Author(s): Louis D’Alecy, 2009

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Cerebral Blood Flow

M1 – Cardiovascular/Respiratory Sequence
Louis D’Alecy, Ph.D.

Fall 2008
Monday 11/10/08, 9:00
Control of Cerebral Blood Flow
19 slides, 50 minutes

1. Normalized blood flow
2. Determinants of CeBF
3. Autoregulation
4. Cushing Response
5. Resistance Control
6. Hypoxia vs. Ischemia
7. Cerebral Ischemia
Cerebral Blood Flow  mL / min?
But how big is the tissue or organ?

**Normalized to mL / 100g / min**

<table>
<thead>
<tr>
<th>Tissue</th>
<th>Flow (mL/min/100g)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Liver</td>
<td>57.7</td>
</tr>
<tr>
<td>Kidneys</td>
<td>420.0</td>
</tr>
<tr>
<td>Brain</td>
<td>54.0</td>
</tr>
<tr>
<td>Skin</td>
<td>12.8</td>
</tr>
<tr>
<td>Skeletal Muscle</td>
<td>2.7</td>
</tr>
<tr>
<td>Heart</td>
<td>84.0</td>
</tr>
<tr>
<td>Rest of body</td>
<td>1.4</td>
</tr>
</tbody>
</table>

**To change organ blood flow you increase CO or redistribute flow (CO).**
Arterial supply

Venous drainage

Source Undetermined
DETERMINANTS OF CEREBRAL BLOOD FLOW

1 PERfusion Pressure
   • Arterial and venous pressure
   • Flow Autoregulation with changes in perfusion pressure

2 IntracraInial Pressure Compression
   • Cerebral Ischemic Reflex

3 Metabolic Control (Resistance Control)

4 Neural Control (Resistance Control)
Autoregulation

Cerebral blood flow (ml/100 gm/min)

Mean arterial blood pressure (mm Hg)

Hypotension

Hypertension
When intracranial pressure (ICP) approaches arterial pressure, the Cushing reflex produces a sustained increase in arterial blood pressure.
Cushing (Cerebral Ischemic Reflex)

- response to compressive ischemia in CNS
- marked increase in arterial blood pressure
- over rides arterial baroreceptor reflex !!
- may involve central chemoreceptors
- presumed to be “protective” of ischemic CNS
- presumably maintains CBF when ICP increases
TISSUE RESISTANCE

(**Assume Perfusion Pressure is Constant**)

- Vasoconstriction \(\Rightarrow \downarrow r \Rightarrow \uparrow R_{tissue} \Rightarrow \downarrow F_{tissue}\)

- Vasodilation \(\Rightarrow \uparrow r \Rightarrow \downarrow R_{tissue} \Rightarrow \uparrow F_{tissue}\)

\[
F_{tissue} = \frac{\text{Perfusion Pressure}}{R_{tissue}}
\]
Vasodilators

“Metabolic”

• ↓ oxygen
• ↑ K⁺, CO₂, H⁺
• Osmolarity
• Adenosine
• Eicosanoids

Other

• Nitric oxide
• Injury molecules
• ?
Cerebral blood flow is extremely sensitive to arterial carbon dioxide.
Cerebral blood flow is mostly insensitive to arterial oxygen in the normal oxygen range.
Cerebral blood flow is mostly insensitive to arterial oxygen except at extremely low levels where consciousness would be lost.
Hypoxia Is Often Misunderstood

• not asphyxia (…unable to breath..)
• hypoxia is often undetectable
• hypoxia produces a feeling of well-being or belligerence
• signs and symptoms prior to unconsciousness are subtle, insidious and often imperceptible.
• many causes
Summary
Control of Cerebral Blood Flow

- Autoregulation assumed important
- CO$_2$ dominant control
- O$_2$ minimal effect normal to high O$_2$
  - Failsafe vasodilation to marked hypoxia
- Cerebral Ischemic (Cushing) Reflex
- Sympathetic alpha vasoconstriction possible
- Parasympathetic vasodilation possible
Cerebral Ischemia

- blood flow to a tissue or organ that is inadequate to maintain function.

- i.e. stroke, transient ischemic attack

- Partially occluded carotid arteries 60 %?
How can cerebral flow remain relatively constant with an 60% “lesion”??

Cerebral Blood Flow

Resting carotid blood flow

Percent lesion diameter

1x

20%
40%
60%
80%
100%
Compensatory Vasodilation here so total series resistance stays the same.

\[ \Delta P = P_i - P_0 \]
\[ \dot{Q} = \frac{\Delta P}{R_s} \]

Series Resistance Network

Hypoxia Is Misunderstood

....Rather, hypoxia is often undetectable and human responses include “Behavioral changes, such as an exceptional feeling of well-being or belligerence...”. This was recognized early in aviation and mountaineering medicine. In fact, the United States Air Force, Army, and Navy have found it necessary to train aircrews, divers, and High Altitude/Low (parachute) Opening (HALO) operators in hypobaric chambers so they may recognize objective and subjective signs of impending unconsciousness as to avoid subsequent death while unconscious. This is done primarily because the signs and symptoms prior to unconsciousness are subtle, insidious and often imperceptible. Excerpted from a 1999 text used by the Royal Air Force in the United Kingdom in the characterization of human’s response to hypoxia,” The overt features of acute hypobaric hypoxia may be summarized as follows: Personality change, lack of insight, loss of judgment, loss of self-criticism, euphoria, loss of memory, mental incoordination, muscular incoordination, sensory loss, and cyanosis.”


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