Power Doppler Neurosonography
Pediatric Potpourri

Paul Maertens, MD
Professor of Neurology
University of South Alabama, Mobile, AL

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SS disease

- TCD in SS disease
- STOP Study
- TWITCH study
- Stroke
Pediatric Incidence of Stroke

- **Overall:**
  - Under the age of 1 year: 0.5/100,000/year
  - between 1 and 14 years: 1.3/100,000/year
    - hemorrhagic: 0.71/100,000/year
    - non-hemorrhagic: 0.58/100,000/year

- **Sickle Cell:** between 1 and 14 years:
  - 285/ 100,000/year (0.28%/year)
    - hemorrhagic: 47/100,000/year
    - non-hemorrhagic: 238/100,000/year

- **Non Sickle Cell:** between 1 and 14 years: black: 0.83/100,000/year; white:
Neuropathology of Vascular Blockade in Sickle Disease

• Large arteries\(^7\):
  – distal ICA
  – proximal MCA

• Intimal thickening due to proliferation and migration of smooth muscle into the intima\(^8\)
TAPV: Time Average Peak Velocity

- is obtained when the area above the horizontal line below the peak systolic velocity ($A_1$) equals the area below this line and above the peak diastolic velocity ($A_2$).

$EDV = \text{end-diastolic velocity, } PSV = \text{peak systolic velocity}$
Calculation of Time-Averaged Peak Velocity (TAPV)

- TAPV = \{PSV+(PEDVX2)\} : 3
  where:
  - PSV is peak systolic velocity
  - PEDV is peak end diastolic velocity
Advantages of Time-Averaged Peak Velocities (TAPV)

• Compared to peak systolic velocity (PSV) and peak end diastolic velocity (PEDV), TAPV:
  – is less dependent on systemic factors such as heart rate, contractility and peripheral resistance
  – is less variable among individuals
  – has a higher correlation with cerebral perfusion
Collection of Time-Averaged Peak Velocities

- The preferred method for determining TAPV is by manually drawing a line across the envelope of the peak velocities over 3 cardiac cycles.
- TAPV should be estimated at least every 2 mm at various depth for each vessel.
- The highest TAPV for each vessel will be used for interpretation.
TCD in Children with Sickle Cell Disease but Without Stroke

- **No cerebrovascular disease**: inverse relationship between TAPV and hematocrit
  
- **Cerebrovascular disease**:  
  - focal narrowing of 50% or more by angiography is associated with TAPV exceeding 200 cm/sec (unless there is obvious neurologic deficit)
  
- High TPA predicts stroke: within 40 months of TCD,  
  - TPA < 170 cm/sec (83% of patients): 2% have stroke  
  - TPA \( \geq 170 \) cm/sec: 28% have stroke  
  - TPA \( \geq 200 \) cm/sec (8% of patients): 40% have stroke within 28 months of TCD
Stenosis in RT ICA
Population in STOP study

• 130 normal SS children between 2 and 16 YO without stroke and with TAPV = or >200 cm/sec were randomized:
  – 67 patients in standard of care group
  – 63 patients in transfusion group; average length of transfusion was 6.3 years
STOP study

• tests the hypothesis that periodic blood transfusion with reduction of HbS to under 30% would result in a 70% reduction in symptomatic cerebral infarction or intracerebral hemorrhage compared to standard care\textsuperscript{4}
Result of STOP study

- 14 of 67 patients receiving standard of care had a stroke within 27 months and required subsequent transfusion.
- 4 patients assigned to the transfusion group declined transfusion at the onset: none developed a stroke.
- 1 of the 63 patients transfused developed a stroke within 27 months. The percent reduction of stroke with transfusion therapy was 92%.
Interpretation of TCD Using the STOP Protocol

- **Normal** if TAPV < 170 cm/sec in all vessels
- **Conditional:**
  - if TAPV = or > 170 cm/sec in ACA, PCA, TOB or BA
  - if TAPV = or > 170 cm/sec but < 200 cm/sec in ICA, MCA or BIF
- **Critical** if TAPV = or > 200 cm/sec in ICA, MCA or BIF
Normal TAPV
Conditional TAPV
Conditional TAPV
Critical TAPV
Imaging of Lt MCA Stenosis in SS
MCA stenosis and Aneurysm
Right PCoA aneurysm (An).

