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Director, Stroke and Neurovascular Center

Stroke & Neurocritical Care
Past, present and future
Past, present and future
Cerebral Blood Flow
Today’s discussion

- Past, present and future
- Cerebral Blood Flow
- ICP monitoring
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- Cerebral oxygen monitoring
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- Cerebral Metabolism
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1940’s: Polio Epidemic
Iron Lung Wards
Neurologists were making decisions regarding mechanical ventilation and various aspects of management of polio patients with respiratory failure.
Positive Pressure Ventilation (PPV)

- Manual inflation of lungs
Positive Pressure Ventilation (PPV)

- Manual inflation of lungs
- Prototype lung inflation device (Boston).
Positive Pressure Ventilation (PPV)

- Manual inflation of lungs
- Prototype lung inflation device (Boston).
- Invention of PPV = Birth of Intensive care unit.
1950’s: Positive pressure ventilation (PPV)

- Generally applied for patient with respiratory failure in general medical and surgical ICUs.
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Neurological patients with coma were often seen as non salvageable.
Generally applied for patients with respiratory failure in general medical and surgical ICUs.

Neurological patients with coma were often seen as non-salvageable.

Neurologists gradually withdrew from critical care.
1960’s and 70’s
Advent of Neurosurgical ICUs

- Focused exclusively on the care of postoperative patients.
- Monitoring = ‘neuro checks’ to detect clinical deterioration as soon as possible
Often does not reveal changes in cerebral function until they are irreversible.
Our understanding about pathophysiology of outcome from severe TBI improves.
Primary Insult

Local

Immediate
- Cell bodies
- Axons
- Blood vessels

Delayed
- Free radicals
- Ca+ influx
- K+ efflux
Primary Insult

Local

Immediate
- Cell bodies
- Axons
- Blood vessels

Delayed
- Free radicals
- Ca+ influx
- K+ efflux

Hematoma

Inflammation

Edema

Ischemia

Increased ICP
Primary Insult

Local
- Immediate
  - Cell bodies
  - Axons
  - Blood vessels
- Delayed
  - Free radicals
  - Ca\(^{+}\) influx
  - K\(^{+}\) efflux
- Hematoma
- Inflammation
- Edema
- Ischemia
- Increased ICP

Systemic
- Stunned Myocardium
- Autonomic dysfunction
- Hypovolumia
- Acute lung injury

I
C
P
ICP monitoring became more widespread
1980’s & 90’s

- ICP monitoring became more widespread
- Advanced neuroimaging
  - Detection of structural lesion, mass effect, shift
  - CBF measurement with Xe-CT/PET scans
- Transportation
- Expertise
- Static nature
Continuous and real time rather than static information.

- Brain tissue O₂ tension
- Neurochemical analysis (microdialysis)
- Continuous EEG monitoring
- Ultrasound
Traditional

• Alarm the clinician when clinical deterioration has occurred.

• Reacting to harmful physiologic events
<table>
<thead>
<tr>
<th>Traditional</th>
<th>Multimodality</th>
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<tbody>
<tr>
<td>• Alarm the clinician when clinical deterioration has occurred.</td>
<td>• Real time physiologic end points to detect secondary injury in its earliest phase</td>
</tr>
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<td>• Reacting to harmful physiologic events</td>
<td>• Prevent harmful physiologic events altogether.</td>
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</table>
Past, present and future

Cerebral Blood Flow

ICP monitoring

Cerebral oxygen monitoring

Cerebral Metabolism
Oxygen and substrate delivery to brain tissue.

- O2 contents of blood = 1.34 x Hb x SaO2
Oxygen and substrate delivery to brain tissue.

- O₂ contents of blood = 1.34 x Hb x SaO₂
- O₂ delivery to any tissue = O₂ contents x C.O.(flow)
Cerebral Blood Flow (CBF)

- Adequate oxygenation requires adequate flow.
Adequate oxygenation requires adequate flow.

Normal CBF=50ml/100gm/min (20% of total C.O.)
Cerebral Blood Flow (CBF)

- Adequate oxygenation requires adequate flow.
- Normal CBF = 50 ml/100 gm/min (20% of total C.O.)
- Amount + Duration
Adequate oxygenation requires adequate flow.

- Normal CBF = 50 ml/100 gm/min (20% of total C.O.)
- Amount + Duration

Ischemia = Low CBF

Infarction = Neuronal death
Cerebral Perfusion Pressure (CPP)

- CPP is driving force of CBF
Cerebral Perfusion Pressure (CPP)

- CPP is driving force of CBF
- CBF = CPP/CVR
CBF Autoregulation

![Graph showing relationship between CBF, CPP, and CVR](image)

\[ CBF = \frac{CPP}{CVR} \]
If volume of one compartment increases, other compartment must decrease, otherwise ICP will increase.
Compensatory Mechanisms

- Shift of CSF into spinal compartment.
- Reduction CBV
Compliance
Compliance
CBF: Measurement

- Kety-Schimdt Technique
- Thermodilution
- Xenon-CT
- SPECT/PET
- Perfusion Weighted MRI
CBF: Continuous Measurement

- Laser Flowmetry
- Thermal Diffusion (Bowman’s Perfusion Monitor)
Perfusion measurement — Recalibration in 00:08:58

