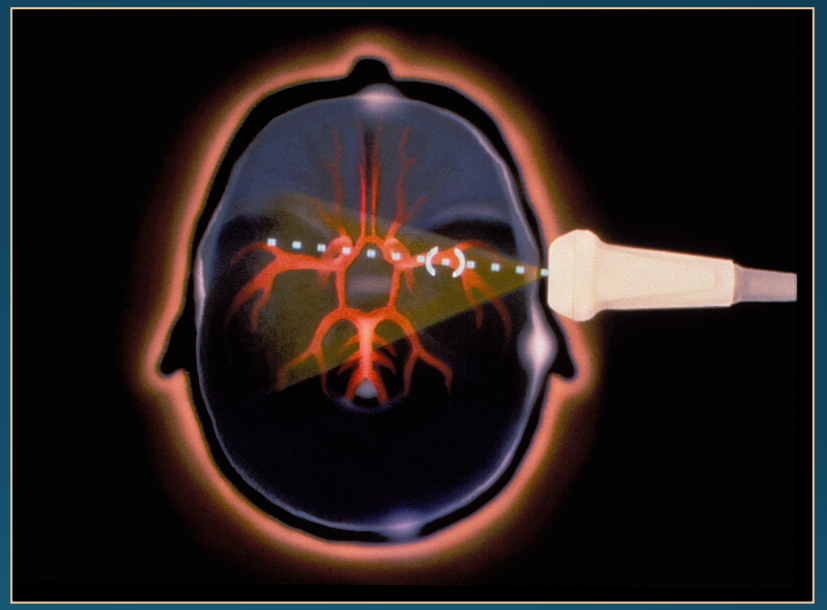
American Society of Neuroimaging 2021

Introduction to Transcranial Color Color Doppler Imaging (TCD-I) Adult



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I have no disclaimers

Objectives

- Learn basic technique used to perform transcranial color Doppler imaging
- Identify grey scale landmarks utilized for TCD-I
- Describe normal spectral waveforms
- Understand validated applications of TCD-I
- Define the limitations and advantages of this technique

Equipment

Anterior

Posterior

Vascular ultrasound w TCD-I software
Grey scale: boney & parenchymal anatomy
Color Doppler: vessel anatomy
*Spectral Doppler: blood flow hemodynamics
Safety Principle: ALARA

Broad band, phased array transducers
1 - 5 MHz B-mode
2 – 3 MHz Doppler

Basic Control Settings

B-Mode
Select 1.0-5.0 MHz range phased array sector transducer and presets for TCD exam
B-mode gain increases or decreases image brightness
Color Doppler
Select a high for color persistence
Keep color Doppler box (gate) width as narrow as necessary to improve the frame rate and color flow signal acquisition
Increase color Doppler gain to increase color fill or decrease if the color is bleeding outside presumed vessel walls
Set color scale/PRF low for slow flow and high for fast flow
Inverting the color scale changes the way negative and positive Doppler shifts (flow direction) are represented on the image
Spectral Doppler
Use spectral Doppler sample volume (SV) size between 5.0-10.0 mm; SV depth and position are adjusted to acquire vessels at different depths or locations
Set spectral Doppler velocity scale to normal values; adjust baseline and scale to record higher or lower velocities so the waveform occupies two-thirds of the area without touching the top or bottom of the display
Optimize spectral gain so the waveform is easily visible without background echoes on the display
Angle correction set at zero degrees unless vessel is >45 degrees off axis avoids overestimation of velocities.
Other Settings
Sweep speed is adjustable, for best analysis of waveform morphology display about 4 cardiac cycles per sweep. To appreciate changes over time or during provocation use a slow sweep speed.
Invert changes the display of the direction of flow. Convention has flow towards above and flow away below the baseline
Enlarge an area of interest using the zoom function
Use the ALARA (as low as reasonably achievable) principle to adjust power output

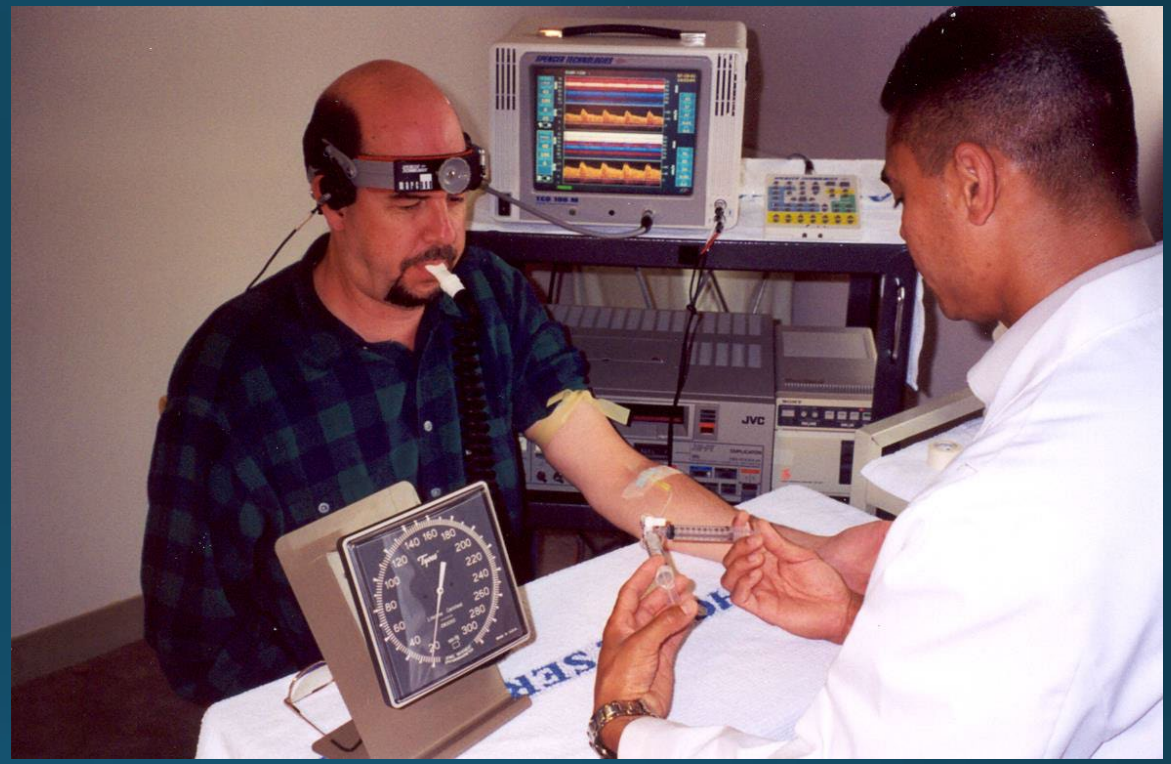
TCD-I Advantages

- Shorter learning curve (seeing is believing)
- Better vessel identification, anomalous anatomy
- Multipurpose equipment: carotid/peripheral/neuromuscular
- Expanded applications:

  Power Doppler for aneurysm identification,
  midline shift, hematoma, tumors, hydrocephalus, Parkinsons

TCD-I Disadvantages

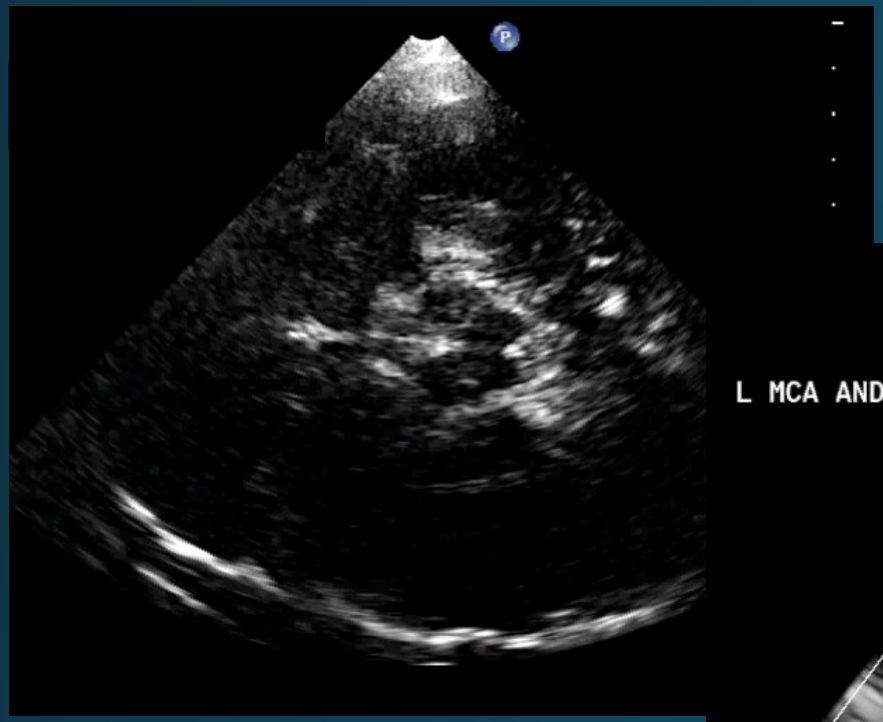
- Transducer design footprint limits access
- No *monitoring* applications
- Cost ?
- Equipment size



Small TCD transducers attached to head band
Bilateral MCA's continuously monitored during PFO Testing

