I, Steven To, do not have a financial interest/arrangement or affiliation with one or more organizations that could be perceived as a real or apparent conflict of interest in the context of the subject of this presentation.
Objectives

• Definition of Transcranial Doppler (TCD)
• Application
• Equipment
• Technique
• **Protocol**
• Number values
  – Velocities/Mean flow velocities (MFV)
  – Pulsatility Index (PI)
  – Power
• Case Studies
History of TCD

• First introduced by Rune Aaslid in 1982
• Single gaited system.
History of TCD

• Mark Moehring added power-motion mode Doppler (PMD) in 2002.
• 33 sampling gaits over 6 cm of intracranial space
• Displays flow intensity and direction
• This simplified and shortened testing time by making it significantly easier to find windows and waveforms.
Transcranial Doppler

- About TCD – a non-invasive, painless technique that uses ultrasound to measure the rate and direction of blood flow inside a vessel.

- TCD examines arteries part of the Circle of Willis.
• Continuous-wave – display information representative of all moving targets in the ultrasound beam.

• Pulsed-wave – uses short bursts of ultrasound with “range gating” to facilitate signal analysis from a small area at a specified depth from the transducer.
  – TCD uses Pulsed-Wave Doppler
Applications
What can TCD be used for?

• TCD can be used to help diagnose a wide range of conditions affecting the brain, which include:
  
  – Cerebrovascular Accidents (CVA)
  – Transient Ischemic Attacks (TIA)
  – Embolisms
  – Circulatory Arrest
  – Subarachnoid Hemorrhage (SAH)
Other applications include:

- Vertebrobasilar Insufficiency
- Steal phenomena in posterior circulation
- Sickle Cell Anemia
- Patent Foramen Ovale (PFO)
- Cerebral vasomotor reactivity (VMR—breath holding)
- Intraoperative monitoring
Advantages

• Non-invasive

• The only modality that can be utilized for asymptomatic microemboli /serial monitoring

• Can detect collateral circulation with carotid stenosis

• Not limited by constant patient movement

Disadvantages

• Operator dependent

• Limited by suboptimal windows
Applications

Other disadvantages

- Angle of insonation is presumed to be zero degrees.

- The skull attenuates about 80-90% of ultrasound waves.

- Demographics play a role in the success of TCD
  - The elderly, females, and some ethnic origins tend to have thicker bone windows.
<table>
<thead>
<tr>
<th>CPT</th>
<th>STUDY</th>
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<tbody>
<tr>
<td>93886</td>
<td>TCD complete</td>
</tr>
<tr>
<td>93888</td>
<td>TCD limited</td>
</tr>
<tr>
<td>93890</td>
<td>Vasoreactivity study</td>
</tr>
<tr>
<td>93892</td>
<td>Emboli detection</td>
</tr>
<tr>
<td>93893</td>
<td>PFO</td>
</tr>
</tbody>
</table>
Equipment

- Machine & wired remote
- 2 MHz transducer (hand-held)
  - Lower frequency
  - Allows for better penetration
Equipment

- Head frame & Monitoring Transducer
Cerebrovascular Anatomy

- PCA
- PCOM
- ACA
- PCA
Normal Flow
TCD Windows

- Orbital (1)
  - Ophthalmic Artery
  - ICA Siphon
- Temporal (4)
  - MCA
  - ACA
  - PCA
  - Terminal ICA
- Foraminal/Suboccipital (3)
  - Vertebral
  - Basilar
- Submandibular (2)
  - ICA
What is on the screen?

• Power M-mode
  – X-axis: Time (s)
  – Y-Axis: Depth

• Doppler
  – X-axis: Time (s)
  – Y-axis: Velocities (cm/s)
Moving the Depth/Sample
Identifying Vessels

- Presence
- Depth
- Direction
- Resistance
- Speed
Identifying Vessels

- Window used
- Orientation of the probe
- Relationship to surrounding vessels
- Response to extrinsic occlusion

- Depth of the sample volume
- Direction of blood flow
- Velocities
Velocities

• Peak-systolic Velocity (PSV) – First peak on TCD waveform from each cardiac cycle.
  – Rapid upstroke suggests absence of severe stenotic lesion proximally

• End-diastolic Velocity (EDV) – should fall within 20-50% of the PSV; this indicates a low resistant artery, which is normal.

