Transcranial Doppler Monitoring in the ICU

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Monitoring in the ICU

• Neurophysiologic Monitoring
• Cerebral Hemodynamic
• Neurochemical & Metabolic
Monitoring CBF
Snapshot
Continuous

- Needs validation
- Invasive
Transcranial Doppler
Introduction

- Transcranial Doppler (TCD) measures blood flow velocities in the major branches of the Circle of Willis through an intact skull.

- This measurement supports the grading of:
  - Vasospasm severity
  - Localization of intracranial stenoses or occlusions
  - Detections of cerebral emboli
  - Monitoring of hemodynamic changes with impaired intracranial perfusion.
  - Assessment of the impact of therapeutic intervention on intracranial hemodynamics.
• TCD locates both the depth and direction of the arterial blood flow relative to the transducer position & the ultrasonic beam direction.

• Flow moving toward the transducer is displayed as a **positive waveform** velocity, whereas flow moving away from the transducer = a **negative waveform** velocity.
TCD Waveform with Velocity Scale
Advantages

- Safe
- Cheap
- Repeatable
- Bedside
- Good learning curve
- Reliable
Main Uses in the ICU

- Vasospasm
- Intracranial Hypertension
- Cerebral Circulatory Arrest
- Autoregulation
- Stenosis
- Subarachnoid Hemorrhage
- Traumatic Brain Injury
- Stroke
- Brain Death
Other uses of TCD

• Sickle Cell Anemia (vasospastic effects)
• Intra-Operative Monitoring
Criteria for Normal TCD

• Optimal window(s) for accurate data
• Presence of a normal velocity ratio: MCA greater than or = to ACA greater than or = to ICA greater than or = to PCA greater than or = to BA greater than or = to VA
• Positive end-diastolic flow velocity of 20%-50% of the peak systolic velocity values.

Used to gather PI data.
What Can Affect TCD Studies?

- Clinical conditions and effects of medications, i.e., dehydration or ↑ blood viscosity, HTN or hypotension.
- Inability to find a vessel by TCD, ...which is ≠ absent vessel flow
- Experience of operator
Gold Standard

Pre-op LICA AP
Neurologic Complications of Cerebral Angiography: Prospective Analysis of 2,899 Procedures and Review of the Literature¹

<table>
<thead>
<tr>
<th>Studies</th>
<th>n</th>
<th>All</th>
<th>Persistent</th>
</tr>
</thead>
<tbody>
<tr>
<td>Grzyska et al. (ref. 4)</td>
<td>1095</td>
<td>0.54%</td>
<td>0.45%</td>
</tr>
<tr>
<td>Heiserman et al. 1994 (ref. 5)</td>
<td>1000</td>
<td>1%</td>
<td>0.5%</td>
</tr>
<tr>
<td>Waugh et al. 1992 (ref. 12)</td>
<td>2075</td>
<td>0.6%</td>
<td>0.3%</td>
</tr>
<tr>
<td>Present study</td>
<td>483</td>
<td>2.3%</td>
<td>0.4%</td>
</tr>
</tbody>
</table>

Complication rates for neurologic deficits associated with cerebral angiography in recent studies
TCD and Vasospasm
Vasospasm

- **Comparison of TCD with angiography for detection of vasospasm**
  - An inverse relationship between vessel diameter and TCD velocities
    - Aaslid et al.
- FVm > 120 cm/s = mild vasospasm
- FVm > 200 cm/s = severe vasospasm

- **Correlation between FVm and angiographic lumen diameter of MCA**
  - FVm < 120 cm/sec - < 25% narrowing
  - FVm 120-200 cm.sec - 25-50%narrowing
  - FVm > 200 cm.sec - > 50% narrowing
    - Aaslid et al
    - Sloan et al
    - Vora et al
    - Lindegaard et al
Sensitivity and Specificity

- Transcranial Doppler Grading for Basilar Artery Vasospasm

- BA/VA ratio > 3 (+ BA FVm > 85cm/sec) = 92% Sensitivity and 97% Specificity for BA narrowing of more than 50%
<table>
<thead>
<tr>
<th>Severity of Vasospasm</th>
<th>MFV Value cm/s</th>
<th>MCA/ICA Ratio</th>
</tr>
</thead>
<tbody>
<tr>
<td>Normal</td>
<td>&lt;85</td>
<td>&lt;3</td>
</tr>
<tr>
<td>Mild</td>
<td>&lt;120</td>
<td>&lt;3</td>
</tr>
<tr>
<td>Moderate</td>
<td>120 to 150</td>
<td>3 to 5.9</td>
</tr>
<tr>
<td>Severe</td>
<td>151 to 200</td>
<td>&gt;6</td>
</tr>
<tr>
<td>Critical</td>
<td>&gt;200</td>
<td>&gt;6</td>
</tr>
</tbody>
</table>
• Predicting Outcome after Traumatic Brain Injury: Development and International Validation of Prognostic Scores Based on Admission Characteristics
  • Ewout W. Steyerberg et al., PLoS Medicine August 2008 | Volume 5 | Issue 8 | e165