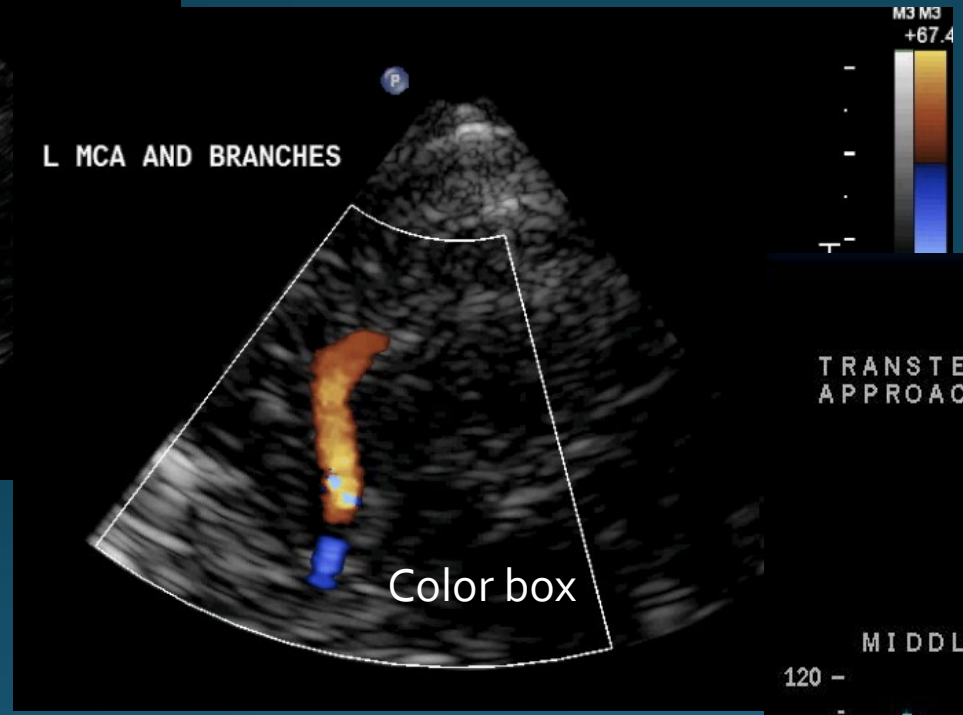
TCDI

B-mode



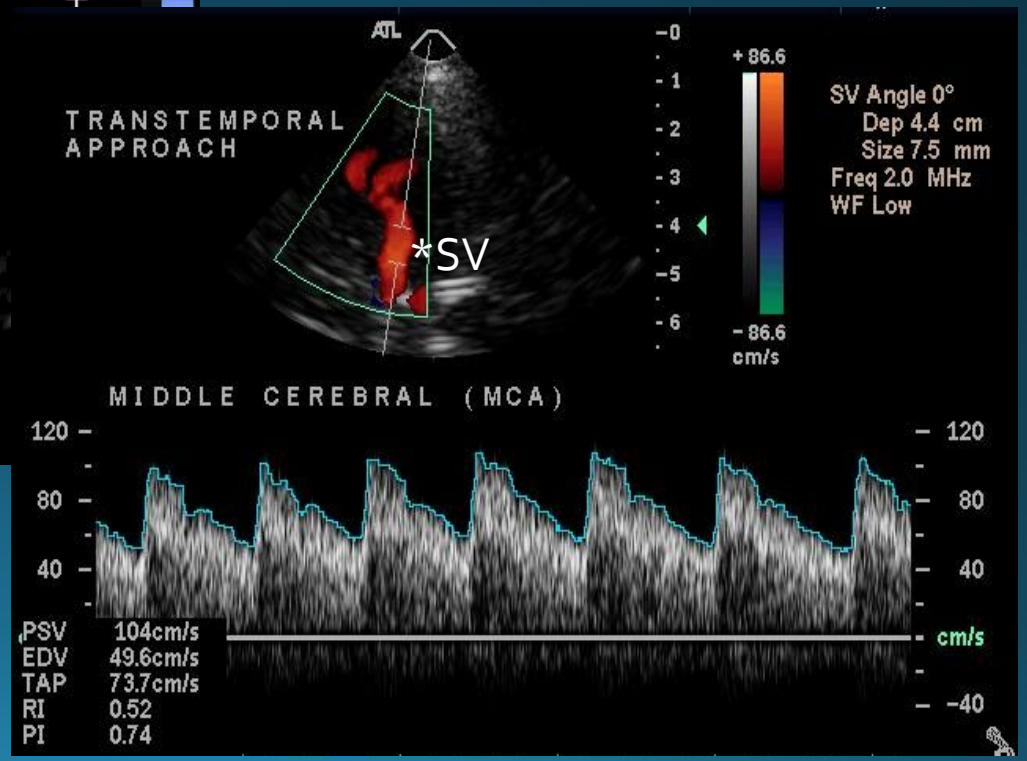
Anatomical Orientation

B-mode + color



Vessel Road Map

B-mode, color + spectal waveform

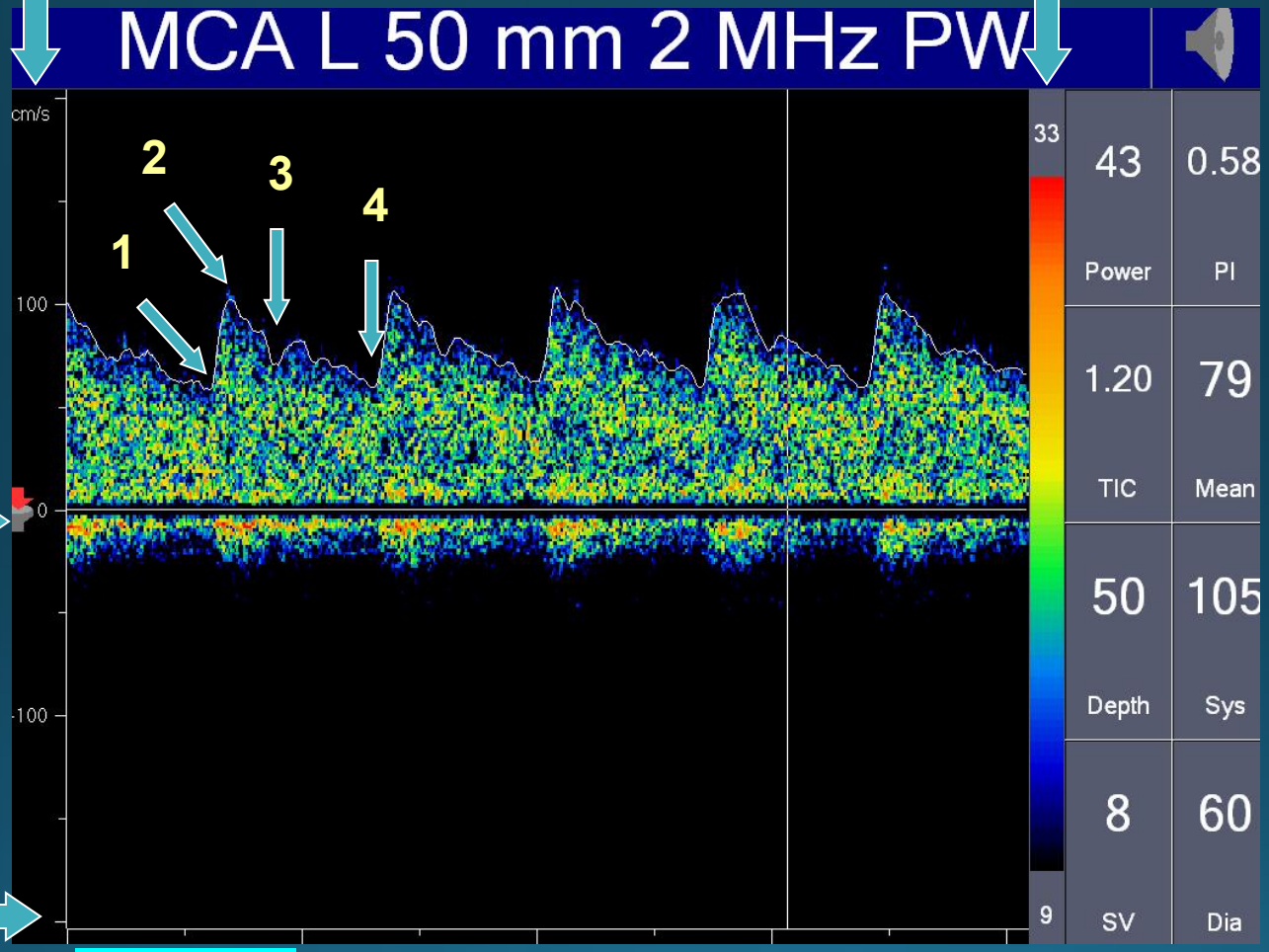


Quantitative Flow Measurements

*SV = sample volume

Velocity Scale cm/sec

Signal Intensity (Amplitude)



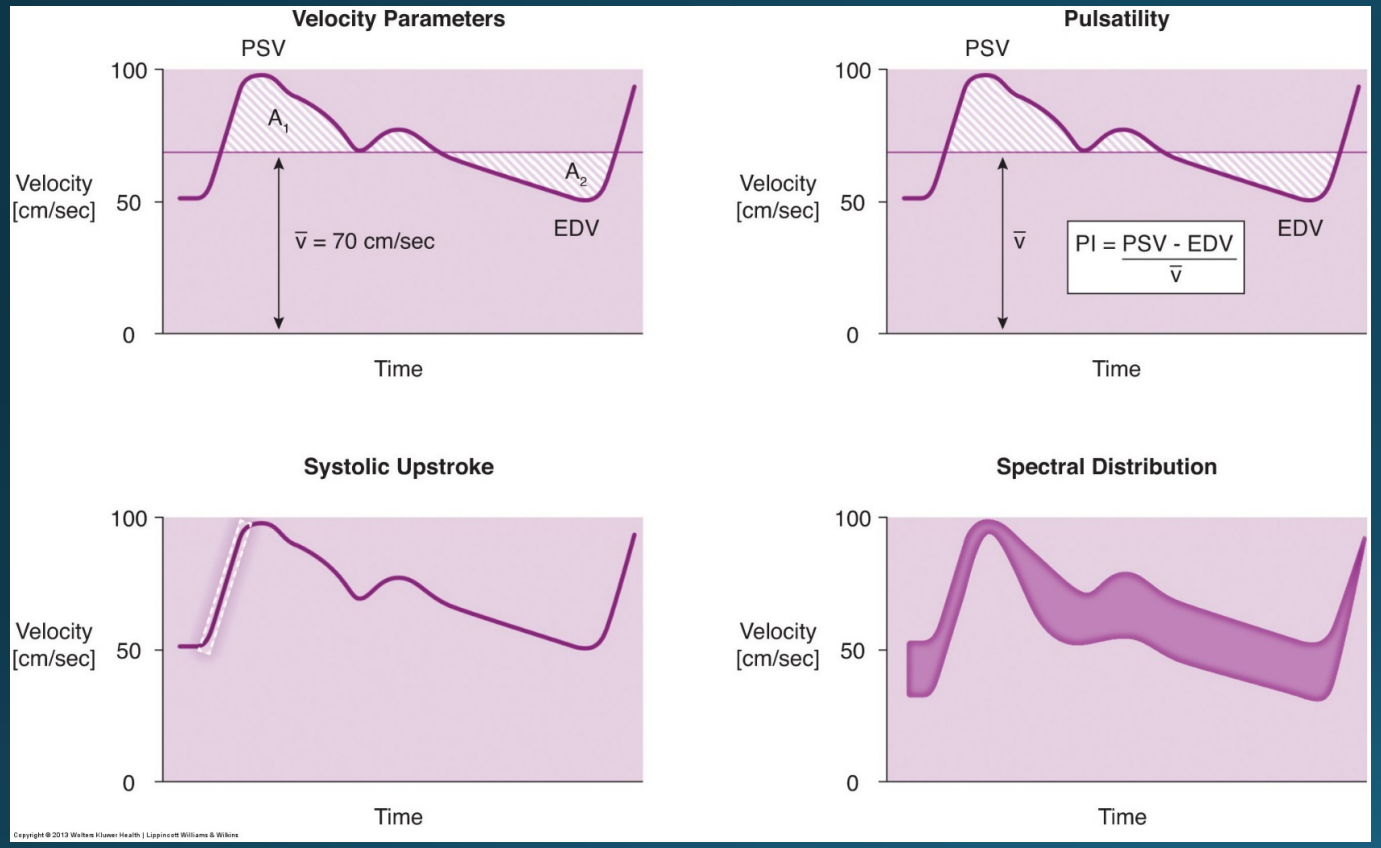
Baseline

Time Axis

1 second

1. Onset Systole
2. Peak Systole
3. Aortic Valve Closure
4. End Diastole

Spectral Waveform Analysis



Quantitative

- Alteration in velocity
- Changes in pulsatility

Qualitative

- Delayed systolic acceleration
- Deviations from laminar flow

* Changes in direction of flow

TCD & TCDI Normal Values

Artery	TCD Normal Velocity, SD (cm/sec)	TCDI Normal Velocity, SD Age 20-39 (cm/sec) Angle corrected	TCDI Normal Velocity, SD Age 40-59 (cm/sec) Angle corrected	TCDI Normal Velocity, SD Age +/> 60 (cm/sec) Angle corrected
TICA	39+/-9	-	-	-
MCA	55+/-12	71-76	69-76	55-61
ACA	50+/-11	57-62	57-64	48-54
PCA (P1)	39+/-10	51-55	48-51	40-45
PCA (P2)	40+/-10	45-49	46-51	39-45
Ophthalmic	21+/-5	-	-	-
Carotid (C2)	41+/-11	-	-	-
Carotid (C4)	47+/-14	-	-	-
ICA (Submandibular)	30+-9	-	-	-
Vertebral (V4)	38+/-10	42-47	38-43	30-36
Basilar	41+/-10	47-53	39-48	31-40

Velocities and resistive indices vary by:

Age
Arterial CO_2 level
Cerbral perfusion
Systemic perfusion

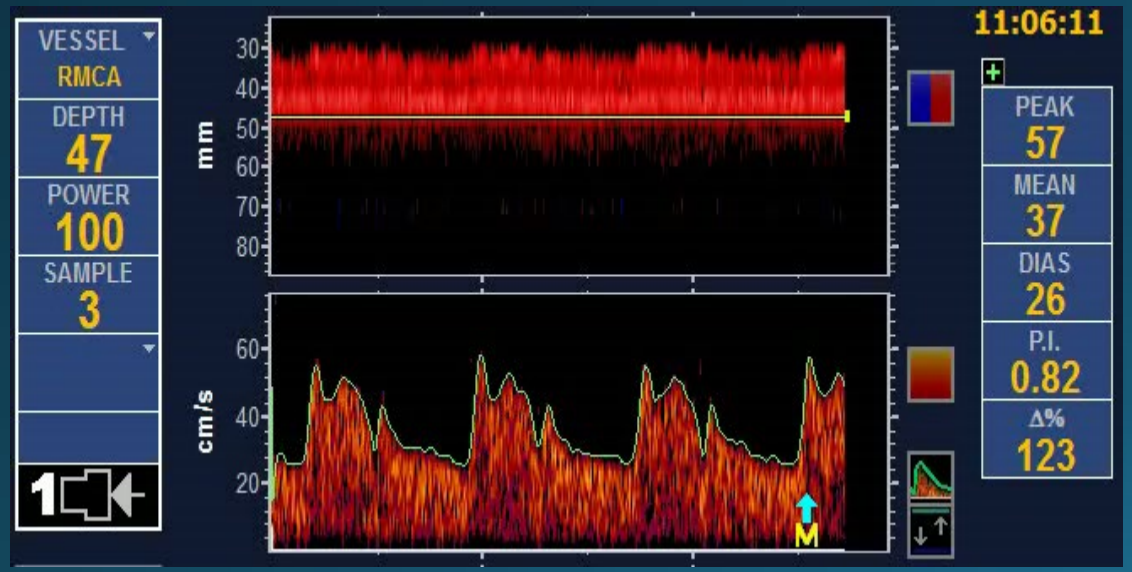
Influenced by:

Body temperature
State of arousal
Mechanical ventilation
Shunt shunts
Cardiac disease
anemia

Arnolds BJ, von Reutern MG. Transcranial Doppler sonography. Examination techniques and normal reference values. *Ultrasound Med Biol*, 1986;12:115-23.