• Mean Flow Velocity (MFV) – A value derived from a combination of the PSV and EDV.
Mean Flow Velocities (MFV)

- Preferred way in reporting velocities, as it takes in consideration both PSV and EDV.

\[(\text{PSV} + (2)\text{EDV}) / 3\]
Normal Velocities
Depth, Direction, Flow

MFV MCA > ACA > Siphon > PCA > BA > VA

*ICA siphons have bidirectional flow signals
** AcomA and PcomA flow direction depends on collateralization
Pulsatility Index (PI)

• This is the most frequently used TCD parameter to determine the flow resistance.

\[(\text{PSV} - \text{EDV}) / \text{MFV}\]

• An index above 1.2 represents high resistant blood flow.
Pulsatility Index

- **SIPHN**
- **OPTH**
- **MCA**

<table>
<thead>
<tr>
<th>PI Value</th>
<th>Description</th>
<th>Range</th>
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</thead>
<tbody>
<tr>
<td>0.6-1.1</td>
<td>0.6 - 1.1</td>
<td>50 - 25%</td>
</tr>
<tr>
<td>1.2-1.6</td>
<td>1.2 - 1.6</td>
<td>&lt; 25%</td>
</tr>
<tr>
<td>1.7-1.9</td>
<td>1.7 - 1.9</td>
<td>≤ 20%</td>
</tr>
<tr>
<td>≥ 2.0</td>
<td>≥ 2.0</td>
<td>0 - 10%</td>
</tr>
</tbody>
</table>

**ASN 42nd Annual Meeting**

**January 24-26, 2019**

**Puerto Rico**
Scanning/Technique

Patient Positioning

- Pt Supine
- Operator behind patient’s head
- Head straight and facing up for
- OA/Siphon (10% power)

Head slightly turned to left/right
- for MCA, ACA, PCA (100% power)

Head turned to left/right, chin down for vertebral/basilar artery
• ALARA – “As Low As Reasonably Achievable”

• Be conscious of how much power you use.
  – Do not exceed 10% maximum emitted power or 17 mW per cm^2 while working in the ophthalmic window.

  – New standards suggest using 80% power while working on other windows.
Protocol

Complete TCD Protocol
Protocol

• Ophthalmic Window
  – 1.) Rt Ophthalmic Artery
  – 2.) Rt Siphon
  – 3 & 4.) Repeat on Lt

• Temporal Window
  – 5.) Rt MCA
  – 6.) Rt ACA
  – 7.) Rt PCA
  – 8.) Rt Terminal ICA
  – 9 to 12.) Repeat on Lt

• Suboccipital Window
  – 13.) Rt Vert
  – 14.) Basilar A
  – 15.) Lt Vert

• If Necessary,
  – 16 & 17.) Submandibular ICA (for SAH).
# Vessel Identification

<table>
<thead>
<tr>
<th>Vessel</th>
<th>Depth (mm)</th>
<th>Flow orientation to Probe</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ophthalmic Artery</td>
<td>50</td>
<td>Toward (High Res)</td>
</tr>
<tr>
<td>ICA Siphon</td>
<td>65</td>
<td>Bidirectional</td>
</tr>
<tr>
<td>MCA (M1)</td>
<td>45 to 65</td>
<td>Toward</td>
</tr>
<tr>
<td>ACA</td>
<td>65 to 70</td>
<td>Away</td>
</tr>
<tr>
<td>P2</td>
<td>60 to 65</td>
<td>Away</td>
</tr>
<tr>
<td>Vertebral</td>
<td>60 to 65</td>
<td>Away</td>
</tr>
<tr>
<td>Basilar</td>
<td>80 to 100</td>
<td>Away</td>
</tr>
</tbody>
</table>
Ophthalmic Artery (50 mm)
Siphon (65 mm)
MCA (45–65 mm)
ACA (65–70 mm)
PCA (60-65 mm)
Vertebral (65 mm)
Basilar (80-100 mm)
Submandibular ICA
Suboptimal Temporal Window

