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

CaO₂ = the Content of Oxygen in Arterial Blood
Hb = Hemoglobin (14 g/dl) SaO₂ = Arterial Saturation (98%) PaO₂ = Arterial PO₂ (100 mmHg)

Figure 1

\[
CaO₂ = \frac{(1.3 \times Hb \times SaO₂)}{\text{amount carried by Hb}} + \frac{(0.003 \times PaO₂)}{\text{amount dissolved in plasma}}
\]

CaO₂ = (1.3 x 14 x 0.98) + (0.003 x 100) CaO₂ = 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 PaO₂ should be reserved for evaluating the efficiency of pulmonary gas exchange
Quick Review: Oxygen Transport

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 / PaO$_2$ 100 / PaCO$_2$ 32 / 96 % Sat

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

OXYGEN DELIVERY

DO$_2$: the Rate of Oxygen Transpirt in the Arterial Blood * it is the product of Cardiac Output & Arterial Oxygen Content

DO$_2$ = Q x CaO$_2$

Cardiac Outup (Q) can be “indexed” to body surface area
Normal C.I.: 2.5 - 3.5 L/min-m$^2$ By using a factor of 10, we can convert vol % to ml/s

DO$_2$ = Q x CaO$_2$ DO$_2$ = 3 x (1.3 x Hb x SaO$_2$) x 10 DO$_2$ = 3 x (1.3 x 14 x .98) x 10 DO$_2$ = 540 ml/min-m$^2$

Normal Range: 520 - 720 ml/min-m$^2$

Figure 5

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 / PaO$_2$ 100 / PaCO$_2$ 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 Ouput and the Arteriovenous Difference in Oxygen Content

VO$_2$ = Q x [(CaO$_2$ - CvO$_2$)]

VO$_2$ = Q x (CaO$_2$ - CvO$_2$) VO$_2$ = Q x [(1.3 x Hb) x (SaO$_2$ - SvO$_2$)] x 10 | VO$_2$ = 3 x [(1.3 x 14) x (.98 - .73)] x 10 | VO$_2$ = 3 x [46] VO$_2$ = 138 ml/min-m$^2$

Normal VO$_2$: 110 - 160 ml/min-m$^2$

Figure 7

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 / PaO$_2$ 100 / PaCO$_2$ 32 / 96 % Sat C.I. = 2.86 SvO$_2$ 71 %

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

EXTRACTION RATIO

ER = the fractional uptake of oxygen from the capillary bed
O$_2$ER: derived as the Ratio of Oxygen Uptake to Oxygen Delivery

Figure 8

Questions:

ER = 18 %, what does this imply?
ER = 40 %, what does this imply?

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 / PaO$_2$ 100 / PaCO$_2$ 32 / 96 % Sat C.I. = 2.86 SvO$_2$ 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 O$_2$ 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

\[ \text{VO}_2 = Q \times \text{Hb} \times 13 \times (\text{SaO}_2 - \text{SvO}_2) \]

\[ Q = 3; \text{VO}_2 = 3 \times 14 \times 13 \times (.97 - .73) = 110 \text{ ml/min-m}^2 \]

\[ Q = 1; \text{VO}_2 = 1 \times 14 \times 13 \times (.97 - .37) = 109 \text{ ml/min-m}^2 \]

**THE DO-VO CURVE**

![Image](image:7)

**MIXED VENOUS OXYGEN**

By rearranging the Fick Equation, the determinants of Venous Oxygen are:

\[ \text{VO}_2 = Q \times \text{Hb} \times 13 \times (\text{SaO}_2 - \text{SvO}_2) \]

\[ \text{SvO}_2 = \text{SaO}_2 - \left( \frac{\text{VO}_2}{Q \times \text{Hb} \times 13} \right) \]

* the most prominent factor in determining SvO₂ is VO₂/Q

Causes of a Low SvO₂:

- Hypoxemia
- Increased Metabolic Rate
- Low Cardiac Output

**ANOTHER POINT: OXIMETRY**

Arterial Oxygen Saturation can be estimated but Venous Oxygen Saturation MUST be Measured!

* 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:

![Image](image:8)

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

**References**
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