Normal Waveform

1. Normal velocity
2. Normal P.I.
3. Straight Upstroke
4. No significant bruit



Pulsatility Index Calculation

Vessel Flow Resistance – Gosling's Index

PI= PSV – EDV/ Mean Velocity

PI - Pulsatility Index
PSV- Peak Systolic Velocity
EDV- End Diastolic Velocity

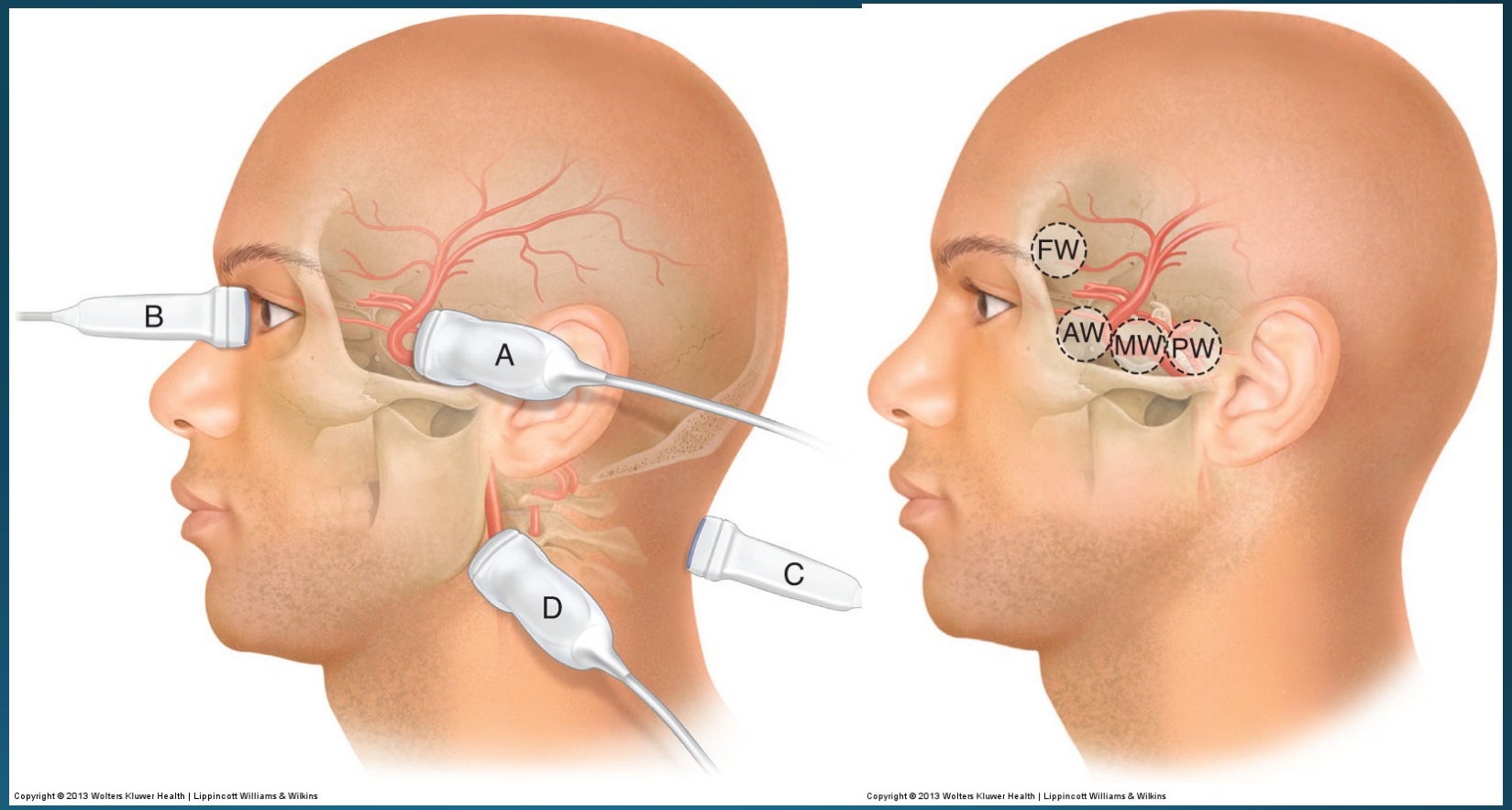
TCD-I Approaches

A. Transtemporal

B. *Transorbital

C. Foramen Magnum

D.**Retromandibular



* Use FDA approved transorbital setting with power reduction

** Primary use is for the calculation of the Lindegaard Index for patients with vasospasm

Window

Vessel Depths

Color Flow-Direction

Normal Adult Velocities (Mean)

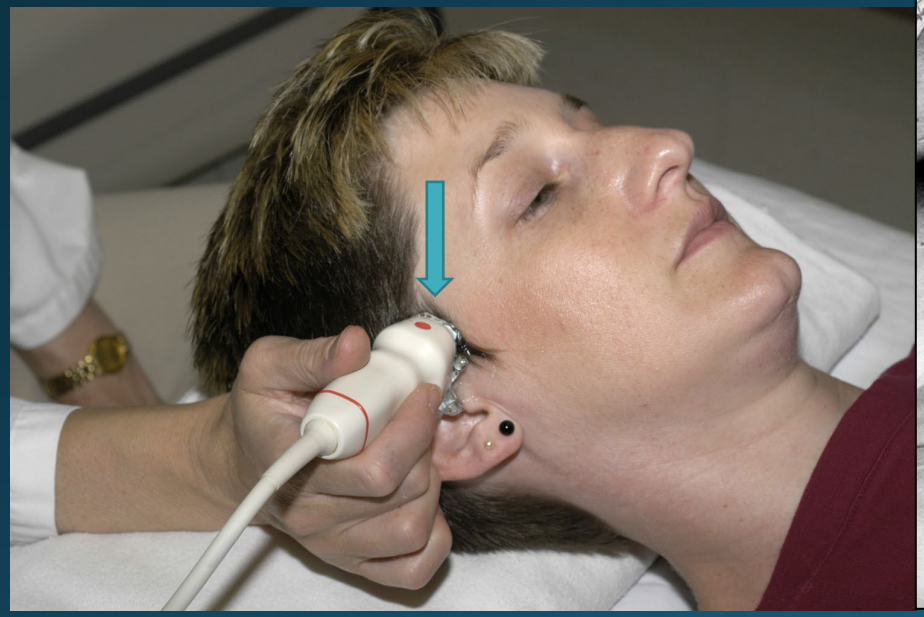
Window-Approach	Artery	Depth Range (mm)	Flow direction relative to transducer	Color flow map	[1]TCD & [2]TCDI: Normal Velocity (cm/sec) No Angle Correction	[3]TCDI: Normal Mean Velocity (cm/sec) Angle Corrected Age 20-40	[3]TCDI: Normal Mean Velocity (cm/sec) Angle Corrected Age 41-60	[3]TCDI: Normal Mean Velocity (cm/sec) Angle Corrected Age >60
Temporal	MCA 1	35-60	Towards	Red	55 +/- 12 58-74	81+/-20	73+/-19	59+/-11
Temporal	MCA 2	25-35	Towards or Away	Red/Blue				
Temporal	TICA	60-70	Towards or Away	Red/Blue	39 +/- 9			
Temporal	TICA Bifurcation	60-70	Towards or Away	Red/Blue				
Temporal	ACA 1	60-75	Away	Blue	50 +/- 11 51-61	56+/-14	53+/-16	44+/-11
Temporal	ACA 2	65-75	Away	Blue				
Temporal	ACOA	65-75	Indeterminant					
Temporal	PCA 1	60-75	Towards	Red	39 +/- 10 42-53	52+/-12	51+/-12	40+/-9
Temporal	PCA 2	60-65	Away	Blue	40 +/- 10 42-47	45-49	46-51	39-45
Temporal	PCOA	60-65	Indeterminant					
Occipital	VA-3 (atlas)	40-50	Away	Blue				
Occipital	VA-4	60-90	Away	Blue	38 +/- 10 33-44	42-47	38-43	30-36
Occipital	PICA	60-90	Towards	Red				
Occipital	BA	70-120	Away	Blue	41 +/- 10 35-50	47-53	39-48	31-40
Submandibular	Extracranial ICA	35-80	Away	Blue	30 +/- 9			
Orbital	OA	35-55	Towards	Red	21 +/- 5			
Orbital	ICA (C_4, C_3, C_2)	65-80	C_4 Towards, C_3 Bidirectional, C_2 Away	C_4 Red, C_3 Red/Blue, C_2 Blue	C_4 47 +/-14 C_2 41 +/- 11			

1. Ringelstein EB. 1989
2. Martin PJ et al. Stroke 1994
3. Krejza J et al. AJR 1999.

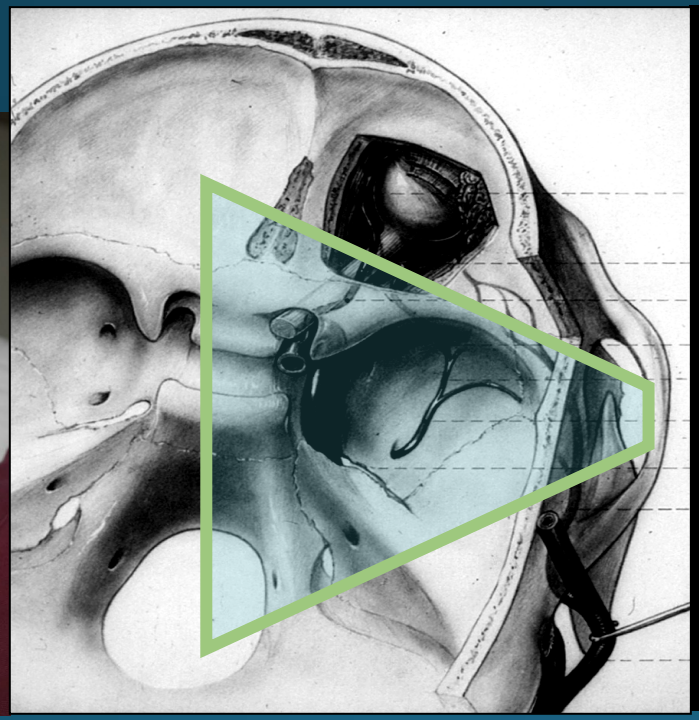
Temporal Approach

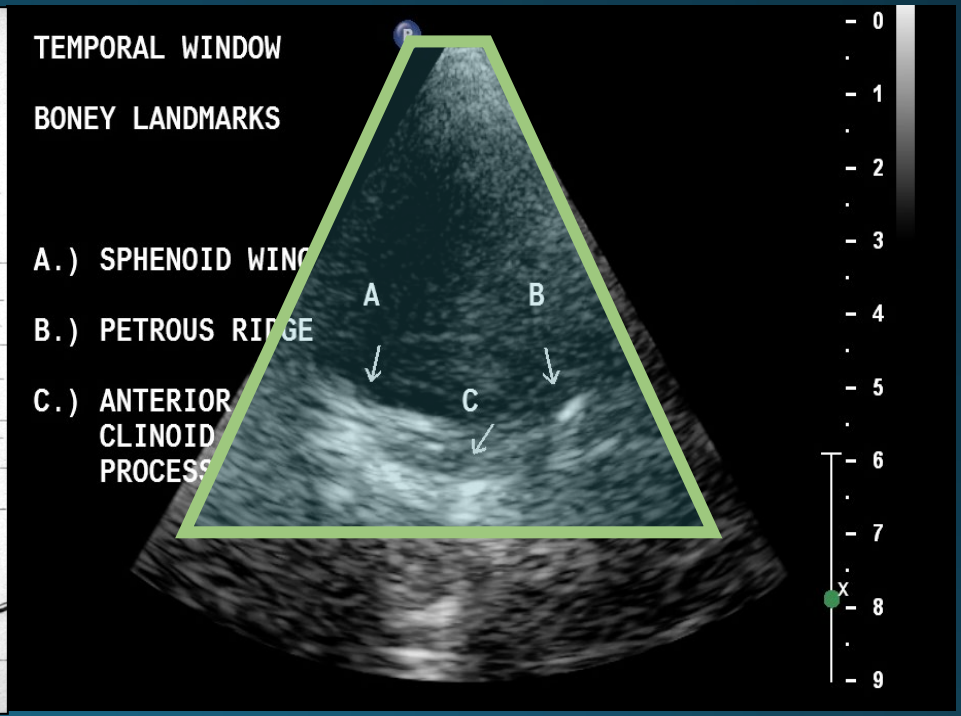
Transducer Placement

Above zygomatic arch
Anterior to tragus of ear
Orientation marker facing anterior



Finding the "Window"



