Transcranial Doppler
Tips in interpretation for stroke risk

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Objectives

- Review TCDI criteria for cerebrovascular disease in sickle cell patients
- Compare TCD /TCDI performance & results
- Understand clinical implications of TCD results
Focal TCD Velocity Increase:

- SSD creates changes in AA anatomy
- Focal areas of narrowing; impacts flow similar to atherosclerotic narrowing
- Potential for thrombotic or ischemic event

- Image courtesy of Mayfield Clinic, Cleveland, Ohio
Sickle Cell Disease

- Children with SSD at risk of cerebral infarction \( 2^\circ \) to occlusive vasculopathy
- Stenosis of ICA, MCA, ACA may progress for years prior to stroke.
- TCD shown to predict risk of stroke in children with SSD
STOP Study

- Demonstrated children with abnormal TCD’s had a 10% risk of stroke
  \[ MCA, dICA TAMx > 200 \text{ cm/sec} \]
  \[ PSV > 250 \text{ cm/sec} \]

- Those treated with hypertransfusion Rx reduced the risk of stroke to <1% per year.

- National Heart Lung Blood Institute recommends TCD screening q 6 months children SSD b/w ages of 2 – 16.
STOP technique needs to be meticulous

- Treatment recommendation made on basis of optimized velocity measurements.

- Crucial to demonstrate that
  - various instruments
  - techniques
  - measuring methods

velocities comparable to STOP results
Sites of Intracranial Narrowing Pediatric Sickle Cell Anemia:

- Proximal MCA (Bifurcation-BIF)
- Intracranial ICA (distal-dICA)
- Need to be area of intense focus for TCD examination
Good news!
Middle Cerebral Artery - MCA

- Most traceable and reliable landmark
- Carries ~80% of blood received by cerebral hemispheres
- Often excellent angle of insonation
Bad news!
MCA - poor technique can result in falsely low results

- Optimization key
- Need to angle until maximum audible Doppler frequency

Padayachee et al Ped Rad 2012
Bad news!
MCA can have false negatives and false positives

- When stenosis severe may have low velocities – false negative
- TAMX < 70 cm/sec may be abnormal particularly if ACA or PCA > MCA
- When asleep or febrile TAMx can be falsely high
Bad news!
Distal Intracerebral Artery Tricky

- Difficult angle of insonation – *falsely low velocities*
- Difficult to track entire vessel
- TAMx < 70 cm/sec may be truly abnormal
Bad news!
Can't ignore Anterior Cerebral Artery

- Difficult angle of insonation – falsely low velocities
- Difficult to track entire vessel
- Can have isolated ACA stenosis
Additional abnormal findings not discussed with STOP

- Low TAMx MCA, dICA <70 cm/sec
- Low RI < .3
- ACA TAMx > 170 cm/sec
- Max velocity PCA, VA, BA > MCA velocity
- Turbulence
- Nonvisualization of MCA with visualization of PCA, ACA
- Extracranial carotid arteriopathy > 160 cm/sec
Tips on identifying abnormal dICA

- Measure several levels of dICA
- If TAMx < 70 cm/sec and/or RI < .3 despite optimization - MRA to exclude stenosis
- Check Opth artery – Collateralization
Ophthalmic Artery
Ophthalmic AA through orbit

7 MHz use lowest power setting
Abnormal if:

- OA max vel > 35 cm/sec
- OA RI < 50
- OA velocity > ipsilateral MCA

Ophthalmic AA collateralization

Left Nl RI .78

Right ABN RI .43
MRA - Absent ACA’s bilaterally prominent right OA
Tips on evaluating ACA

- Track along the ACA
- If ACA > 170 cm/sec should be considered abnormal
- If ACA velocity > than MCA -
  - MCA may be abnormal with collateralization
- If ACA reversed – MCA/dIICA stenosis
6 yo
Lt ACA 142cm/sec RI.43
Lt MCA 130cm/sec

Chronic ACA occlusions
Why does STOP use Tamm, TAP, TAMMx velocity?

**CON**
- multiple confusing names
- not commonly used in radiology
- different measurement methods (electric, manual, line) with variable results
Can we use Peak Systolic Velocity?

*Adams et al* found

PSV highly correlated to TAMx

- **Normal** PSV $\leq 200$ cm/sec
- **Conditional** PSV 200-250 cm/sec
- **Abnormal** PSV $>250$ cm/sec
Should We Angle Correct?

- Variations least in MCA and dICA
  - predictable course
  - angle of insonation 0-30°.
- ACA, PCA tortuous often angle>30°.
Doppler shift

- Greater than 30 degrees will underestimate velocity

\[ \text{Vel (cm/s)} = \frac{77f_D \text{ (KHz)}}{F \text{ (MHz)} \cos (\alpha)} \]
Angle Correction

? Which is correct?

