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

\[
CaO₂ = \left(1.3 \times Hb \times SaO₂\right) + \left(0.003 \times PaO₂\right)
\]

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
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 Transport in the Arterial Blood * it is the product of Cardiac Output & Arterial Oxygen Content

\[
DO₂ = Q \times CaO₂
\]

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

\[
DO₂ = Q \times CaO₂ \quad DO₂ = 3 \times (1.3 \times Hb \times SaO₂) \times 10 \quad DO₂ = 3 \times (1.3 \times 14 \times .98) \times 10 \quad DO₂ = 540 \text{ ml/min-m}²
\]

Normal Range: 520 - 720 ml/min-m²

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 / 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

\[
VO₂ = Q \times [(CaO₂ - CvO₂)]
\]

\[
VO₂ = Q \times (CaO₂ - CvO₂) \quad VO₂ = Q \times [(1.3 \times Hb) \times (SaO₂ - SvO₂) \times 10] \quad VO₂ = 3 \times [(1.3 \times 14) \times .98 - .73] \times 10 \quad VO₂ = 3 \times .46 \quad VO₂ = 138 \text{ ml/min-m}²
\]

Normal VO₂: 110 - 160 ml/min-m²

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 / 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
O₂ER: derived as the Ratio of Oxygen Uptake to Oxygen Delivery

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
Quick Review: Oxygen Transport

The Normal Response to a Decrease in Blood Flow is an Increase in \( O_2 \) Extraction sufficient enough to keep \( VO_2 \) in the normal range

\[
VO_2 = Q \times Hb \times 13 \times (SaO_2 - SvO_2)
\]

For \( Q = 3 \):

\[
VO_2 = 3 \times 14 \times 13 \times (.97 - .73) = 110 \text{ ml/min-m}^2
\]

For \( Q = 1 \):

\[
VO_2 = 1 \times 14 \times 13 \times (.97 - .37) = 109 \text{ ml/min-m}^2
\]

THE DO-VO CURVE

Anemia

ANOTHER POINT: OXIMETRY

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

* Remember the shape of the Oxyhemoglobin Curve * The \( SaO_2 \) 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 \( SvO_2 \) or \( PvO_2 \) to monitor changes in \( DO_2 \) or \( VO_2 \)

The Transport Variables:

Anemia

MIXED VENOUS OXYGEN

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

\[
VO_2 = Q \times Hb \times 13 \times (SaO_2 - SvO_2)
\]

\[
SvO_2 = SaO_2 - \frac{VO_2}{Q \times Hb \times 13}
\]

* the most prominent factor in determining \( SvO_2 \) is \( VO_2/Q \)

Causes of a Low \( SvO_2 \):

- Hypoxemia
- Increased Metabolic Rate
- Low Cardiac Output

References
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