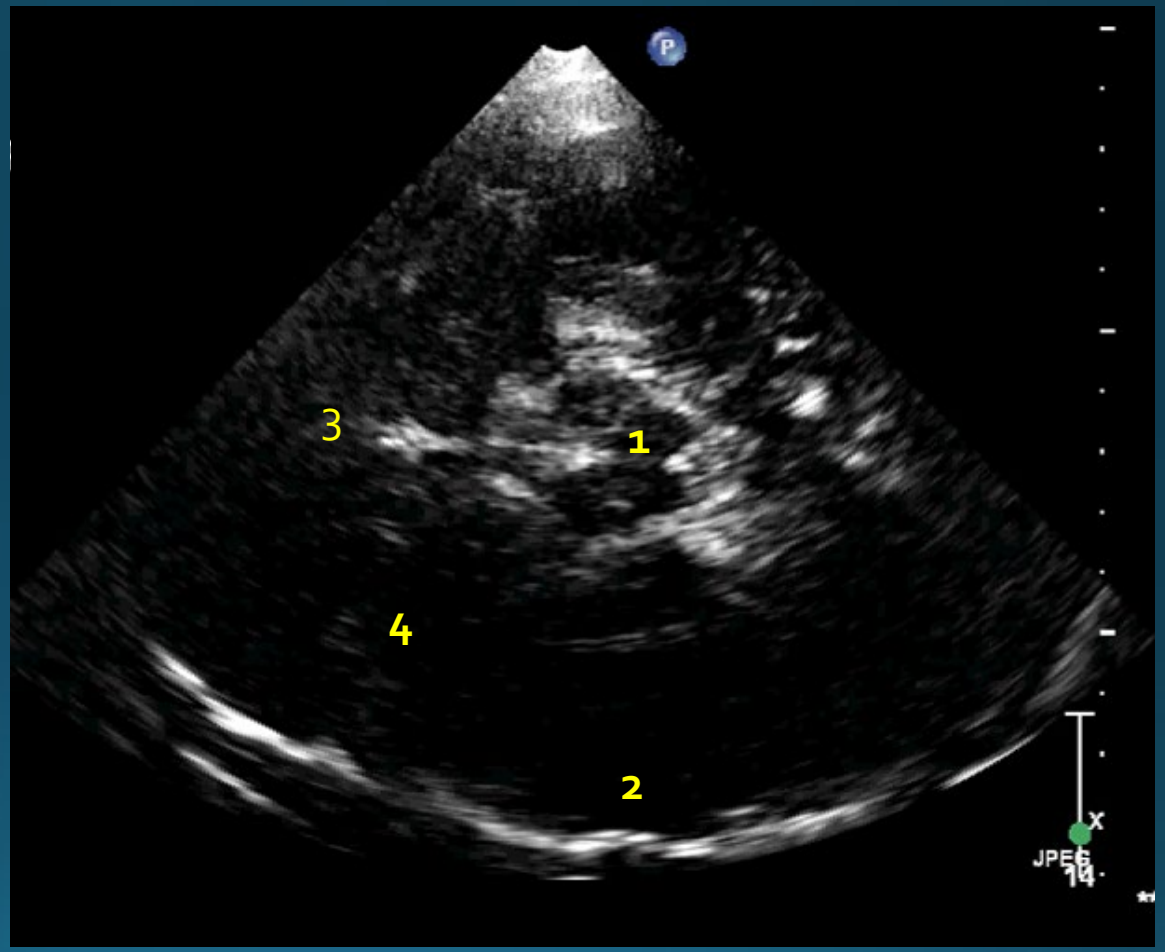


Axial scan Plane: skull base

Temporal Approach

Parenchymal Landmarks

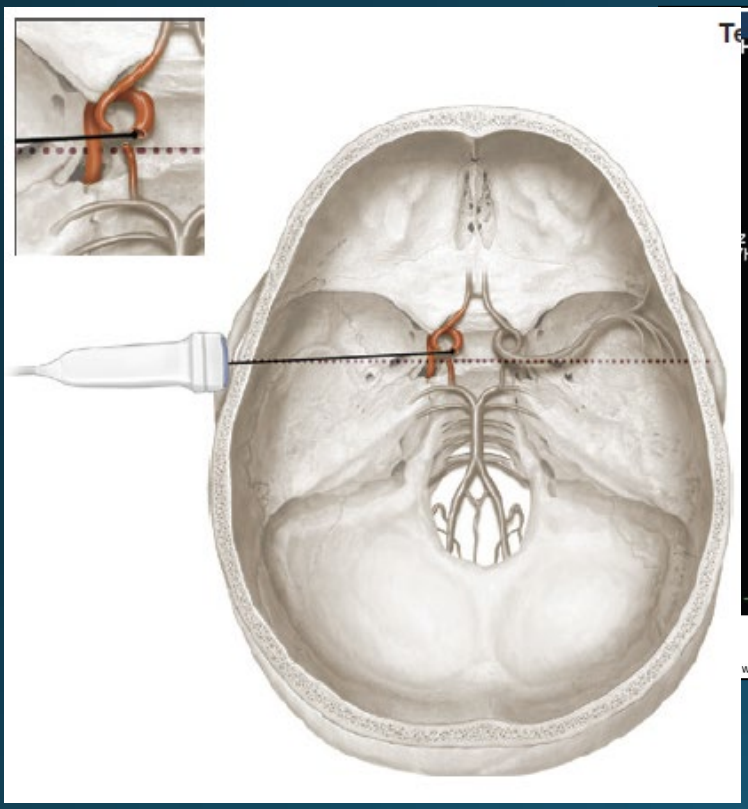
1. Cerebral Peduncle
2. Contralateral Skull
3. Midline
4. Optic chiasma, tract

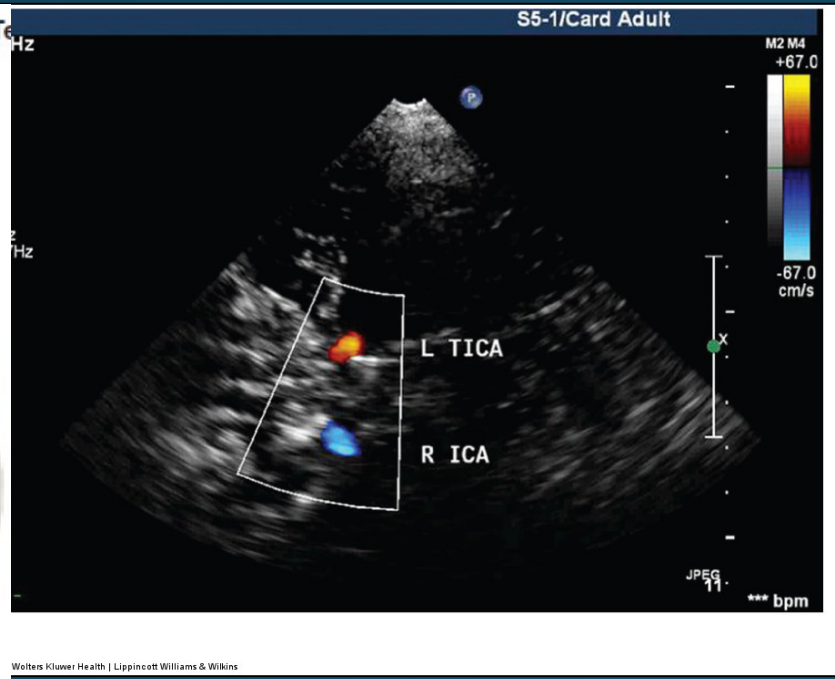


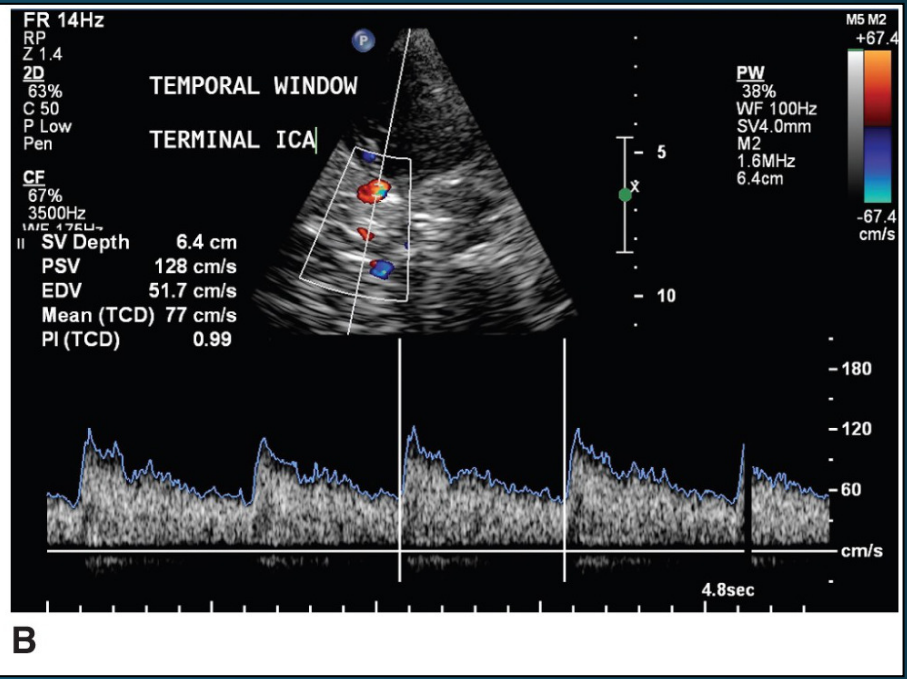
Axial scan plane - Mesencephalic

Temporal Approach

Terminal Internal Carotid Artery (TICA)



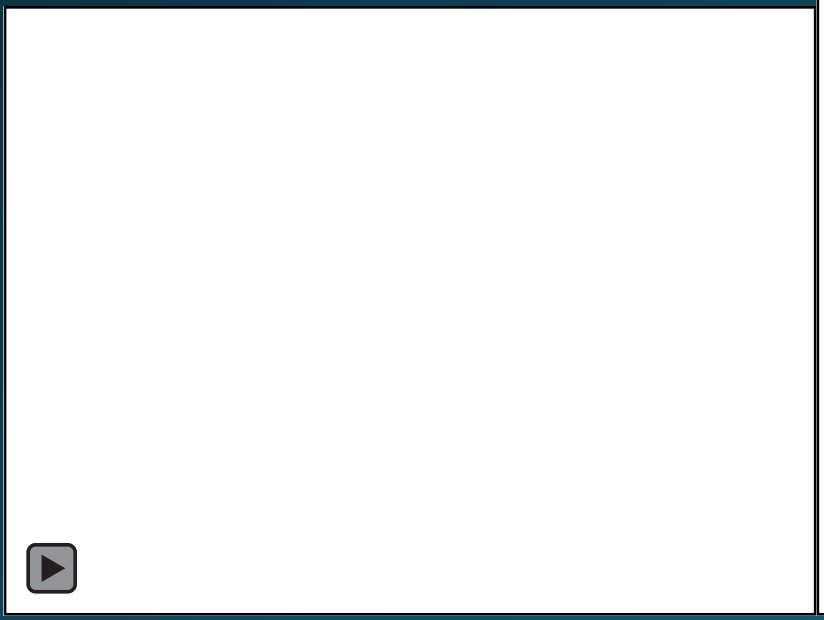




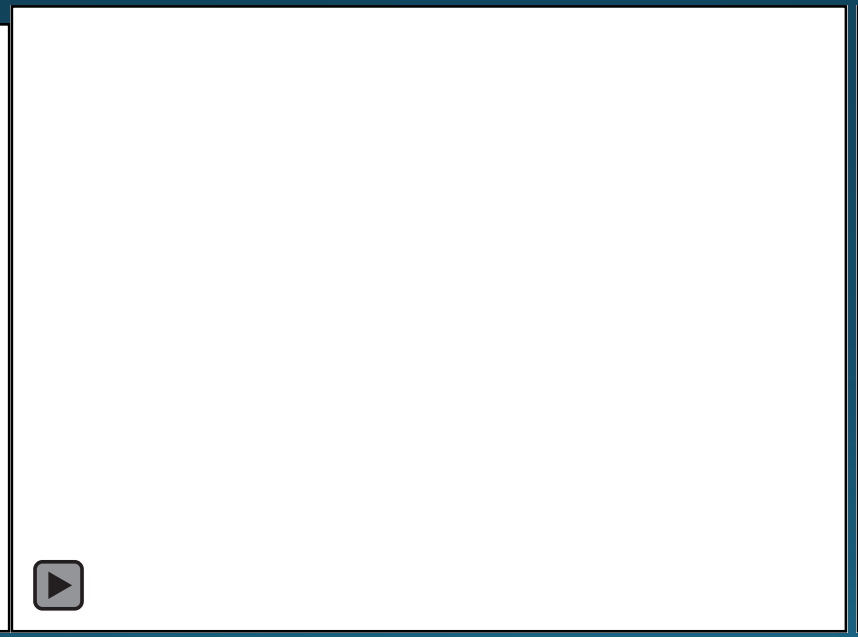
Color box placed over anterior clinoid process, bilateral TICAs in cross-section

Doppler sample volume placed in TICA with Spectral waveform

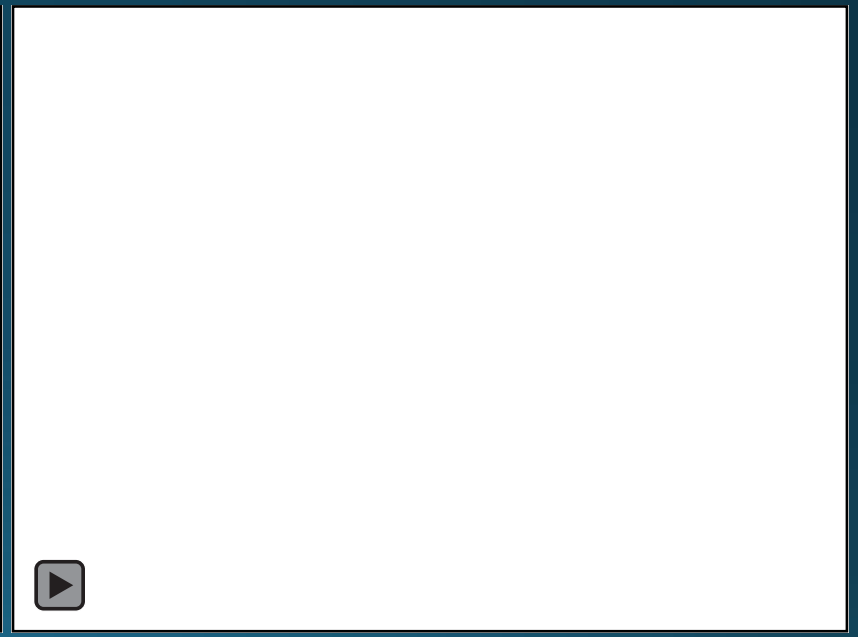
Skull Base Boney Reflectors – Grey scale



