Cerebral physiology and Cardiopulmonary Bypass

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Content

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Is there a problem? Yes the incidence of major neurologic morbidity is 1-6% and up to 16% in high risk patients

Type 1 (cerebral death, nonfatal stroke, TIA and coma)
- Post op 10-40%
- 3 to 6 months 5-20%

Type 1 Ann Thorac Surg 2003;75:472-1684pt
4.6% stroke
CABG 3.6%
OPCAB 1.6%
Aortic valve surg 4.6%
Mitral valve surg 8.9%
CABG + valve surg 7.4%
Double or triple valve surg 9.7%
Western Danish Heart Registry 7304 pt.
2.2% stroke; TIA
Cognitive dysfunction 20-30%, due to CPB?

- No meaningful cognitive outcome differences at 3 and 12 month in age- and health-matched cardiology and cardiac surgery patients
  - Ann Thorac Surg 2003; 75: 1377-84
- Incidence 25-30% in older patients undergoing major surgery

Cognitive decline is a function of the elderly brain and perioperative factors rather than specific intraoperative events due to bypass.

Normal CBF/CMRO₂ physiology

- Brain = 2% of body weight
  - 15% of Cardiac output (splanchnicus =26%, Kidneys= 20%)
  - CBF = 50 ml/100gr/min
- Energy
  - CMRO₂ = 3.5 mL/100gr/min
  - Glucose

Normal CBF/CMRO₂ physiology

Regulation

- Autoregulation
- CO₂
- Metabolic
- Temperature
- Neurogen
Normal CBF/CMRO\textsubscript{2} physiology

- Regulation of CBF
  - Autoregulation
    - The ability to maintain normal CBF despite changes in arterial blood pressure.
    - Autoregulation may be impaired by intracerebral disasters

- Regulation of CBF
  - \textit{CO}\textsubscript{2} reactivity
    - CBF changes linearly with \textit{PaCO}\textsubscript{2} = 20-80 mmHg
    - 2-4\% change in CBF/mmHg
    - \textit{CO}\textsubscript{2} changes tonicity in the vessels by changes in extracellular pH
    - Hypotension reduces \textit{CO}\textsubscript{2} reactivity

- Regulation of CBF
  - Metabolic regulation
    - CBF - CMRO\textsubscript{2} relation
      - CBF changes according to the metabolic demand of the brain

Pain-stimulus
Normal CBF/CMRO\textsubscript{2} physiology

\textbf{CBF / CMRO2 and Temperature}

\begin{center}
\includegraphics[width=0.5\textwidth]{normal_cbf_cmoso2_physics.png}
\end{center}

\begin{itemize}
\item Regulation of CBF
\begin{itemize}
\item Neurogen regulation
\begin{itemize}
\item Less importance
\begin{itemize}
\item Stimulation by sympathetic and parasympathetic fibers only lead to discrete changes in vessel tonicity.
\end{itemize}
\item Molecules which influence on CBF: NO, Endothelin, prostaglandines, free radicals ……
\end{itemize}
\end{itemize}
\end{itemize}

Anesthesia: influence on CBF/CMRO\textsubscript{2}

\begin{itemize}
\item Inhalational anesthesia (isoﬂurane/sevoﬂurane)
\item CBF
\begin{itemize}
\item CMRO\textsubscript{2}
\end{itemize}
\item Intravenous anesthesia (propofol/barbiturates)
\item CBF
\begin{itemize}
\item CMRO\textsubscript{2}
\end{itemize}
\item Opioids (fentanyl/sufentanil)
\item CBF
\begin{itemize}
\item CMRO\textsubscript{2}
\end{itemize}
\end{itemize}

\textbf{CBF: solid line, CMRO2: dashed line}
Cardiopulmonary bypass

- Variables affecting CBF/CMRO₂
  - Blood pressure MAP
  - PaCO₂
  - Hct
  - Temperature

CPB: MAP & CO₂

- CBF is assured by MAP between 50 – 150 mmHg
- During bypass an elevated PaCO₂ is associated with a higher CBF for any given MAP.
CPB : Flow, Pulsatility, ECC-duration