A. Intra-arterial digital subtraction angiography (IADSA) image demonstrating an obvious large right PCoA aneurysm (An).

B. TCDS of same aneurysm, also showing part of the circle of Willis. RT indicates right; LT, left; PCA, posterior cerebral artery; and Bas, basilar artery.

White P M et al. Stroke 2001;32:1291-1297
A, IADSA of a small 3-mm left terminal carotid aneurysm (arrow).

White P M et al. Stroke 2001;32:1291-1297
Aneurysm
Vasospasm after Removal of Craniopharyngioma
INTRAOPERATIVE PDI

• The Power Doppler ultrasound scanning provides the neurosurgeon with the simplest and the cheapest possibility of direct intraoperative pathological and normal vasculature visualization.

• These technique enables the fantastic estimation of tumors vascularization, helps to avoid unnecessary bleeding from earlier detected supplying vessels and to preserve vessels being in contact with tumor.

• It may be extremely useful in the vascular neurosurgery – in the estimation of AVM’ feeders and in the correctness of clip application, although our modest experience don’t allow to prove it doubtfully and it requires further examinations.

• References in authors possession.
useful in the localization of small arteriovenous malformations (AVMs) and feeders estimation.
Aco-A saccular aneurysm in the Power Doppler sonography
Anterior communicating artery aneurysm
A case of tentorial meningioma adherent to the sagittal sinus. In the Power Doppler presentation you can see the tumor in the relation to the sinus.
TBI before and after craniotomy
Subdural and Cerebral Contusion
Subarachnoid Space Enlargement

Figure 1. a-d. Positive cortical vein sign on axial T2-weighted MR image (a) and cortical veins visualized with power Doppler US (b–d) in the subarachnoid space in a case of benign subarachnoid space enlargement.
Differentiation of Subarachnoid from Subdural Fluid Collections

- **Wide Subarachnoid**: because superficial cortical blood vessels lie within the pia-arachnoid, fluid in this subarachnoid space surrounds and lifts the cortical vessels away from the brain surface.

- **Subdural**: fluid in the subdural space pushes cortical vessels toward the brain surface and is separated from these vessels by a thin membrane.
Brain Death
Brain Death

- Power Doppler only visualizes ICA and proximal BA
Luxury Perfusion in Area of Ischemia

Fig. 2a, b Parasagittal cranial ultrasound with PDI through the right sylvian fissure: a normal vascularity; b increased vascularity around the left middle cerebral artery territory
Fig. 3 A coronal cranial ultrasound scan with PDI showing increased colour signal in the distribution of the left middle cerebral artery territory.

Fig. 4 A cranial CT scan (non-contrast) showing high gyrus attenuation in the left middle cerebral artery territory and dilatation of the left lateral ventricle.
PDI is a signal-processing technique evaluating the total signal energy rather than the mean frequency as with CFD. When utilising CFD, which is based on mean frequency shift, noise in the signal appearing as speckle artefact can be misinterpreted as flow, hence “gain” and “threshold” have to be set so that noise does not submerge “true” vascular signals. In PDI the gain may be set high and, as noise is uniform throughout the image, the vascular signal is still apparent. As there is no directional encoding with PDI more processing time per pulse allows better assessment of low amplitude information. Hence PDI has been calculated to be between three and five times more sensitive for low flow [3], and this enables luxury cerebral perfusion to be more easily demonstrated, as in the case of our pa-
Rt Lobar Hemorrhage in NN with seizures
Temporal Lobe Tumor
Recent Advances in Power Imaging

• 1. 3D Power imaging
• 2. Functional Power Imaging: power Doppler is suitable for imaging microvascular hemodynamics
3D Power Imaging

• Allows angiographic imaging of complex vascular structures
power Doppler rendering of the circle of Willis in a 36-week fetus.
Neonatal brain
3D (lower) Reconstructed Image of Normal Medullary Veins at 28 weeks
3-D Power Doppler Imaging of Vertebrobasilar Circulation

3D power Doppler angiogram of Vein of Galen Aneurysm
3D power Doppler angiogram with superimposed gray scale image of Vein of Galen Aneurysm
tumor

Feedin arteries of tumor
Anterior cerebral a. It middle cerebral a.