• In the event you have unilateral optimal temporal window, it’s possible to shoot through the good window to get the signals on the other side of the head.
High grade carotid stenosis or occlusion

- Carotid occlusive disease cuts off efficient flow to the ipsilateral MCA.
- Bloodflow is redirected to the affected MCA via available collaterals:
  - Anterior communicating artery
  - Posterior communicating artery
- Higher velocities in compensating arteries
- Usually retrograde flow in ipsilateral ACA
- Blunted/Abnormal signals in affected MCA
Compensatory Flow

Reduced Flow

Occlusive Disease
Occlusive Disease

74 cm/s

45 cm/s

51 cm/s

42 cm/s
Intra-aortic balloon pump (IABP)

- IABPs are balloon catheters that are inserted within the aorta and inflate when the heart relaxes with the intention of pushing more flow towards the coronary arteries.

- Creates an unique Doppler signal
  - Doppler signals change with different settings (delay/pump)
  - Ideally, flow should always be moving unidirectionally
IABP Waveform
Schutt RC, Bhimiraj A, Estep JD, Guha A, Trachtenberg BH, Garami Z. Circ Heart Fail. 2016 Sep;9(9).
Chronic Hypertension

- Results in higher resistance/pulsatility index

<table>
<thead>
<tr>
<th>PI</th>
<th>0.6-1.1</th>
<th>1.2-1.6</th>
<th>1.7-1.9</th>
<th>≥ 2.0</th>
</tr>
</thead>
<tbody>
<tr>
<td>≤ 0.6</td>
<td>0.7</td>
<td>1.2</td>
<td>1.7</td>
<td>N/A</td>
</tr>
<tr>
<td>EDV &gt; 50%</td>
<td>50 - 25%</td>
<td>&lt; 25%</td>
<td>≤ 20%</td>
<td>0 - 10%</td>
</tr>
</tbody>
</table>
Chronic Hypertension
Embolic Activity

• Demonstrated by a signal that presents as a slash on Power M-mode.

• Bright echo in the Doppler signal cannot cross the baseline and must move a certain velocity.

• Creates an audible chirp.
EMBOLUS TRACK ON POWER M MODE DOPPLER
Artifacts

- embolus
- jaw movement
- tapping
• Patients with DeBakey LVADs have pulseless arterial flow

• High-intensity transient signals (HITS) are commonly seen, but deficits are rare.
Stenosis

- Sudden increase in velocities
- Distal segments demonstrate blunted signals and turbulence
- Possible aliasing
- Audible bruit
- Double waveform phenomenon
Stenosis

- Sudden increase in velocities
- Distal segments demonstrate blunted signals and turbulence
- Possible aliasing
- Audible bruit
- Double waveform phenomenon
Circulatory Arrest

- Bidirectional flow
- Extremely high resistant indicative of possible increased CSF
- Arterial thump
- TCD very sensitive in confirming.
- Requires a MAP of 80 mmHg
Transcranial Colorflow Doppler

- Possible to perform TCDs using a duplex machine and using proper frequency settings.

- Can angle correct the ultrasound beam

- Allows you to appreciate the COW as a whole, rather than in linear segments.
Transcranial Colorflow Doppler
Conclusion
Final Thoughts, Tips

• Imagine a microscope: coarse tuning → fine tuning

• Scanning TIPS:
  – Scan in a controlled manner
  – Cover surface area efficiently
  – Be able to backtrack and recover strong signals
  – Avoid making compound movements (angling and changing window location simultaneously)
  – Look at your hand/window often on successful insonation
  – Demographics vs. optimal temporal windows
• **Vessel Identity:**
  – Depth, Direction, Mean Velocities

• **Interpretation depends on quality of the study performed**
  – Pay attention to changes to Doppler waveforms:
    • Pulsatility index that is outside normal range.
    • Blunting of signals/delayed upstroke or acceleration time.
    • Aliasing and bruits.
References


• https://neuralanalytics.com/


