TCD: Critical Tool for Critical Care

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DISCLOSURES

FTE, Private Practice for profit

IMPORTANT:
- ICP monitoring
- Pb02
- CBF

Multimodal Monitoring
- MAP
- SaO2
- ECG
- ETCO2
- CVP
- Urine output
- ICP
- CBFV/TCD
- PbO2
- eEEG

Perfusion
Specific TCD Applications for Critical Care

- Vasospasm diagnosis/monitoring and treatment effect evaluation after TBI, SAH, intracranial hemorrhage, tumor resection
- Stroke diagnosis/monitoring and treatment effect evaluation
- PFO screening for cryptogenic stroke and risk assessment
- Emboli and Fat emboli monitoring
- CEA/CAS effect evaluation
- Neuroradiology test-occlusion (pre, during and post)
- Neuroradiology stenting (pre, during and post)
- Pre- and Post-treatment AVM evaluation
- Septic patients evaluation
- Diagnosis and monitoring of intracranial hypertension
- Brain Death

TCD Criteria for diagnosis of vasospasm

<table>
<thead>
<tr>
<th>Mean CBFV (cm/s)</th>
<th>MCA/ICA ratio (Lindegaard Ratio)</th>
<th>Interpretation</th>
</tr>
</thead>
<tbody>
<tr>
<td>&lt;100</td>
<td>&lt; 3</td>
<td>Nonspecific</td>
</tr>
<tr>
<td>100-140</td>
<td>3-6</td>
<td>Mild</td>
</tr>
<tr>
<td>140-200</td>
<td>3-6</td>
<td>Moderate</td>
</tr>
<tr>
<td>&gt;200</td>
<td>&gt;6</td>
<td>Severe</td>
</tr>
</tbody>
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Positive Predictive Values

- Need 80% PPV prior to more invasive testing
- Need 90% NPV before repudiating the need for further treatment
  - Only values <120 or >200cm/s
  - Values between 140 and 200cm/s: 50% PPV
  - EXCEPTION TCD CBFV 160-199 cm/s with >40cm/s difference between sides!
Role of TCD: Vasospasm

- The presence and temporal profile of CBFV’s in all available vessels must be detected and serially monitored.
- The pattern of CBFV’s elevation may indicate the need to follow patient carefully for evidence of deficits related to specific vascular territory.
- TCD waveform appearance either regionally, or globally may be clinically significant.

- Vasospasm is a very important source of morbidity and mortality. Too often, the first sign is a neurologic deficit, which may be too late to reverse.
- TCD assists in the clinical decision-making regarding further diagnostic evaluation and therapeutic interventions.
- As TCD-defined vasospasm preceded the neurological deficit in 64%, earlier intervention might reduce the incidence of vasospasm-related stroke in military hospitals with similar practice patterns.

Role of TCD: Vasospasm

- When performed in isolation, the contribution of TCD to improving patient outcome has not been established in the prospective studies. Nevertheless, TCD has become a regularly employed tool in neurocritical care.
- TCD can easily identify onset and time-course of vasospasm and augments neurological examination.
- TCD can evaluate effect of treatment, especially after endovascular interventions.

Guidelines for the Management of Aneurysmal SAH

**Summary and Recommendations:**
1. SAH is a medical emergency...
2. CT scanning for suspected SAH is strongly recommended...
3. Selective cerebral angiography to document...
4. TCD is recommended for the diagnosis and monitoring of VSP, although the cerebral angiography may be required for definitive diagnosis.
2011 AHA/ASA Metrics for Measuring Quality of Care in Comprehensive Stroke Centers

• Among different measures for Comprehensive Stroke Centers is:

Median frequency of noninvasive monitoring for surveillance for vasospasm in patients with aneurysmal SAH during the period between three and 14 days after SAH

Factors influencing TCD data interpretation

• Patient age
• The presence of moderate to severe anemia (Hct <27)
• Impaired CBF autoregulation (passive CBFV variation with MAP changes)
• Hyperemia induced by triple-H therapy

TCD & INTRACRANIAL HYPERTENSION

• Numerous data shows a highly significant correlation between TCD PI and ICP independent of intracranial pathology.
• Accordingly, in patients with suspected increase in ICP or where an increased ICP has to be excluded, PI may be of guidance and repeated PI measurements might prove a useful tool in neurointensive care or out-patient settings.
**Role of TCD: Intracranial hypertension evaluation**

- TCD wave-form changes indicate abnormally high ICP, especially after 20 mm Hg.
- TCD changes may alarm Neuro-ICU personnel and may indicate malfunctioning of ICP probe.
- Abnormally globally decreased pattern of the CBFV’s in parallel with increased PI’s indicate onset of diffuse intracranial hypertension.
- Sudden onset of asymmetrical CBFV’s and PI’s changes may indicate potential mid-line shift.
- TCD quantitative and qualitative analysis must be taken into account for evaluation of intracranial hypertension, however, MAP, PaCO2 and cardiac output must be within the normal limits.

