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 focussing of the transducer, duration of transmitted sound burst at a specific pulse repitition 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 Electonics developed the Trans-scan, device capable of three dimensional, multiprojectioal 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 X cosine of angle of insonation

Vessel Identification Criterion

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

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 pulsatilty Vs>>Vd
- Damped pulsatility Vd > 50% of Vs

Pulsatility Index

- Gosling Equation

$$PI = Vs - Vd / Vm$$

- 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 CO_2 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 cm/s = Vasospasm

  > 200 cm/s = Severe Vasospasm
- Velocity Increase > 50 cm/S over 24 hour period – high risk for DIND
- D/D vasospasm and Hyperemia
- Lindegaard Ratio

  V_{MCA}/V_{ICA} (1.7 ± 0.4)

  > 3 = 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
- CO_2 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