Anterior cerebral a.
Draining vein of tumor
Internal carotid a.
Functional Power Imaging

- fUS uses plane-wave illumination at high frame rate and can measure blood volumes in smaller vessels than previous ultrasound methods.

- Applications
  - 1. Imaging of normal brain function: imaging of whisker-evoked cortical and thalamic responses
  - 2. Imaging of abnormal brain function: imaging of the dynamics of blood volume in response to epileptiform activity and the propagation of...
Functional ultrasound imaging of the brain

Renee Marder, Andrea Milanesi, Thomas P. Frieden, Michael B. Heiss, and Mark A. Frankel

Introduction: Functional ultrasound imaging (FUSI), a non-invasive method for imaging neural activity in living brain tissue, has been used to study a variety of neural processes. FUSI relies on the propagation of ultrasound waves through tissue, which can be detected using sensitive detectors. In this study, we used FUSI to investigate neural activity in the primary motor cortex of a macaque monkey. We observed that the motor cortex is activated by electrical stimulation of the hand, and that this activation is accompanied by a decrease in ultrasound intensity.
Normal Functional Imaging
fUS imaging of task-evoked brain activation in the rat brain

(a) 250 PD images over time with On and Off stimuli.
(b) Correlation coefficient maps showing S1 and VPM regions.
(c) Correlation coefficient scale.
(d) Diagram of EEG signal.
(e) Time series of PD images at 28, 44, 59, and 75 s.
(f) EEG signal with PD data over time.
(g) Power Doppler and propagation delay maps.
Epileptic seizure propagation
Power Doppler of Carotids
Internal & external carotid artery

Power Doppler US

2 small branches originating from ECA

Variants resulting from elongation of ICA

- C-shaped Course
- S-shaped course
- Coiling
- Kinking
Variations in extracranial circulation

Few

- Left CCA & SCA share single trunk
- Left vertebral artery arising directly from aortic arch
- Right vertebral origin arising directly from aortic arch

Power Doppler US is better for differentiation of surface plaque morphology, and it better depicts low-, middle-, and high-grade stenosis, compared with color Doppler US, in the evaluation of internal carotid arterial

Griewing B et al. Stroke 1996;27:95-100
Middle-grade ICA stenosis visualized with the use of CFD in a longitudinal section (top left); PD in cross section, enabling an area measurement (bottom left).

PD in a longitudinal section (top right);

Griewing B et al. Stroke 1996;27:95-100
Large plaque ulcer

**Color Doppler**
- Pseudo-dissection

**Power Doppler**
- “eddy flow”

Large plaque ulcer

Color Doppler
Pseudo-dissection

Power Doppler
“eddy flow”
Estimation of carotid stenosis

Diameter reduction

Surface reduction
Relationship between diameter reduction & cross-sectional area reduction

<table>
<thead>
<tr>
<th>Diameter reduction (%)</th>
<th>Cross-sectional area reduction (%)</th>
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<tbody>
<tr>
<td>30</td>
<td>50</td>
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<tr>
<td>50</td>
<td>75</td>
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<tr>
<td>70</td>
<td>90</td>
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High grade “string sign” stenosis

Tardus-Parvus waveform

Tardus: Long rise time
Parvus: Low PSV
Power Doppler image through the right internal carotid artery, demonstrating a sub-occlusion.

Colour flow image and spectral Doppler display demonstrating significant increase (in velocity) within a stenosis with respect to the graft proximal to the stenosis.
High-grade ICA stenosis. a, Poor display on CDFI without visualization of the residual stenotic lumen due to a calcified plaque at the anterior vessel wall with a dense echo shadow. b, Color signals of PDI contrast the stenotic vascular lumen and the plaque...

Long stenosis of ICA

RICA:  
PSV  183 cm/sec  
EDV  105 cm/sec  

CCA:  
PSV  76 cm/sec  

PSV ratio:  2.4  
Inconsistent data

Long stenosis of ICA > 70%