**TCD and Acute Stroke**

- Different stroke therapies may offer a benefit for one mechanism but for other others.
- If the mechanism can be determined in the first few hours after stroke, then patients with different stroke subtypes could be selected for specific therapies in clinical practice.

**MRA/CTA: Overestimation of brain vasculature lesions**
Hemodynamic studies in early ischemic stroke

Akopov et al., Stroke, 2002

- 47 acute stroke patients
- Three serial TCD (24 hrs, 24-48 hrs, between 4 and 8 days); Single MRA
- Serial TCD studies revealed an evolution (improvement or deterioration) of intracranial hemodynamics in 34%. Single MRA study may not demonstrate dynamic changes
- Serial TCD studies is a useful, inexpensive adjunct to MRA study, transforming the static MRA picture of cerebral perfusion into a dynamic evaluation of cerebral circulation

Role of TCD: Acute Stroke/TIA

- TCD within 24 hours of symptoms onset improves the early accuracy of stroke subtype diagnosis, especially in patients with large artery atherosclerosis
- Early detection may also affect therapeutic strategies in patients with acute/subacute cerebral ischemia or extra- or intracranial lesions (symptomatic or asymptomatic)

American Society of Neuroimaging
38th Annual Meeting

Role of TCD: Acute Stroke/TIA

- TCD can identify hemodynamically significant abnormalities and lesions of the brain vasculature
- TCD is an accurate indicator of blood flow status and may be as reliable as angiography and correlated well with MRI, MRA, DSA, and CTA at a fraction of the cost and no risk for patients
- TCD could identify the active source of embolism in a very cost-effective manner. Detection of emboli may deliver clues for identification of the true, embolically active lesion

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Role of TCD: Acute Stroke/TIA

- TCD can be performed rapidly and effectively in acute setting (ER, OR, ICU) or done longitudinally to evaluate progression and/or regression of disease.
- TCD allows rapid, non-invasive and cost-effective manner evaluation of the blood flow status in basal cerebral arteries and offer new insight into the process of acute stroke and provide guidance for and monitoring of therapeutic interventions.

Monitoring of Acute Stroke Treatment

Role of TCD: Monitoring of acute stroke treatment

- TCD could be ideal to guide aggressive treatment.
- TCD can help in the primary and repetitive diagnosis of the vessel occlusion by indicating whether the lesion is present at all, still present or already re-canalized.
- TCD can confirm the clinical diagnosis, can be done repetitively and close to the anticipated time of fibrinolysis.
Role of TCD: Monitoring of acute stroke treatment

- A confirmatory TCD before angiography is the key to prevent exogenous fibrinolysis, which bears a high risk of intracranial bleeding
- A noninvasive bedside and expeditious TCD able to add key prognostic information in patients with a similar clinical presentation:
  - MCA occlusion predicts death or disability at 3 month
  - Patent MCA facilitates more aggressive therapeutic interventions such as induced hypothermia or decompressive craniotomy

Outcome prediction/prognosis

Treatment monitoring

Treatment effect evaluation

Possible favorable effect of ultrasound on recanalisation after acute onset of ischemia

- The potential therapeutic use of external high-intensity focused US was explored by Lynn et al. (J Gen Physiology, 1942). Lynn et al. postulated that external HIFU can induce localized tissue damage at a focal point within the body with no effect on the surface or on the overlying or surrounding tissue

Current approach

- In vivo arterial clot dissolution can be achieved:
  - With i/v microbubbles and transcutaneous US
  - With i/v thrombolysis facilitated by transcutaneous US
  - By transcutaneous therapeutic US
  - Catheter based therapeutic US
Role of TCD: Stroke Treatment

• Work in progress

TCD AND EMBOLI, STROKE RISK EVALUATION AND FAT EMBOLI

Role of TCD: Emboli Monitoring

1. Quantitative count of emboli
2. Localization of the embolic source responsible of stroke
3. Identification of high-risk patients for stroke recurrence
4. Monitoring of the therapy effectiveness
5. Monitoring of cardiovascular surgery
6. Monitoring different type of invasive procedures

