Cardiovascular Response to Anemia?
Cardiovascular Response to Hypoxia?
Cardiovascular Response to Hypoxia?

Anemia = Low CaO2 = Tissue Hypoxia
Cardiovascular Response to Anemia?

If the purpose of **RBCs** are to **deliver oxygen**, how will oxygen-deprived tissues respond?

Vasodilate!!!
Cardiovascular Response to Anemia?

Vasodilate!!!

\[ CO = HR \times SV \]

If you vasodilate, what happens to afterload?

If afterload decreases, what happens to SV?

If SV increases, what happens to CO?

If SV increases, what happens to pulse pressure?
Cardiovascular Response to Anemia?

Vasodilate!!!

\[ CO = HR \times SV \]

If you vasodilate, what happens to afterload?
If afterload decreases, what happens to SV?
If SV increases, what happens to CO?

If SV increases, what happens to pulse pressure?

Pulse Pressure
1. Systolic - Diastolic
2. Compliance (aortic) \times SV
Low oxygen delivery to tissue/periphery:

Vasodilation → ↓ Afterload
SV ↑ due to ↓ Afterload (and ↓ blood viscosity)
CO ↑ due to ↑ SV (and HR via SNS)
Pulse Pressure ↑: \( SV \times \text{Compliance (aortic)} \)
**Patient with Hgb 10 (12-15) and HCT of 30% (40-45)**

<table>
<thead>
<tr>
<th>PaO2</th>
<th>SaO2</th>
<th>CaO2</th>
<th>SV, CO, PP</th>
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**CV Response to ↓ O2 Content:**

↑CO, SV, PP (pulse pressure)

FYI...example of 'hi output failure'
Q. Stimulus to EPO: GFR or Anemia?

Hello Kidneys!
Erythropoietin production (interstitial cells) driven by:

OXYGEN CONTENT

\[(Hb \times 1.34) \times (95-100\% \text{ SaO}_2 + 0.3) = 12 \text{ ml O}_2/\text{dl}\]
Erythropoietin production (interstitial cells) driven by:

**OXYGEN CONTENT**

\[(\text{Hb} \times 1.34) \times 95-100\% \, \text{SaO}_2 + 0.3 = 12 \, \text{ml O}_2/\text{dl}\]
Q. Stimulus to EPO: GFR or Anemia?

Yes, oxygen content drives EPO, not GFR (they are dissociated)

This concept also explains the physiologic erythrocytosis seen in patients with chronic lung disease.
• **Measures of Oxygen Transport**
  - $\text{PaO}_2$ (mm Hg)
  - $\text{SaO}_2$ (%)
  - $\text{CaO}_2$ (ml O2/dL)

• Reviewed how anemia effects those measures

• Reviewed cardiovascular response to anemia

• Reviewed renal/erythropoietin response to $\downarrow \text{CaO}_2$

• Let’s review how abnormal oxygen binding ($\text{CO}$) and abnormal iron ($\text{Fe}^3+$) impacts these measures.
Carbon Monoxide (CarboxyHgb)

PaO2 unchanged
(abundant amount of oxygen in atmosphere)
O2 has been displaced

Oxygen Saturation (SaO2) is ↓↓
Oxygen Saturation ($SaO_2$) is ↓↓

$CO \gg O_2$ Binding Affinity

Normal

$CO$ exposure

Left Shift
Carbon Monoxide (CarboxyHgb)

Oxygen Content:
\[ [\text{Hgb} \times 1.34 \text{ (no change)}] \times \text{SaO2} \downarrow\downarrow + 0.3 \]
Carbon Monoxide
200x affinity for Hgb
O2 dissociation curve → left

History: Exposure
PE: CNS depression
Skin color: cyanotic or cherry red???

Exposure/Presentation:
Working in a garage with heater running.
Bought to ER by friend.
Appears Cherry Red.
carbon monOXIDE
Carbon Monoxide
200x affinity for Hgb
O2 dissociation curve → left

History: Exposure
PE: CNS depression
Skin color: cyanotic or cherry red???

Clinical Dx: CarboxyHgb level
USMLE Dx: Oxygen Content

Rx: Oxygen

PaO2: no change
SaO2: decreased
CaO2: decreased
Covered

- Measures of Oxygen Transport
  - $\text{PaO}_2$
  - $\text{SaO}_2$
  - $\text{CaO}_2$
- Reviewed how anemia effects those measures
- Reviewed cardiovascular response to anemia
- Reviewed renal/erythropoietin response to $\downarrow \text{CaO}_2$

- Let’s review how abnormal oxygen binding (CO) and abnormal iron (Fe+3) impacts these measures.
Oxygen freely diffuses into RBCs
SaO2 measures Hgb binding sites bound to oxygen

Oxygen Saturation (SaO2)
Oxygen freely diffuses into RBCs
SaO2 measures Hgb binding sites bound to oxygen

Methemoglobinemia

Oxygen Saturation (SaO2)
Methemoglobinemia
Ferrous (Fe+2) → Ferric (Fe+3)

Drugs

Oxygen Content?
Methemoglobinemia
Ferrous (Fe+2) → Ferric (Fe+3)

Drugs

Oxygen Saturation (SaO2) ↓↓

No Change in PaO2

No Change in Hgb: [Hgb x 1.34]

Oxygen Content ↓↓
Dapsone
Antifolate (PABA antagonist)
Indication: Leprosy, PCP ppx, DH
AE (>10%): MetHgb, hemolysis (G6PD)

Leprosy
Bug: mycobacterium leprae
Painless, nonhealing skin lesions
Rx: Dapsone and Rifampin

Q. Patient is given a drug for nonhealing skin lesions and...
Methemoglobinemia
Fe$^{+3}$ is unable to bind oxygen
Remaining Fe$^{+2}$ has increased affinity (shift curve → left)

**History:** Offending drug
(esp dapsone/sulfa, nitrates, topical anesthetics)
**PE:** cyanosis/’dusky’
‘chocolate brown blood’ (in OR)
**Data:** (in box)

**Rx:** Methylene blue
(electron acceptor)

**Special Notes:**
Cyanide poisoning and nitroprusside

PaO$_2$ unchanged
SaO$_2$ ↓↓
Oxygen Content ↓↓
MetHgb level ↑
Methemoglobinemia

Fe\(^{3+}\) is unable to bind oxygen
Remaining Fe\(^{2+}\) has increased affinity (shift curve \(
\rightarrow \) left)

History: Offending drug (esp. dapsone/sulfa, nitrates, topical)

PE: cyanosis/'dusky' 'chocolate brown blood' (in OR)

Data: (in box)

Rx: Methylene blue (electron acceptor)

Special Notes:
Cyanide poisoning and nitroprusside

Cyanide Toxicity Rx:
Thiosulfate is classic.
Amyl Nitrate induces MetHgb.
Ferric (Fe\(^{3+}\)) can bind cyanide molecule.
Using MetHgb for good instead of evil!

PaO\(_2\) unchanged
SaO\(_2\) \(\downarrow\downarrow\)
Oxygen Content \(\downarrow\downarrow\)
MetHgb level \(\uparrow\)
Material Covered

• Measures of Oxygen Transport
  – PaO2
  – SaO2
  – CaO2
• Reviewed how anemia effects those measures
• Reviewed cardiovascular response to anemia
• Reviewed renal/erythropoietin response to ↓ CaO2

• Let’s review how abnormal oxygen binding (CO) and abnormal iron (Fe+3) impacts these measures.
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  - PaO2
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- Let’s review how abnormal oxygen binding (CO) and abnormal iron (Fe+3) impacts these measures.

Don’t be stubborn!

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