Perfusion

28
ml/100g-min

Continuous Mode (PCV)

Δ Temp °C 2.582
Temp °C 37.027
K 4.982

PPA 0.0

Alarms

No Label

2010-Jul-08 15:22:57 27.9

15:16:31 Thu, Jul 8, 2010

15:42:38 Thu, Jul 8, 2010
CBF Measurement: Clinical Applications
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Cerebral Blood Flow (CBF) Measurement: Clinical Applications

Papaverine is a potent vasodilator that has been proposed to counteract vasospasm in patients with subarachnoid hemorrhage. In 2001, Vajkaczy et al. using continuous BPM CBF measurements generated a detailed dose-response curve to IAP that show the benefits of IAP in treating vasospasm are transient.
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ICP: Clinical Determination

- Headache, nausea, and vomiting, are impossible to elicit in comatose patients.
- Papilloedema is unreliable marker in acute settings.

Headache, nausea, and vomiting, are impossible to elicit in comatose patients.

Papilloedema is unreliable marker in acute settings.


Pupillary dilatation and decerebrate posturing, can occur in the absence of intracranial hypertension.
Signs of brain swelling, such as midline shift and compressed basal cisterns, are predictive of raised ICP, but intracranial hypertension can occur without these findings.  

Indications: TBI

- GCS of < 8 \textit{and}
- Abnormal CT Scan

OR
Indications: TBI

- GCS of < 8 and Abnormal CT Scan

OR

- GCS of < 8 and Normal CT Scan and One of following
Indications: TBI

- GCS of < 8 \textit{and}
- Abnormal CT Scan

OR

- GCS of < 8 \textit{and}
- Normal CT Scan \textit{and}
- One of following
  1) Age > 40 yrs.
  2) Motor posturing
  3) SBP < 90 mm Hg
ICP elevations after SAH result from:
- CSF outflow obstruction and
- Cerebral edema.

ICP control is essential before treatment of the aneurysm and is associated with more favorable outcome by:
- protection against cortical injury and
- facilitation of surgical exposure of the aneurysm.

ICP monitoring devices

- Microtransducers (Subdural/Epidural/Parenchymal)
- Intraventricular drains
<table>
<thead>
<tr>
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<th>Microtransducers</th>
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| **Advantages**      | • Low infection rate  
                        | • Low risk of hemorrhage |
| **Disadvantages**   | • Considerable zero drift  
<pre><code>                    | • Cannot be re-zeroed after insertion |
</code></pre>
<table>
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<th><strong>Microtranducers</strong></th>
<th><strong>Intraventricular Catheters</strong></th>
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<td><strong>Advantages</strong></td>
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<td>• Low risk of hemorrhage</td>
<td></td>
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<tr>
<td></td>
<td>• More accurate</td>
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<tr>
<td></td>
<td>• Allow ICP control by CSF drainage</td>
<td></td>
</tr>
<tr>
<td></td>
<td>• Re-zeroed externally</td>
<td></td>
</tr>
<tr>
<td><strong>Disadvantages</strong></td>
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<td>• Cannot be re-zeroed after insertion</td>
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<td></td>
<td>• Higher complication rate</td>
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Risk of infection = 10%, which increase with longer duration of monitoring (Czosnyka M., Neurol Neurosurg Psychiatry 75. (6): 813-821.2004;
Antibiotic coating of intraventricular drains may prevent or delay the onset of ventriculitis (Hamilton A.J Neurosurgery 40. (5): 1043-1049. 1997;
Normal compliance, normal ICP

Percussion wave
Dicrotic wave
Tidal wave

Normal ICP; normal compliance

Compromised compliance, normal ICP
Blood  CSF

10%  10%

Brain  80%

Normal compliance, normal ICP

0  10  20  30  40

Compromised compliance, normal ICP

Mass

Normal ICP; normal compliance

Percussion wave  Dicrotic wave  Tidal wave

Elevated ICP; reduced compliance
ICP trend over time.

- Plateau A Wave
Today’s discussion

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- Cerebral Hemodynamics
- ICP monitoring
- Cerebral oxygen monitoring
- Cerebral Metabolism
• Jugular Venous Oxygen saturation (SjvO2)
• Brain Tissue Oxygen Pressure (PBO2)

Cerebral Oxygen Monitoring
Retrograde placement of a catheter equipped with an oximeter.

Dominant internal jugular vein

Positioned in bulb
Indications

- Severe TBI with GCS < 8.
- High grade aneurysmal SAH.
- During neurosurgical procedures.
Jugular Venous Oxygen saturation (SjvO₂)

- Absolute value in percentage.
- A-V difference in O₂ supply.

\[\text{Hb} \times \text{SaO}_2 \times 1.34\]

\[\text{Hb} \times \text{SvO}_2 \times 1.34\]
Jugular Venous Oxygen saturation (SjvO₂)

- **AVDO₂ = CMRO₂/CBF**
Adequacy of balance between supply (Cerebral O2 delivery) & demand (Cerebral metabolic rate)
Conclusion

- Real-time monitoring in NCCU can give immediate insight in the physiologic and metabolic state of brain regions at risk for ischemia and injury.
- NCCU enhances the potential of early effective interventions to reverse pathologic states in stroke patients.