Terminal ICA - Color Doppler



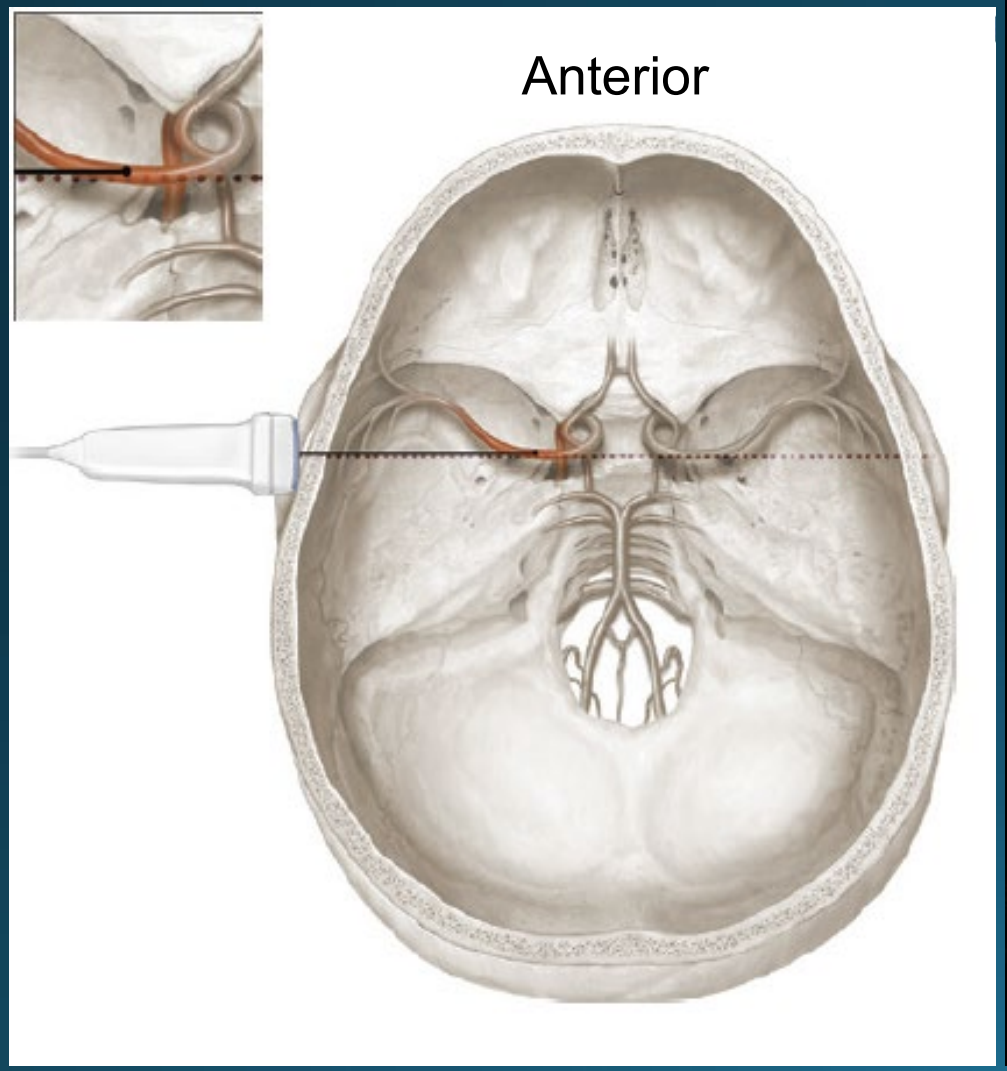
Spectral Waveform

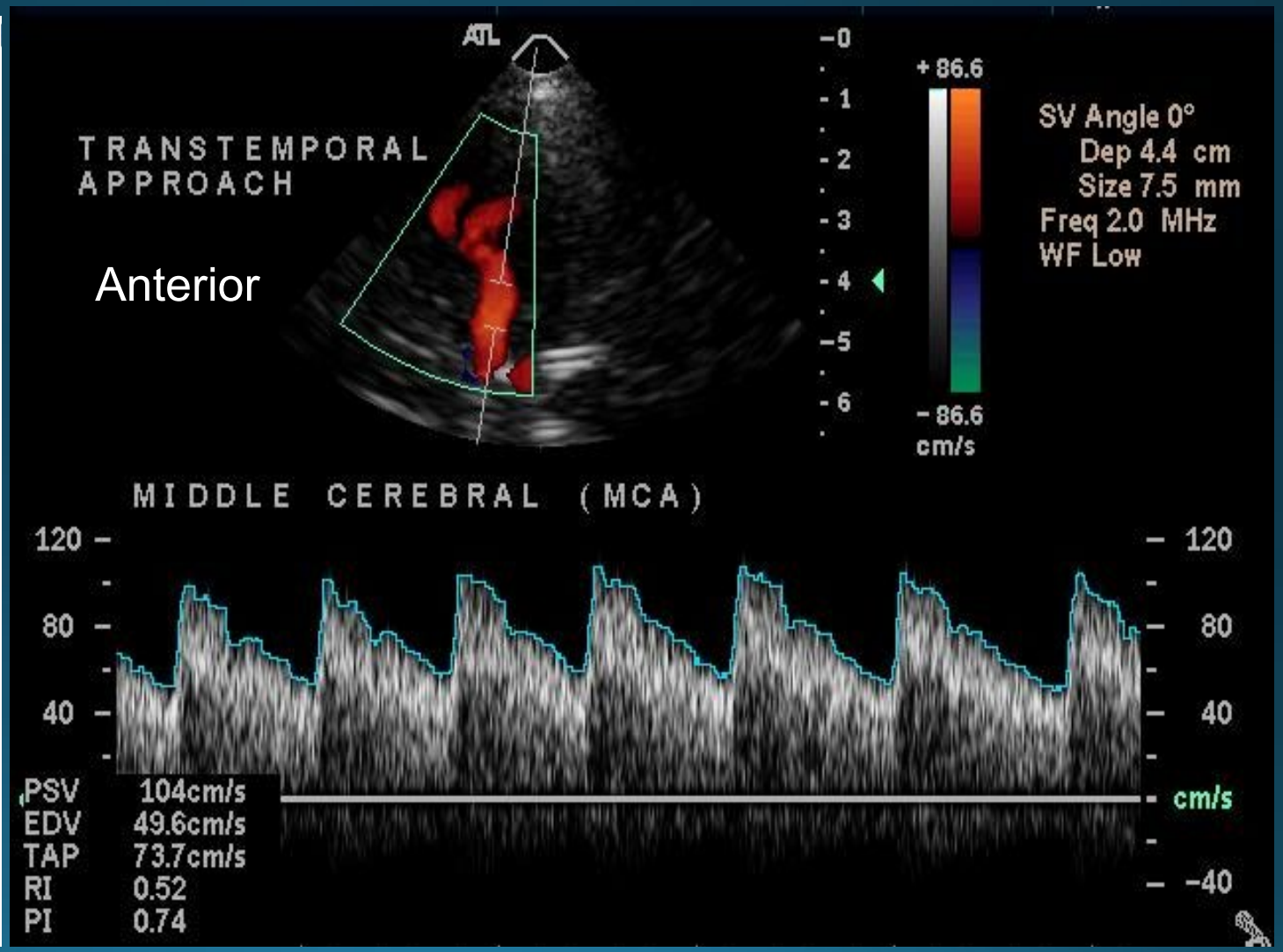


Temporal Approach

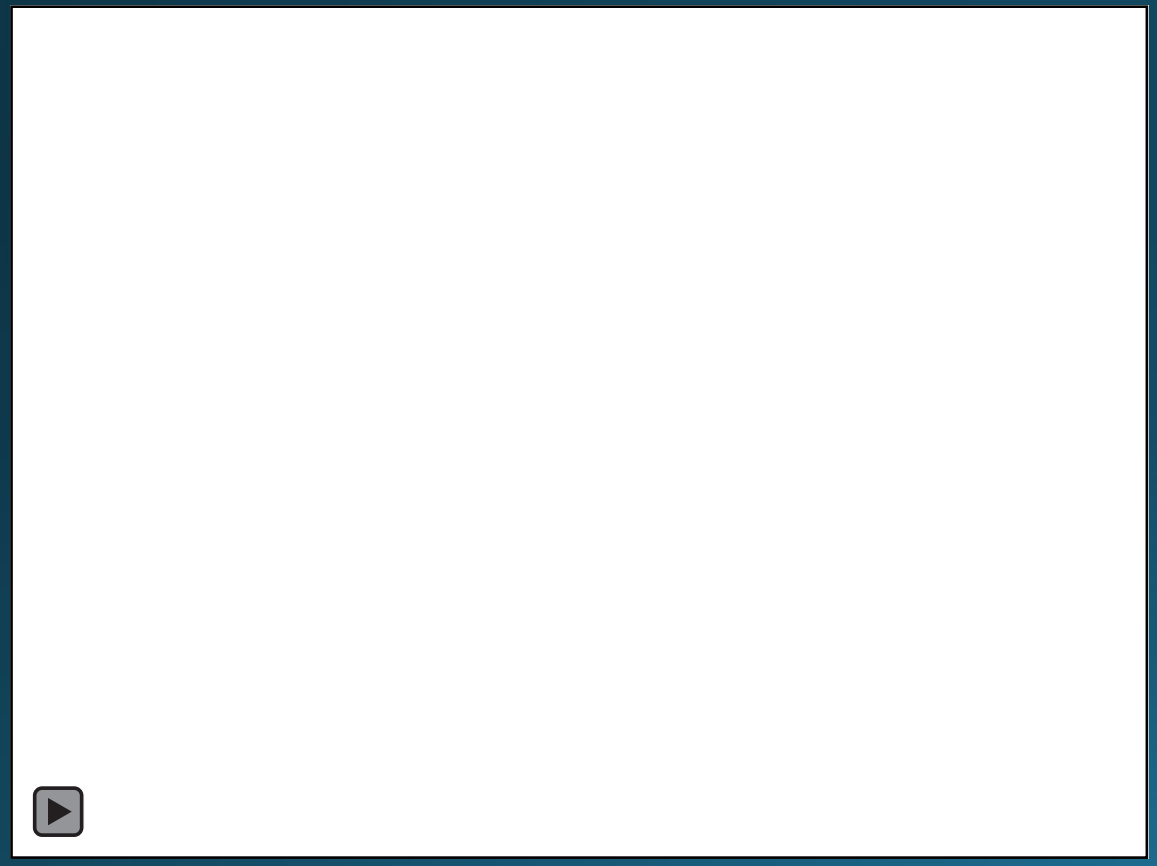
Middle Cerebral Artery (MCA)

