TRANS CRANIAL DOPPLER
Transcranial Doppler

- 1982, Aaslid and colleagues introduced TCD as a non-invasive technique for monitoring blood flow velocity in basal cerebral arteries in patients with SAH
- Now increasingly used in intensive care units and anesthesia for research and clinical practice
Doppler Effect

- 1842, Christian Doppler - frequency shift of reflected and scattered signals that occurs whenever there is relative motion between the emitter and the object or interface reflecting the sound
Principles

- Uses a handheld, directional, microprocessor-controlled, low-frequency (2-MHz), pulsed doppler transducer to measure the velocity and pulsatility of blood flow within the arteries of the circle of Willis and vertebrobasilar system.

- Noninvasive, nonionizing, portable, inexpensive, safe for serial or prolonged studies.
Based on detection of frequency shifts from insonated RBC moving through a small preselected arterial spatial region (sample volume).

Sample volume is determined by lateral focusing of the transducer, duration of transmitted sound burst at a specific pulse repetition rate (PRF) and duration of the range gate opening (Ts)
History

- 1979, Nornes described the intraoperative pulsed doppler sonographic method to study cerebral hemodynamics
- 1982, Aaslid et al introduced the 2 MHz pulsed doppler device that enabled the noninvasive transcranial measurement of blood flow velocity in large intracranial basal vessels
1986, Eden Medical Electronics developed the Trans-scan, device capable of three dimensional, multiprojectional flow mapping, colour coded for flow direction and velocity.

1988, EME introduced the TC20005 scanner, TCD with advanced post-processing and display capabilities.

Recent developments- introduction of intravascular sonographic contrast agents, multi-channel transcranial doppler.
Examination Technique

- Can be performed in any patient - awake or comatose
- Four naturally occurring cranial windows
  - Transtemporal - 3 windows
  - Transorbital
  - Transforaminal
  - Submandibular
  - In addition - open fontanelle, burr holes
■ WINDOWS
A. Transtemporal,
B. Transorbital
C. Transforaminal,
D. Submandibular
Criteria for Vessel Identification

1. Cranial window used
2. Depth (mm) of sample volume
3. Direction of flow (toward or away from transducer, bidirectional)
4. Distance (mm) over which vessel can be traced without branching
5. Relationship to TICA/MCA/ACA junction
6. Angle of transducer in relationship to patient’s head and cranial windows
7. Relative flow velocity (MCA > ACA > PCA = BA = VA)
8. Response to common carotid artery compression
Angle of insonation

- Angle between the ultrasound beam and the vessel being recorded from
- Important to measure true TCD velocity
- Observed velocity = True velocity \times \cosine of angle of insonation
## Vessel Identification Criterion

<table>
<thead>
<tr>
<th>Vessel</th>
<th>Window</th>
<th>Depth</th>
<th>Direction</th>
<th>Velocity</th>
</tr>
</thead>
<tbody>
<tr>
<td>MCA</td>
<td>TT</td>
<td>45-65</td>
<td>Toward</td>
<td>46-86</td>
</tr>
<tr>
<td>ICA Bifur</td>
<td>TT</td>
<td>60-65</td>
<td>Bidirectional</td>
<td></td>
</tr>
<tr>
<td>ACA</td>
<td>TT</td>
<td>60-75</td>
<td>Away</td>
<td>41-76</td>
</tr>
<tr>
<td>PCA 1</td>
<td>TT</td>
<td>60-75</td>
<td>Toward</td>
<td>33-64</td>
</tr>
<tr>
<td>PCA 2</td>
<td>TT</td>
<td>60-75</td>
<td>Away</td>
<td>33-64</td>
</tr>
<tr>
<td>Ophthalmic</td>
<td>TO</td>
<td>45-60</td>
<td>Toward</td>
<td>21-49</td>
</tr>
<tr>
<td>ICA (supra- clinoid)</td>
<td>TO</td>
<td>60-75</td>
<td>Away</td>
<td>50-60</td>
</tr>
<tr>
<td>Vertebral</td>
<td>TF</td>
<td>65-85</td>
<td>Away</td>
<td>27-55</td>
</tr>
<tr>
<td>Basilar</td>
<td>TF</td>
<td>90-120</td>
<td>Away</td>
<td>30-57</td>
</tr>
</tbody>
</table>
Pulsatility

