEN CONTENT
The oxygen in the blood is either bound to hemoglobin or dissolved in plasma

The sum of these two fractions is called the Oxygen Content

CaO$_2$ = the Content of Oxygen in Arterial Blood
Hb = Hemoglobin (14 g/dl)
SaO$_2$ = Arterial Saturation (98%)
PaO$_2$ = Arterial PO$_2$ (100 mmHg)

Figure 1

\[
CaO_2 = \frac{(1.3 \times Hb \times SaO_2)}{amount \ carried \ by \ Hb} + \frac{(0.003 \times PaO_2)}{amount \ dissolved \ in \ plasma}
\]

CaO$_2$ = (1.3 x 14 x 0.98) + (0.003 x 100) CaO$_2$ = 18.1 ml/dl
(ml/dl = vol %; 18.1 vol %)

* at 100% Saturation, 1 g of Hb binds 1.3 ml of Oxygen!
* at 100% Saturation, 0.003 ml/mmHg of Oxygen is Dissolved in Plasma!

The PaO$_2$ should be reserved for evaluating the efficiency of pulmonary gas exchange
Example # 1: 35 yr old male s/p GSW to Chest

Pulse 126 - BP 164 / 72 - RR 26 Hb = 12 Hct = 36 ABG's: pH 7.38 / PaO₂ 100 / PaCO₂ 32 / 96 % Sat

Question # 1: What is this Patient's Oxygen Content?

**OXYGEN DELIVERY**

DO₂: the Rate of Oxygen Tranport in the Arterial Blood * it is the product of Cardiac Output & Arterial Oxygen Content

\[ \text{DO}_2 = Q \times \text{CaO}_2 \]

Cardiac Output (Q) can be “indexed” to body surface area

Normal C.I. : 2.5 - 3.5 L/min-m² By using a factor of 10, we can convert vol % to ml/s

\[ \text{DO}_2 = Q \times \text{CaO}_2 \]

\[ \text{DO}_2 = 3 \times (1.3 \times \text{Hb} \times \text{SaO}_2) \times 10 \]

\[ \text{DO}_2 = 3 \times (1.3 \times 14 \times .98) \times 10 \]

\[ \text{DO}_2 = 540 \text{ ml/min-m}^2 \]

Normal Range: 520 - 720 ml/min-m²

**Figure 5**

\[ O_2 \text{ER} = \frac{\text{VO}_2}{\text{DO}_2} \times 100 \]

\[ O_2 \text{ER} = 130 / 540 \times 100 \]

\[ O_2 \text{ER} = 24 \% \]

Example # 2: 35 yr old male s/p GSW to Chest

Pulse 126 - BP 164 / 72 - RR 26

Hb = 12 / Hct = 36 ABG's: pH 7.38 / PaO₂ 100 / PaCO₂ 32 / 96 % Sat C.I. = 2.86

Question # 2: What is this Patient's Oxygen Delivery?

Oxygen Consumption

Oxygen uptake is the final step in the oxygen transport pathway and it represents the oxygen supply for tissue metabolism

The Fick Equation: Oxygen Uptake is the Product of Cardiac Output and the Arteriovenous Difference in Oxygen Content

\[ \text{VO}_2 = Q \times [\text{CaO}_2 - \text{CvO}_2] \]

\[ \text{VO}_2 = Q \times (\text{CaO}_2 - \text{CvO}_2) \]

\[ \text{VO}_2 = 3 \times (1.3 \times \text{Hb} \times (\text{SaO}_2 - \text{SvO}_2)) \times 10 \]

\[ \text{VO}_2 = 3 \times (1.3 \times 14 \times .98 - .73) \times 10 \]

\[ \text{VO}_2 = 3 \times 46 \]

\[ \text{VO}_2 = 138 \text{ ml/min-m}^2 \]

Normal VO₂: 110 - 160 ml/min-m²

Example # 3: 35 yr old male s/p GSW to Chest

Pulse 126 - BP 164 / 72 - RR 26 Hb = 12 / Hct = 36 ABG's: pH 7.38 / PaO₂ 100 / PaCO₂ 32 / 96 % Sat C.I. = 2.86 SvO₂ 71 %

Question # 3: What is this Patient's Oxygen Consumption?

**EXTRACTION RATIO**

ER = the fractional uptake of oxygen from the capillary bed

\[ \text{O}_2 \text{ER} = \text{VO}_2 / \text{DO}_2 \]

\[ \text{VO}_2 = 3 \times (1.3 \times 14 \times .98 - .73) \times 10 \]

\[ \text{VO}_2 = 3 \times 46 \]

\[ \text{VO}_2 = 138 \text{ ml/min-m}^2 \]

Normal Range: 16 - 19 vol %

Example # 4: 35 yr old male s/p GSW to Chest

Pulse 126 - BP 164 / 72 - RR 26 Hb = 12 / Hct = 36 ABG's: pH 7.38 / PaO₂ 100 / PaCO₂ 32 / 96 % Sat C.I. = 2.86 SvO₂ 71 %

Question # 4: What is this Patient's Extraction Ratio?

The uptake of oxygen from the microcirculation is a set point that is maintained by adjusting the Extraction Ratio to match changes in oxygen delivery

The ability to adjust O₂ Extraction can be impaired in serious illness
The Normal Response to a Decrease in Blood Flow is an Increase in O₂ Extraction sufficient enough to keep VO₂ in the normal range

\[
VO₂ = Q \times Hb \times 13 \times (SaO₂ - SvO₂)
\]

\[
Q = 1; VO₂ = 1 \times 14 \times 13 \times (.97 - .37) = 109 \text{ ml/min-m}^2
\]

**THE DO-VO CURVE**

*Remember the shape of the Oxyhemoglobin Curve* *The SaO₂ falls on the flat portion & can be safely estimated, while the Venous % Sat (68 - 77 %) falls on the Steep Portion and can vary significantly even with small errors in estimation!*

In Critically-ill patients, augmenting the extraction ratio (in response to a change in oxygen delivery) may not be possible! In these patients, the Venous Oxygen Levels may change little in response to changes in Cardiac Output! Thus, the Relationship between CO(Q) and Mixed Venous Oxygen must be determined before using SvO₂ or PvO₂ to monitor changes in DO₂ or VO₂

The Transport Variables:

**DO₂ & VO₂ are indexed to body surface area**

**References**
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