TAMV 58 – 74 cm/sec

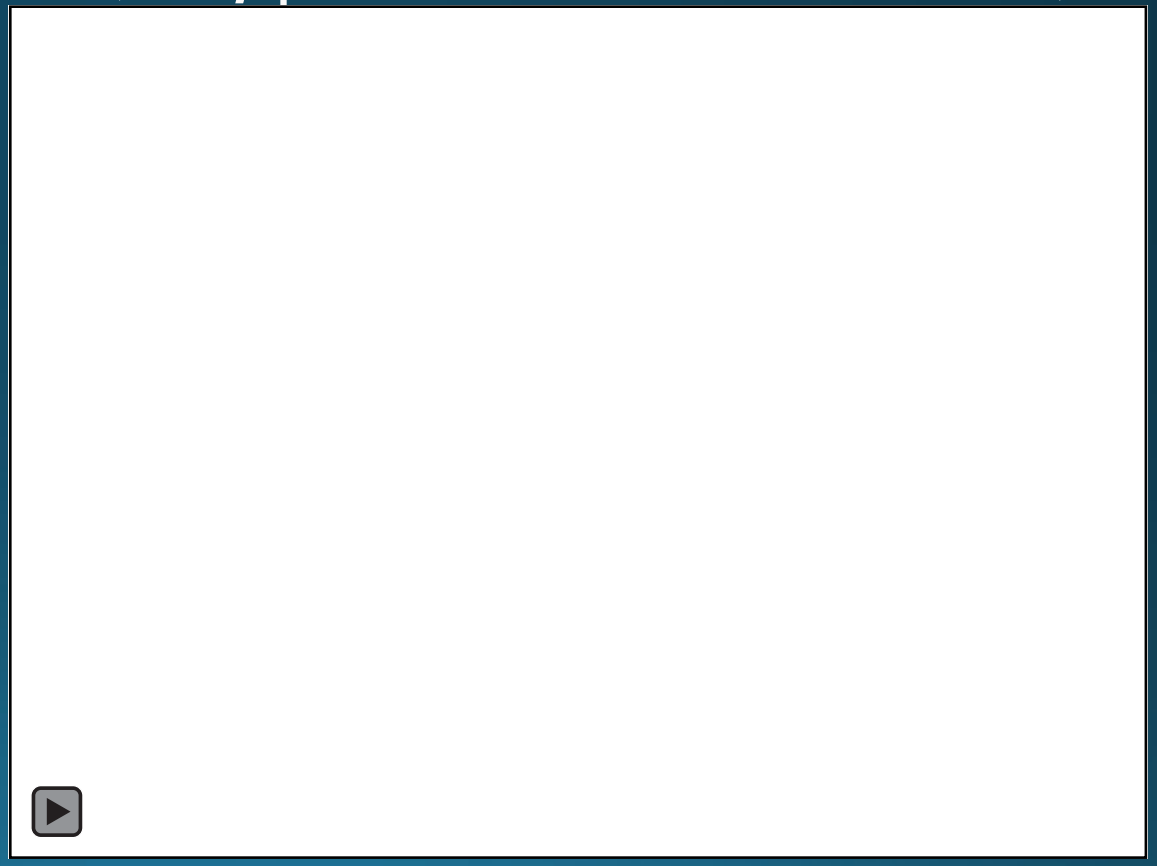




T- ICA



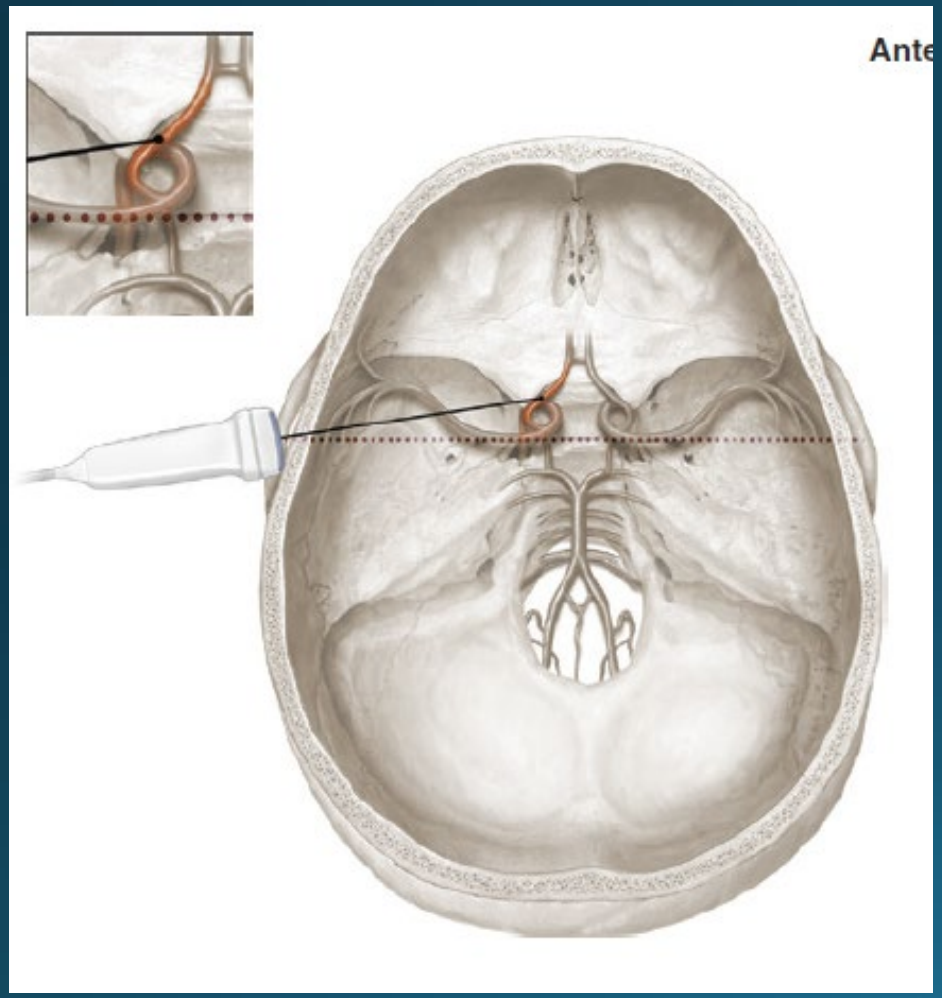
MCA
(M1, proximal M2 branches)

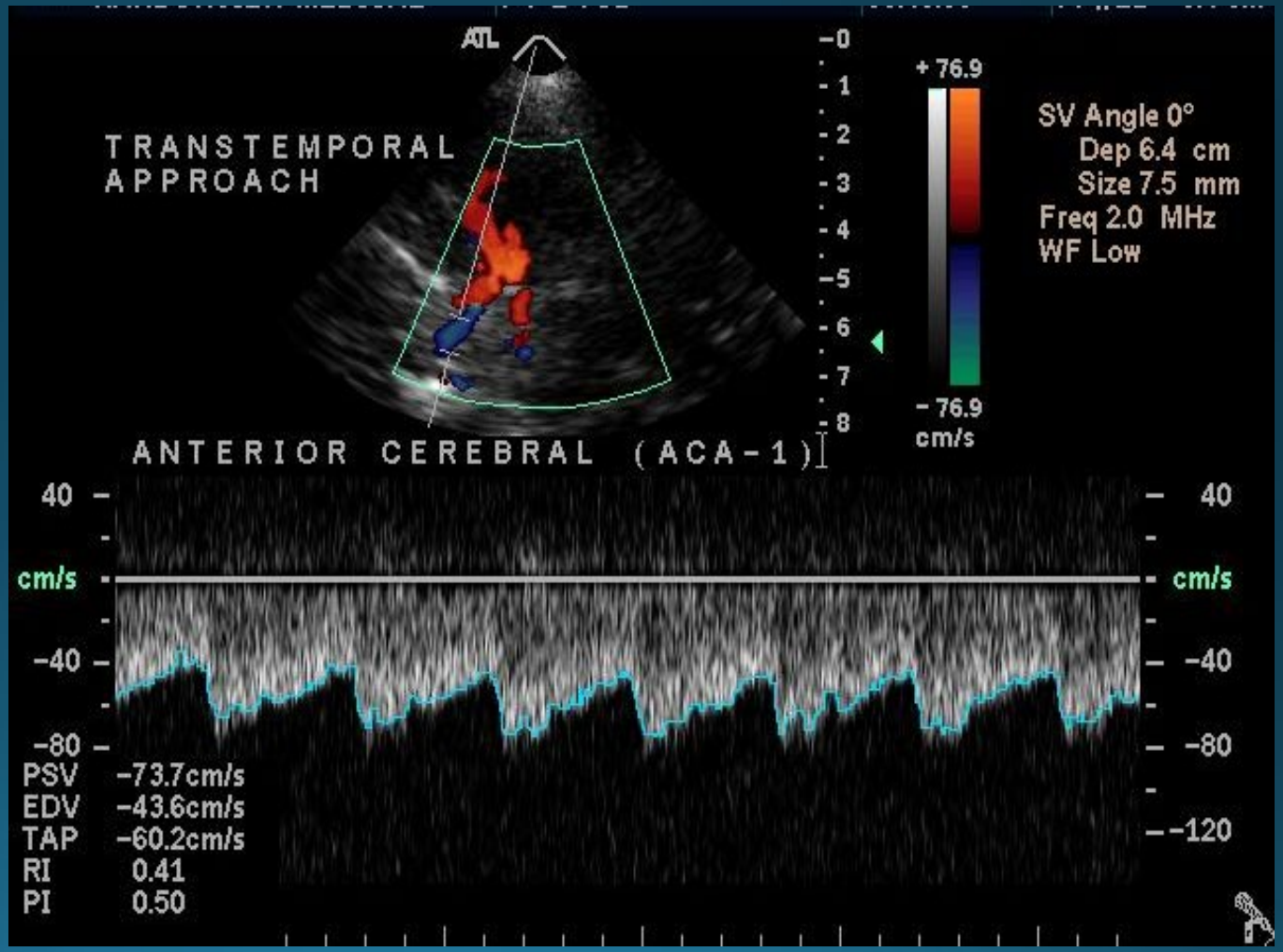


Temporal Approach

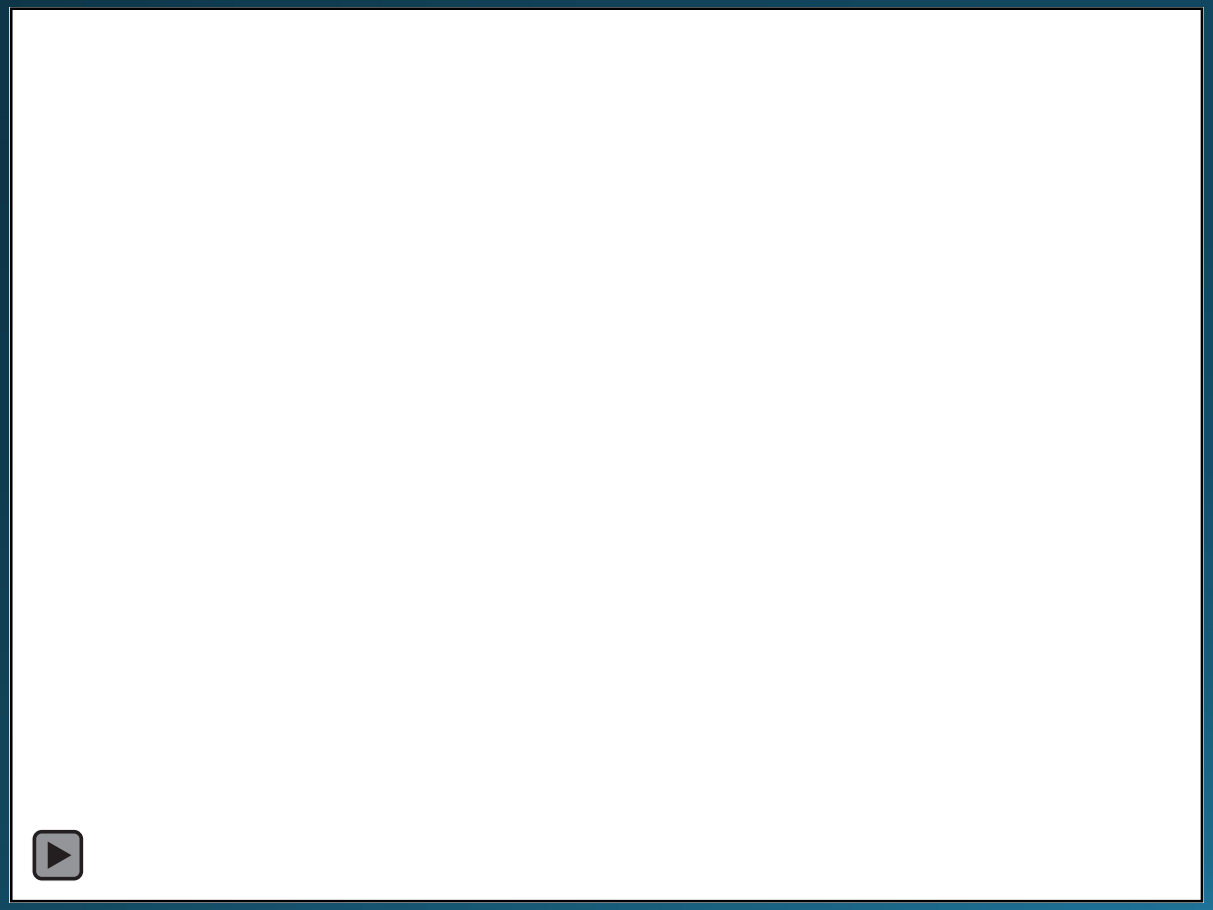
Anterior Cerebral Artery (ACA)

TAMV 51 – 61 cm/sec

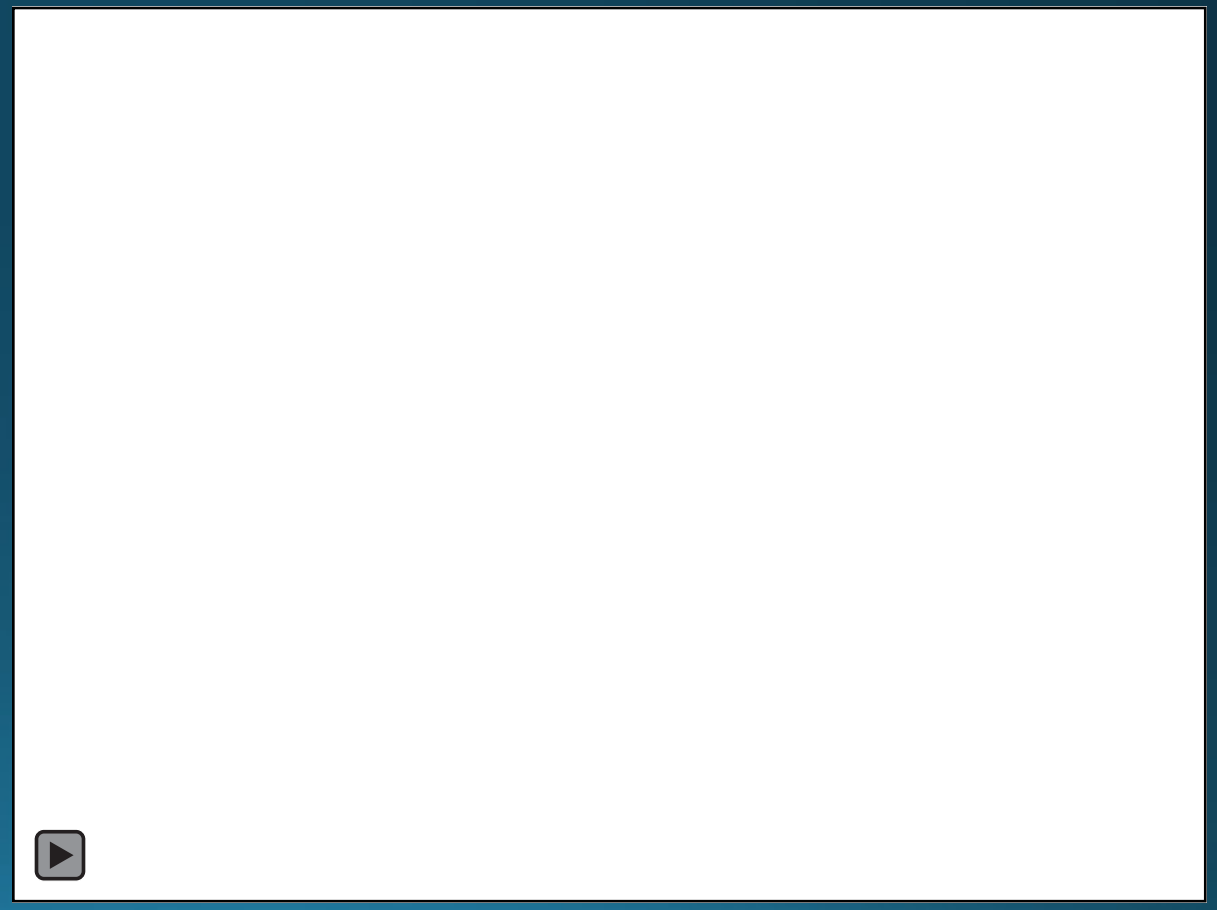




ACA (A1, proximal A2)