- CBF flow maintenance is not sufficient to guarantee cerebral perfusion if MAP is low
- No convincing evidence of beneficial physiologic effect of pulsatility
- No evidence of decrease in CBF with bypass time

CPB and hematocrit

- Hematocrit
  - Hemodilution reduces Hgb 1/3
  - ↓ viscosity, ↑ PVR
  - ➖ CBF and CDO₂
- Progressive hemodilution: CBF and O₂ extraction can no longer compensate reduced transport capacity

CPB: Temperature

°C increases ischemic tolerance
CMRO₂ is reduced app. 7% / °C

Autoregulation is ceased by profound hypothermia (15-20 °C)

Does temperature have any effect on neurologic outcome??
**CPB: Temperature**

- **Temperature:** 20 studies
  - Warm bypass: 33-37°C
  - Cold bypass: 23-32°C

No clear evidence !!!!

**CPB: Cerebral ischemia**

- **Cerebral ischemia:**
  - When CBF is too low to meet cerebral O2 and glucose demand

**CPB and neurologic damage**

- **Embolism**
  - Macro (focal defects)
    - Atheroma and debris
  - Micro (cognitive defects)
    - Air
    - Lipids
    - Cellular aggregates
    - Emboli from HLM

- **Inflammatory response**
  - Platelet aggregation and degranulation
  - Neutrophil and complement activation
  - Cytokine release
  - Endothelium dysfunction

- **Cerebral Hypoperfusion**

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Number of embolic events per minute from cannulation to after end of bypass.
CPB and neurologic damage
Surgical and technical interventions

- Epi-aortic scan
- Single clamp technique
- Off bypass CABG
- Insufflation of CO2 in wound
- CPB circuit management
  - Heparin coated
  - Biocompatible
  - Filters
- Minimization of cardiomyocircuit suction
  - Main source of lipid embolism
- MAP > 50 mmHg
  - Higher when pts. with DM or HA
  - Pilot study 1985
- Hct (ECC > 15 - 18, post ECC > 30)

CPB and neurologic damage
Cerebral monitoring

- Jugular bulb SjO2
  - Focal events undetected
  - Research tool
- EEG
  - Only cortical activity
  - CPB and anaesthesia artefacts
  - No clear relation to outcome
- Visual/somato evoked potentials
  - As for EEG
- Bi-spectral index (BIS)
  - Affected by temperature and anaesthetic agents
- Near-infrared spectroscopy (NIRS)

NIRS (INVOS, FORE\-SIGHT, EQUANOX)

- Continuous, noninvasive transcutaneous assessment of regional brain oxygenation
- Tissue oxygen saturation at microvascular level
- Extracerebral contamination minimised
- Not influenced by depth of anaesthesia
- Pulsatility independent
- No ECC and temperature artefacts
- Outcome studies are evolving
- Thresholds have to be defined
**Cardiopulmonal bypass**

- **Conclusion**
  - Neurologic morbidity frequent on CPB
  - CPB variables which influence on CBF:
    - Temperature, PaCO$_2$, Hct, MABP
  - Choice of anesthesia has no documented effect on neuroprotection
  - No evidence on neurologic outcome on "warm" vs "cold" ECC

**Deep hypothermic circulatory arrest**

- **Brain protection**
  - Studies show evidence of decreased IQ
  - Other studies demonstrate no adverse effect on intellectual capacity
  - Minimal adverse effects on psychomotor results with arrest times of about 35 min at 18°C (NEJM, 1995;32:549)

**Hypothermia: Alpha-stat, pH-stat**

- Decreasing temp increased solubility of gas, decrred partial pressure
  - Temp. 40: PaCO$_2$↓→pH 7.35, CO$_2$ content unchanged
  - Temp. 20: PaCO$_2$↓→pH 7.65, CO$_2$ content unchanged

- **Alpha stat (−CO$_2$):**
  - Advantage: normal enzyme activity, autoregulation, flow-metabolism coupling

- **pH stat (+CO$_2$):**
  - Advantage: increased CBF, more homogeneous cooling, increased oxygen delivery