TCD and Emboli

• Etiology of stroke is embolic in 32%
• TCD technique is the “gold” standard to detect emboli in real-time while emboli going through the cerebral circulation
• TCD emboli monitoring could be useful for patients with stroke, TIA, potential cardiac sources of emboli, symptomatic and asymptomatic carotid stenosis, complications of dialysis, etc.
TCD FOR ASSESSMENT FOR THE RIGHT-TO-LEFT CARDIAC SHUNT AND RISK EVALUATION

• TEE
  - Seminvasive
  - Sedation
  - Not possible to perform in patients with swallowing difficulties
  - Involves many specialists, expensive equipment

  Global Fee $1400.00

• Bubble-TCD is the cost-effective and minimally invasive compared to bubble-TEE
• Provides direct evidence for emboli in the cerebral vessels
  
• Global Fee $293.00

Bubble TEE and Bubble TCD

TCD as a screening technique for detection of PFO before surgery in the sitting position

• Venous air-embolism occur in 23-45% of patients undergoing neurosurgical procedures
• Prospective study, 92 pts, c-TCD, c-TEE (ref. standard) and c-TTE
• A PFO was detected in 24 pts (26%) using c-TEE, c-TCD correctly identified 22 pts (24%), c-TTE only 10 pts (11%)

Stendel R. et al, 2000
TCD PFO testing and monitoring during operations on long-bone fractures

- It is well known that during these types of surgeries the fat embolism syndrome (FES) is a frequent complication. The incidence of FES after single long-bone fractures is estimated to be 0.5% to 10%.
- TCD is only one unique standard today that allows monitoring for emboli and their detection in real time and we can monitor for emboli and potentially prevent complications during surgery.
- Paper from Forteza et al. (Circulation, 2011;123, 1947-52) showed that in patients with long bone fractures, the presence of a PFO was associated with larger and more frequent microemboli signals to the brain detected by TCD (PPV 86%, NPV 97%).

TEE Cost

- National Transesophageal Echocardiography Procedure Pricing Summary
  - National Minimum Price $875 (Harriman, TN)
  - National Average Price $3,700
  - National Maximum Price $10,100 (Lock Haven, PA)
- Transesophageal Echocardiography Cost Averages Around the Country
  - Phoenix, AZ Transesophageal Echocardiography Cost Average $3,200
  - Washington, DC Transesophageal Echocardiography Cost Average $4,100
  - Philadelphia, PA Transesophageal Echocardiography Cost Average $3,900
  - Houston, TX Transesophageal Echocardiography Cost Average $3,600
  - Miami, FL Transesophageal Echocardiography Cost Average $3,625
  - Dallas, TX Transesophageal Echocardiography Cost Average $3,900
  - Chicago, IL Transesophageal Echocardiography Cost Average $3,625
  - Los Angeles, CA Transesophageal Echocardiography Cost Average $4,400
  - New York, NY Transesophageal Echocardiography Cost Average $4,000
  - Atlanta, GA Transesophageal Echocardiography Cost Average $2,550
TCD wave form progression from intact CBFV to circulatory arrest

Hassler et al., 1988

TCD pattern in Brain Death

CPP = 0

Role of TCD: Brain Death

• Quickly detects dramatically elevated ICP
• Confirms brain death in comatose patients
• Reliably determines arrest of cerebral circulation, which can shorten observation time for organ retrieval in patient with brain death

What TCD Service Could Achieve

• Immediate bed-side results
• Provides accurate blood flow velocity information for determination of disease severity
• Detects even minimal cerebral hemodynamic changes
• Ideal modality for following disease progression, therapeutic, radiological or surgical revascularization, stages of recovery and long-term therapeutic
What TCD Service Could Achieve

• Accurate, cost-effective method for diagnosis of intracranial disease and effect of extracranial disease on cerebral circulation
• The economic effect is clear. In a climate where doing more with less is imperative, any service/methods that increases productivity without compromising quality will positively impact Patient Outcome and success of the Hospital

TCD as a Modality

• Will be very good, reliable and accurate, if:
  • Dedicated Personnel
  • Daily Monitoring of the Technical Performance Quality
  • Quality of Interpretation

TCD is a Critical Tool in Critical Care

• The use of TCD on admission allows identification of patients with brain hypoperfusion due to the cerebral ischemia (stroke, vasospasm) and/or intracranial hypertension. In such high-risk patients, early TCD goal-directed therapy can restore normal cerebral perfusion and might then potentially help in reducing the extent of brain injury
• TCD could provide information about abnormally high ICP
• Incorporation of TCD data may facilitate more injury- and time-specific therapies for wartime or civilian TBI patients