• Head injury patients with SAH have a worse prognosis than patients without SAH or Vasospasm.
Delayed Ischemic Deficit (DID)

- **Ability of TCD to predict onset of DID’s following SAH**
  - DID’s occurred in **20–30%** of SAH pts. within **3–14 days after bleed.**
  - Vasospasm-related DID’s were the major cause of bad outcome
    - Kassell NF et al.
  - 8 of 21 patients with SAH developed DID.
  - Good correlation between TCD and DID.
    - Sekhar et al.
• The accuracy of TCD to detect vasospasm in patients with aneurysmal subarachnoid hemorrhage
  • L. Mascia et al. Intensive Care Medicine 2003

• FVm > 160 cm/s
TCD and ICP

• The earliest sign of increased ICP is increased pulsatility
• $PI = \frac{(FVs - FVd)}{FVm}$
TCD, ICP and CPP

• There is a strong correlation between PI and ICP (ICP values $> 20 \text{ mmHg}$), and between PI and CPP (CPP values $< 70 \text{ mmHg}$).
  
  • Voulgaris et al.
Vascular

Transcranial Doppler Sonography Pulsatility Index (PI) Reflects Intracranial Pressure (ICP)

Johan Bellner, M.D.,* Bertil Romner, M.D., Ph.D.,* Peter Reinstrup, M.D., Ph.D.,* Karl-Axel Kristiansson, M.L.T.,† Erik Ryding, M.D., Ph.D.,† and Lennart Brandt, M.D., Ph.D.†

Surg Neurol 2004;62:45-51
Graph demonstrating a significant correlation between the CPP and PI with a correlation coefficient of $-0.493$ ($p < 0.0001$) and a correlation formula of: CPP = 89.646 - 8.258 $\times$ PI. The correlation between CPP and PI is mainly when PI > 3. The dotted lines are the 95% confidence interval for the regression line, which can be significantly affected by outliers when PI is large.
Graph demonstrating a significant correlation between the ICP and the PI with a correlation coefficient of 0.938 ($p < 0.0001$) and a correlation formula of: $ICP = 10.927 \times PI - 1.284$. The dotted lines are the 95% confidence interval for the regression line, which can be significantly affected by outliers when PI is large.
# TCD in Acute Ischemic Stroke

<table>
<thead>
<tr>
<th>Grade</th>
<th>FV* Pattern</th>
<th>Characteristics</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>Absent</td>
<td>1) No FV signal despite different grades of background noise.</td>
</tr>
<tr>
<td>1</td>
<td>Minimal</td>
<td>1) Velocity systolic peak and duration variable; 2) No diastolic FV during cardiac cycle based on visual interpretation of periods with no flow at the end of diastole; (reverberating flow is a minimal pattern)</td>
</tr>
<tr>
<td>2</td>
<td>Blunted</td>
<td>1) Delayed or blunted systolic acceleration, with variable duration as compared to control; 2) Positive end-diastolic velocity; 3) PI &lt; 1.2 **</td>
</tr>
<tr>
<td>3</td>
<td>Dampened</td>
<td>1) Normal systolic acceleration; 2) Positive end-diastolic velocity; 3) Reduction of mean flow velocity ≥ 30% when compared to contralateral vessel (control).</td>
</tr>
<tr>
<td>4</td>
<td>Stenosis</td>
<td>1) Mean flow velocity &gt; 80cm/sec and difference &gt; 30% compared to control 2) If difference between velocities is &lt; 30%, observe turbulence signs; 3) If velocity in both sides is &lt; 80cm/sec, observe 30% difference and turbulence signs;</td>
</tr>
<tr>
<td>5</td>
<td>Normal</td>
<td>1) Difference from control side &lt; 30%; 2) Similar wave spectrum in both sides.</td>
</tr>
</tbody>
</table>
Case

- 44 YOM with slurred speech and sudden right hemiparesis.
• TCD in ER
Angiography
• Left MCA stroke
• Thrombolysis given
Conclusion

• TCD is relatively inexpensive, noninvasive, portable and fairly easy to use.
• It allows frequent repeated measurements and continuous monitoring.
• Immediate, real time detection of changes in cerebrovascular hemodynamics is possible.