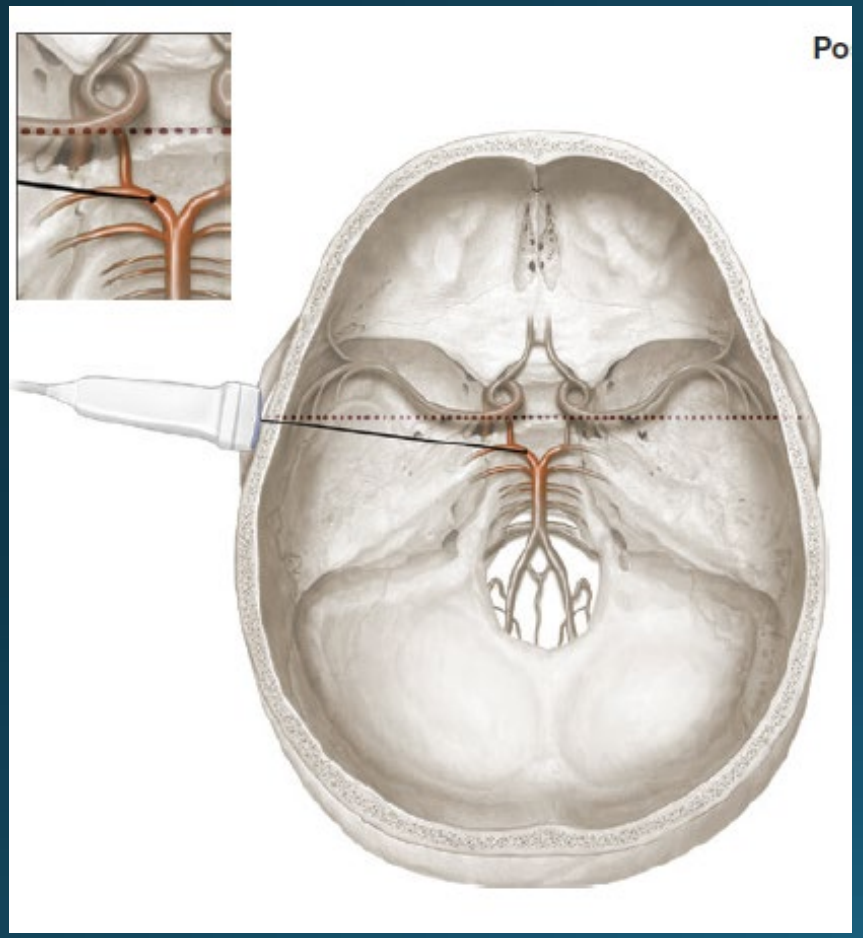
Circle of Willis

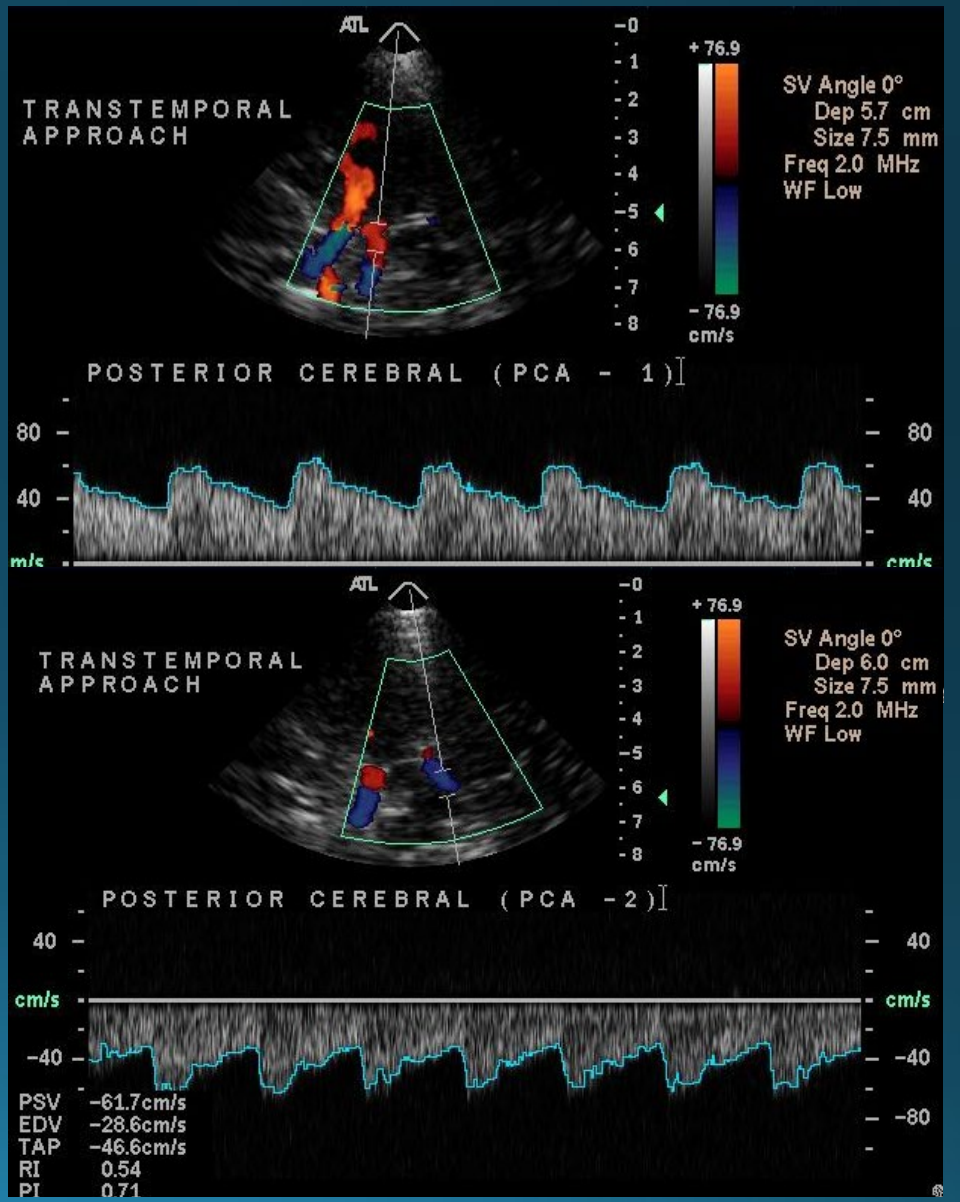


Temporal Approach

Posterior Cerebral Artery

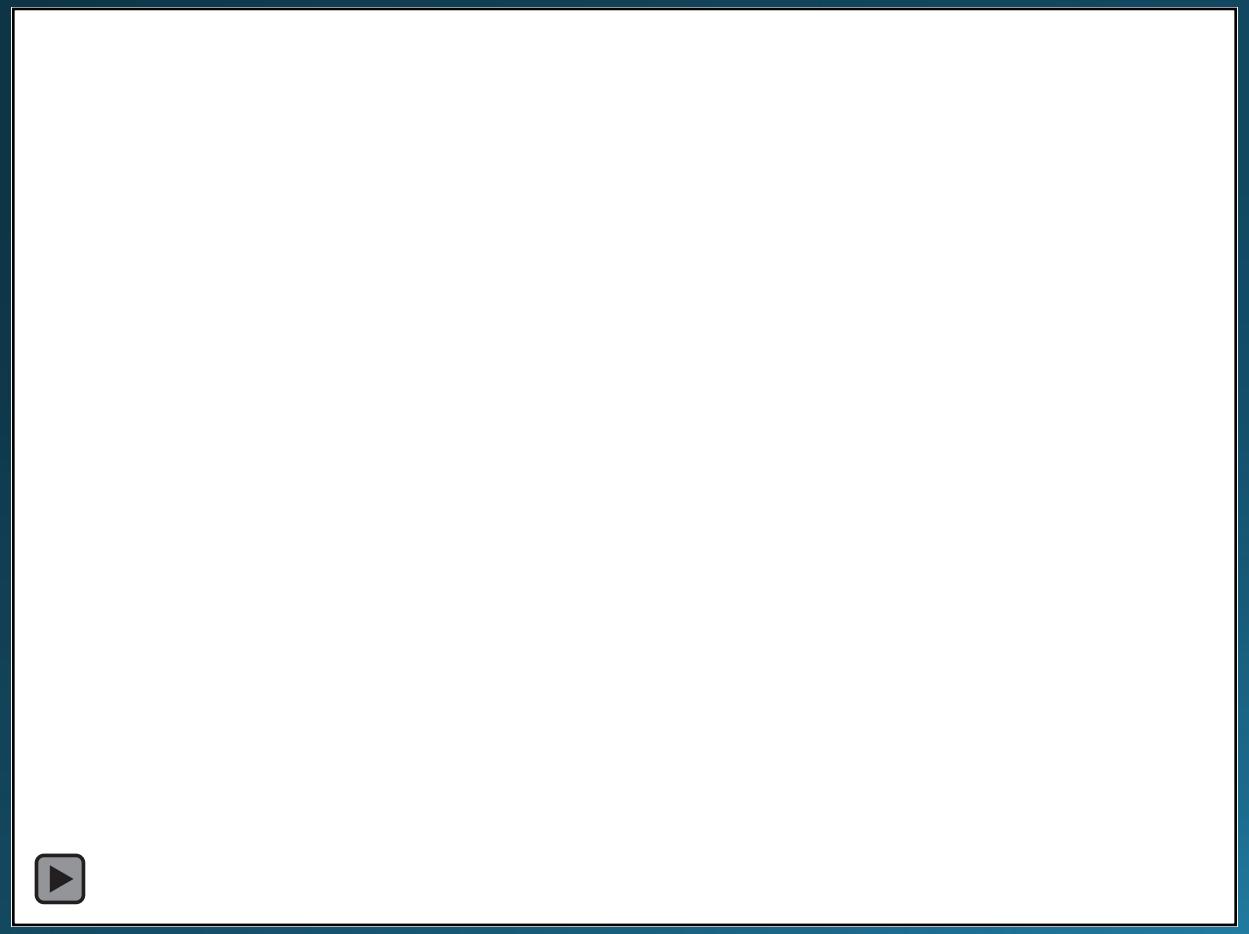
TAMV 42-53 cm/sec (P1)
TAMV 42-47 cm/sec (P2)