100 cm/sec

193 cm/sec
Angle Correction

- Tempting to angle correct to narrow velocity differences between the two techniques but

**NOT validated**

- Overestimation could lead to unwarranted treatment recommendations.
Optimization is key

- Need to angle until maximum audible Doppler frequency
- Improved training can decrease difference between imaging and nonimaging technique

Padayachee et al Ped Rad 2012
Extracranial carotid arteriopathy in children w SCA detection by submandibular Doppler Verlac et al Ped Rad 2014

Adding extracranial ICA via submandibular window detected 10% of at risk patients using a velocity of > 160 cm/sec. Low Hemoglobin and tortuosity can result in high velocities as well. Further studies needed.
Cases
Case – 9 yo
LMCA TAMx 285cm/s  PSV 359 cm/sec

What STOP Risk?
1. Normal
2. Conditional
3. Abnormal
MCA stenosis – Moya Moya changes
10 yo male for screening
TAMx:
RMCA  86 cm/sec        LMCA  272 cm/sec
R Bif   39 cm/sec       L Bif   110 cm/sec

What STOP Risk Stratification does he fall into?

1. Normal
2. Conditional
3. Abnormal
RMCA 86 cm/sec
RBif 39 cm/sec
LMCA 272 cm/sec

Abnormally high LMCA velocity
Low RBif
admitted to recent left sided weakness
MRA:
LMCA stenosis
Absent flow RICA
Case
Right MCA TAMX 212 cm/sec
No left MCA visualized
MRA

- Abn RMCA
- No LMCA
- Left dural anastomosis

Get good history!
Case - LMCA 192 cm/sec
Right MCA 185   Right ACA 188 cm/sec
LMCA 192 cm/s    RMCA 185 cm/s
RACA 188 cm/s

What STOP Risk Stratification does he fall into?

1. Normal
2. Conditional
3. Abnormal

What should you do?
Rescanned RMCA (185 cm/s)

RMCA 202 cm/sec   LMCA 192 cm/sec
REMEMBER!!

When velocities are high need to spend more time optimizing to get the highest velocities possible
3 yo MCA 162cm/sec  MRA normal

- When should his next study be performed?
FU 2 yrs later – low flow MCA < 40 cm/sec
Progressed to moyamoya
Remember!!

- Yearly follow up important even when results normal
- Particularly in younger patients
Case - 10 yo
Lt ACA 236 cm/sec
MCA     150 cm/sec
dICA    140 cm/sec
ACA     236 cm/sec     RI .42

What STOP Risk Stratification does he fall into?

1. Normal
2. Conditional
3. Abnormal
Remember!

- ACA may be the only vessel with an abnormal velocity and should be insonated with each exam
Case: 8 yo
MCA 52 cm/sec, RI .43

Left MCA

SV Depth 4.9 cm
PSV 70.7 cm/s
EDV 40.6 cm/s
RI 0.43
TAPV 52.4 cm/s
Hard to find left dICA
PCA 74 cm/s Basilar 117 cm/s
MCA 52 cm/s
MRA
- occluded ICA w/ collateralization of PCA
Remember!!

- Low TCD velocity may be just as abnormal as a high velocity
- Can progress to occlusion acutely or chronically and warrants careful follow up
Case - 8 yo  MCA 50 cm/sec  RI .40
Low LMCA velocity
Left dICA  40 cm/sec
Low

SV Depth  6.3 cm
PSV  62.0 cm/s
EDV  23.5 cm/s
RI  0.62
TAPV  40.4 cm/s
Reversed Lt ACA

SV Depth 6.8 cm
PSV 87.4 cm/s
EDV 25.4 cm/s
RI 0.71
TAPV 48.3 cm/s
LPCA 78 cm/s > LMCA 50 cm/s
Basilar 117 cm/s > L MCA 50 cm/s
- LMCA 50 cm/s
- LdICA 40 cm/s
- LPCA 78 cm/s
- LACA reversed
- Bas 117 cm/s
Severe dICA stenosis
What happens to TCD velocities following treatment?
Hypertransfusion initiated

TCD after 6 mos on Rx:
RMCA 132   LMCA 206

TCD after 20 months on Rx:
RMCA 101   LMCA 170

TCDS improved only to
CONDITIONAL RANGE
Case – 3 yo with Lt CVA

MRA pretreatment:
Bilateral ICA stenosis
Case – 3 yo with Lt CVA

TCD after 6 months Rx:
Bilateral MCA < 70 cm/sec

TCD after 18 months Rx increased:
RMCA 152 cm/sec
LMCA 170 cm/sec

Low TCD initially increased to normal range on Rx
BUT  Cerebral angio after 2 yrs Rx:
Bilateral dICA stenoses
Bilateral MCA stenoses

Low velocities PROGRESSED TO
Moya moya despite therapy
Which is more sensitive?
TCD vs MRA?
Rt MCA 200cm/s    Lt 204cm/s
MRI normal

Treated with Hydroxyurea
TCD is standard of care for Sickle Cell Anemia:

- Begin studies at 2 years- continue to 16yrs
- Compare studies to previous exams
- Increased velocity in dICA / MCA significant
- Changes in ACA velocity should be monitored
- Conditional exams: repeat 6-12mos.
- Abnormal exams: Emergency
Conclusions

- TCD is a powerful tool in the evaluation of sickle cell patients at risk for stroke.
- Those who perform TCD provide an important role in the care of children with SSD.
- Small application with a **BIG IMPACT**
Thank you!!