- Described by the shape of the spectral waveform
- Relates to the peripheral resistance of the cerebral tissue supplied by the insonated vessel and the input signal

- Normal Vs > Vd
- High pulsatility Vs >> Vd
- Damped pulsatility Vd > 50% of Vs
Pulsatility Index

- **Gosling Equation**
  \[ PI = \frac{Vs - Vd}{Vm} \]

- **Normal** = 0.8 - 1.2

- **Increased** > 1.2, seen in Increased ICP, hypocapnia, aortic insufficiency, bradycardia

- **Decreased** < 0.8, seen in vessel supplying AVM due to decreased peripheral vascular resistance, downstream high grade stenosis
Physiologic factors affecting TCD

- Age
- Sex
- Hematocrit
- Temperature
- Hypoglycemia
- Blood CO2 level
- Cardiac Output
- Brain Activity
Use in Neurosurgery and Anesthesia

- Intracranial and extracranial Vascular Abnormalities
  - Intracranial
    - SAH and Vasospasm
    - Head Injury
    - Arteriovenous Malformation
    - Arterial stenosis and Occlusion
    - Detection of aneurysm
    - Brain Death
  - Extra cranial
    - Subclavian steal Syndrome
    - Carotid Stenosis
    - Positional Vertebral artery Occlusion
Use in Neurosurgery and Anesthesia

- Intraoperative and procedural Monitoring
  - Carotid Endarterectomy
    - For cross-clamp Hypoperfusion
    - Detection of emboli
    - Postoperative hyperperfusion
    - Postoperative occlusion
  - Cardiopulmonary Bypass
SAH and Vasospasm

- Most accurate in MCA
- Velocity $> 120 \text{ cm/s} = \text{Vasospasm}$
  
  $> 200 \text{ cm/s} = \text{Severe Vasospasm}$
- Velocity Increase $> 50 \text{ cm/S over 24 hour period} - \text{high risk for DIND}$
- D/D vasospasm and Hyperemia
- Lindegaard Ratio
  
  $V_{MCA}/V_{ICA} (1.7 \pm 0.4)$
  
  $> 3 = \text{vasospasm}$
- Monitoring response to Tripple H therapy, Endovascular therapy

- Detection of Intracranial Aneurysm – introduction of trans-cranial colour coded sonography

- Peroperatively can be used for assessing the vasospasm, patency of vessels, residual aneurysm
Head Injury

- Blood flow velocity from relative flow changes - Vasospasm/ Hyperemia
- CO2 reactivity
- Cerebral Autoregulation
  - Static autoregulation
  - Dynamic autoregulation
- Post-traumatic Vasospasm
- Vascular Dissection
Brain death

- False positive
  - Cerebral circulatory arrest can be transient
  - Residual brainstem circulation
  - Abnormally low diastolic pressure; IABP

- False Negative
  - Complete destruction of brainstem with preserved supratentorial flow
Arteriovenous Malformation

- High velocity in feeding arteries
- Low pulsatility index s/o decreased peripheral vascular resistance
- Defective autoregulation
- Intraoperative use to detect residual aneurysm during surgery or neuroendovascular procedures
Intraoperative and Procedural Monitoring

- Carotid Endarterectomy
  - For cross-clamp Hypoperfusion
  - Detection of emboli
  - Postoperative hypoperfusion
  - Postoperative occlusion
During Cardiopulmonary Bypass

- Dynamic evaluation of cerebral blood flow
- Detection of emboli during aortic cannulation and cardiac manipulation
Latest development

- Transcranial colour coded Ultrasonography
- f-TCD