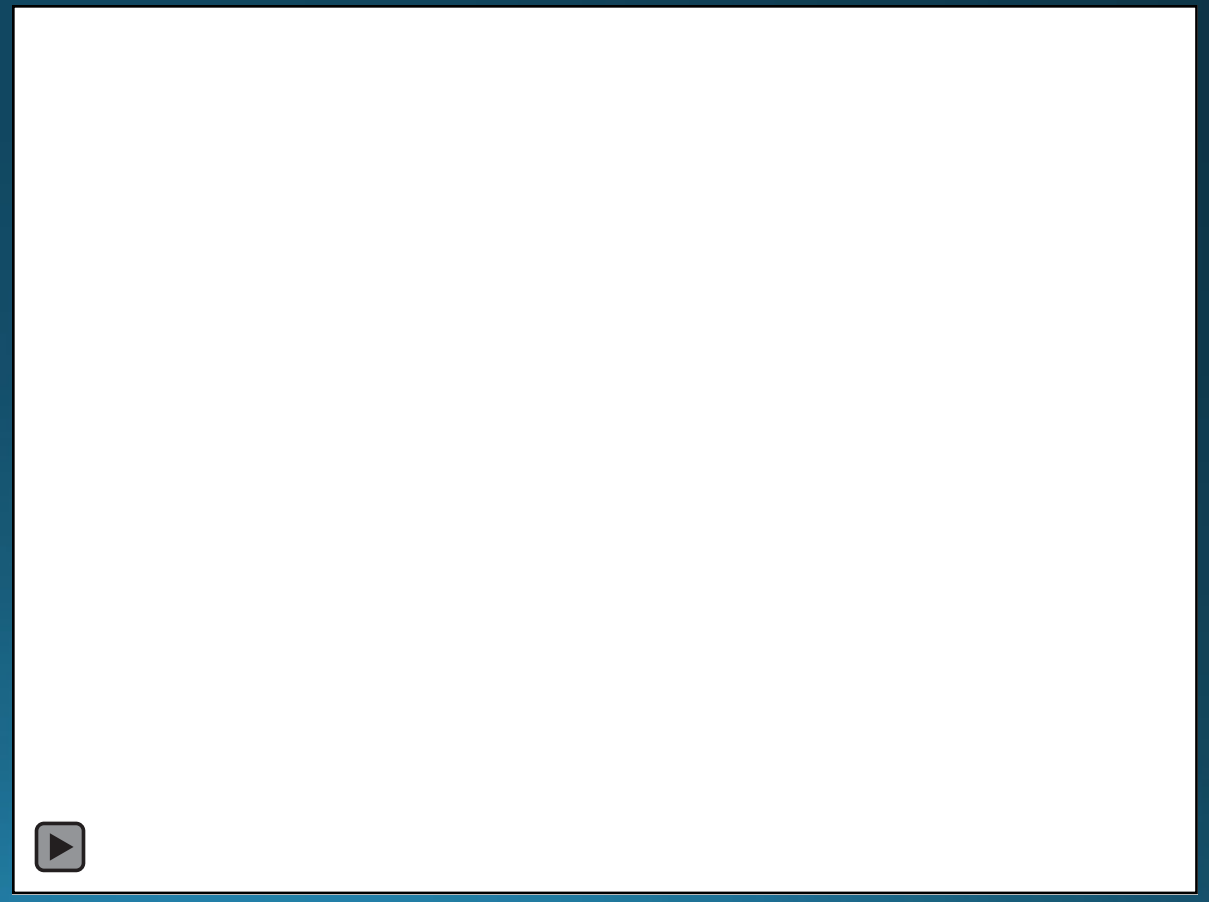


PCA

Pre-communicating, P1



Post communicating, P2

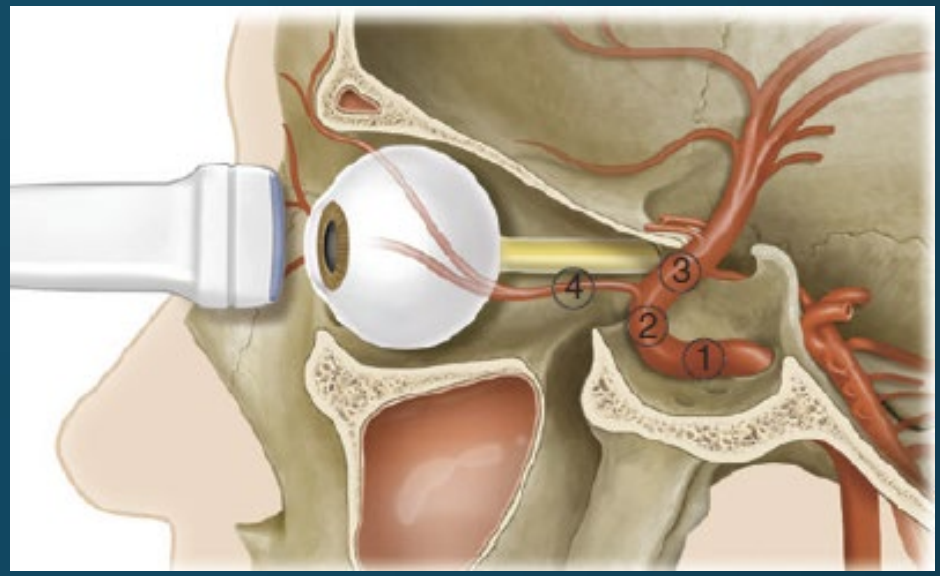


Orbital Approach

Reduce power to MI of 0.23

4. Ophthalmic Artery

1. Cavernous ICA



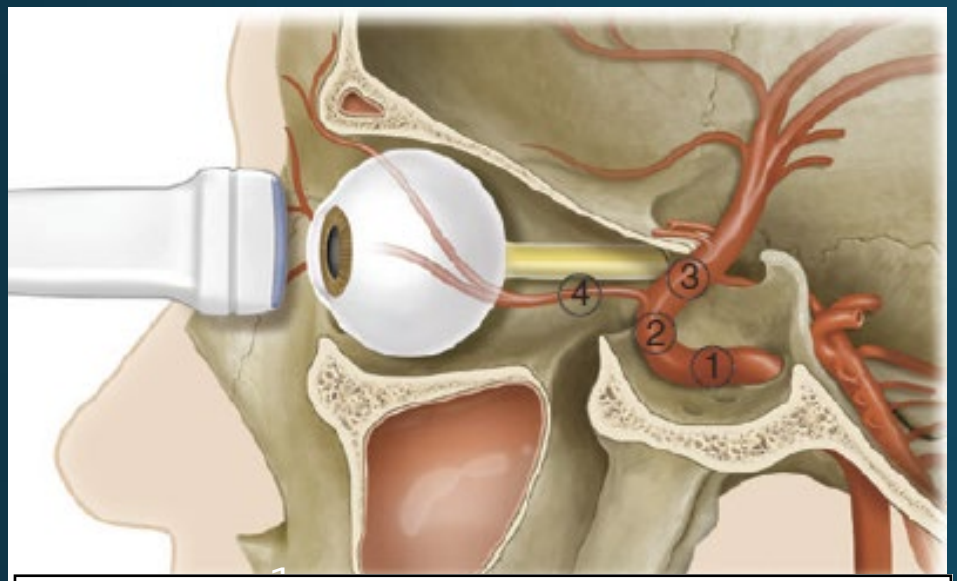
Transducer marker towards nose

OA TAMV 21 +/- 5 cm/sec

Cavernous carotid

www.fda.gov/downloads/MedicalDevices/DeviceRegulationGuidance/GuidanceDocuments/UCM070911.pdf

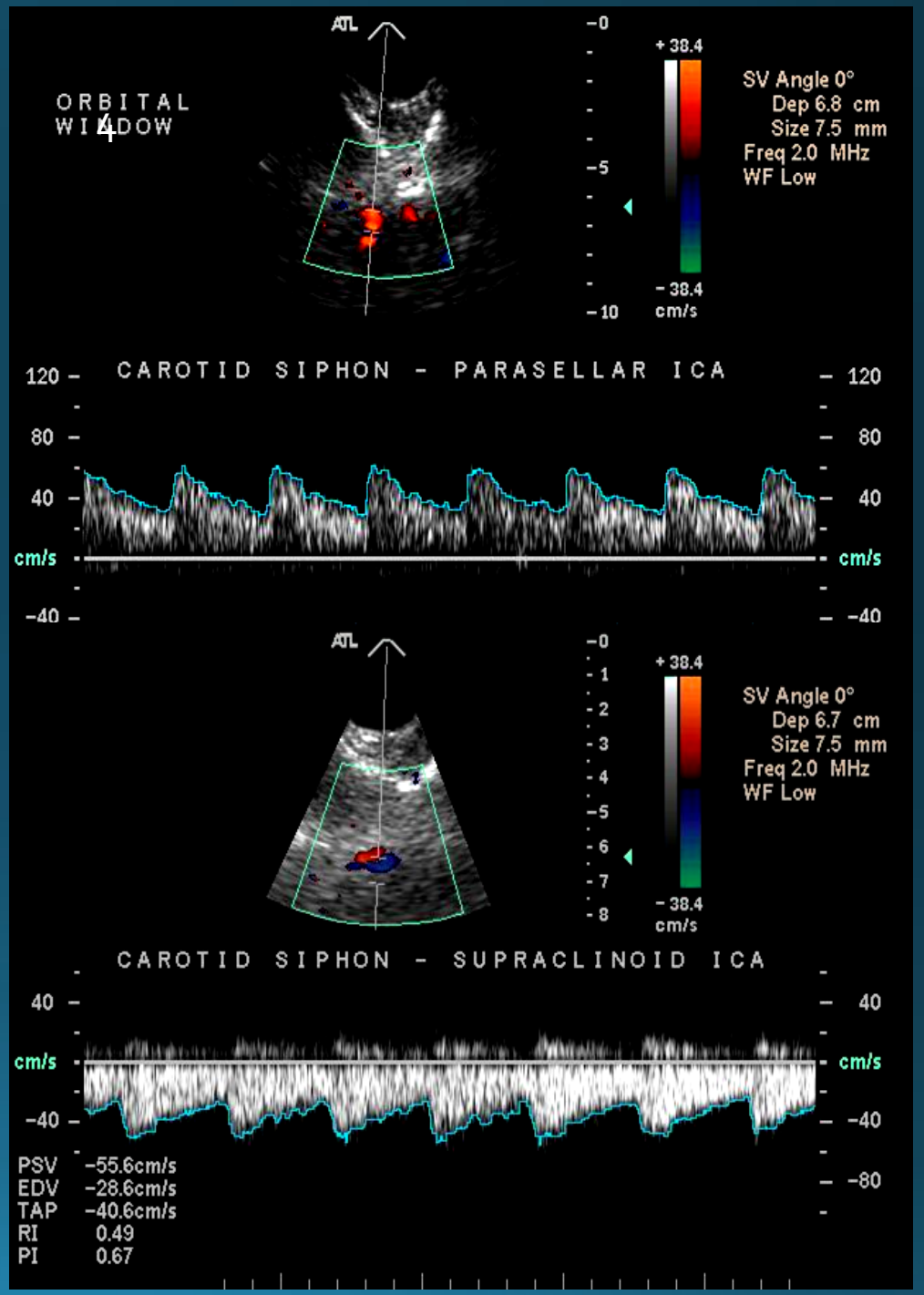
Orbital Approach



ICA

1. parasellar

41+/- 11 cm/sec



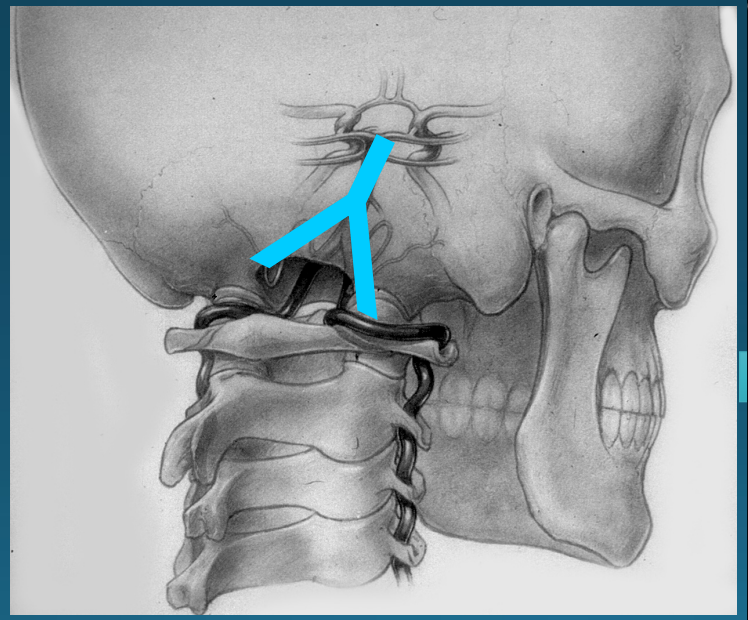
ICA

2. supraclinoid

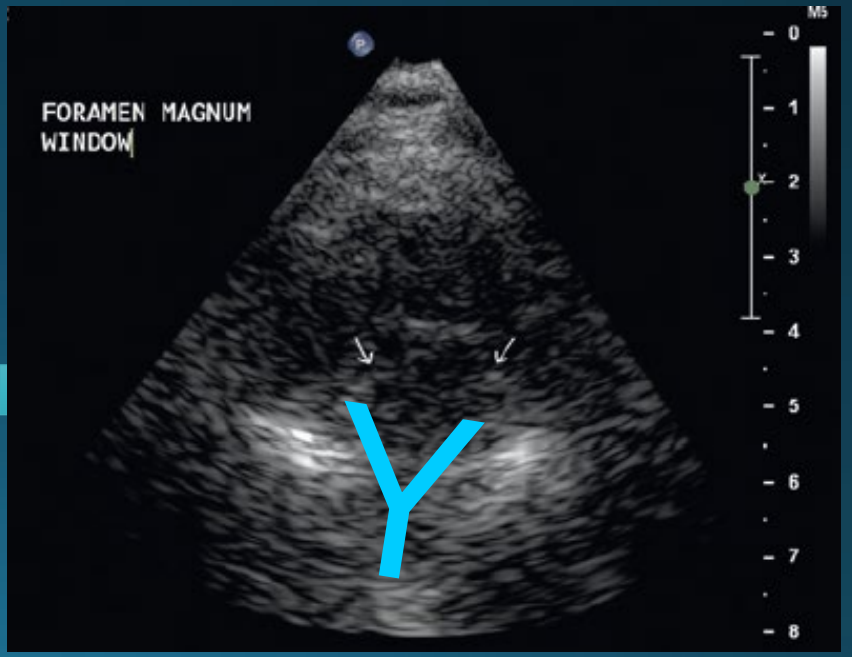
41+/- 11 cm/sec

Suboccipital Approach

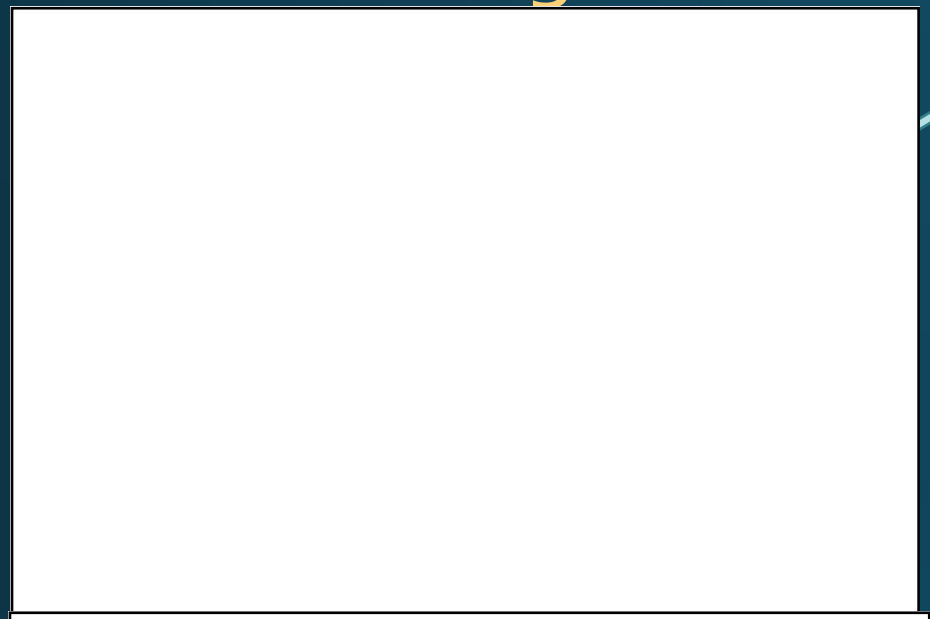
Transducer at base of skull
Ultrasound beam aimed towards nasion (midline approach)
Beam aimed towards contralateral orbit (lateral approach)
Transducer orientation marker to the right



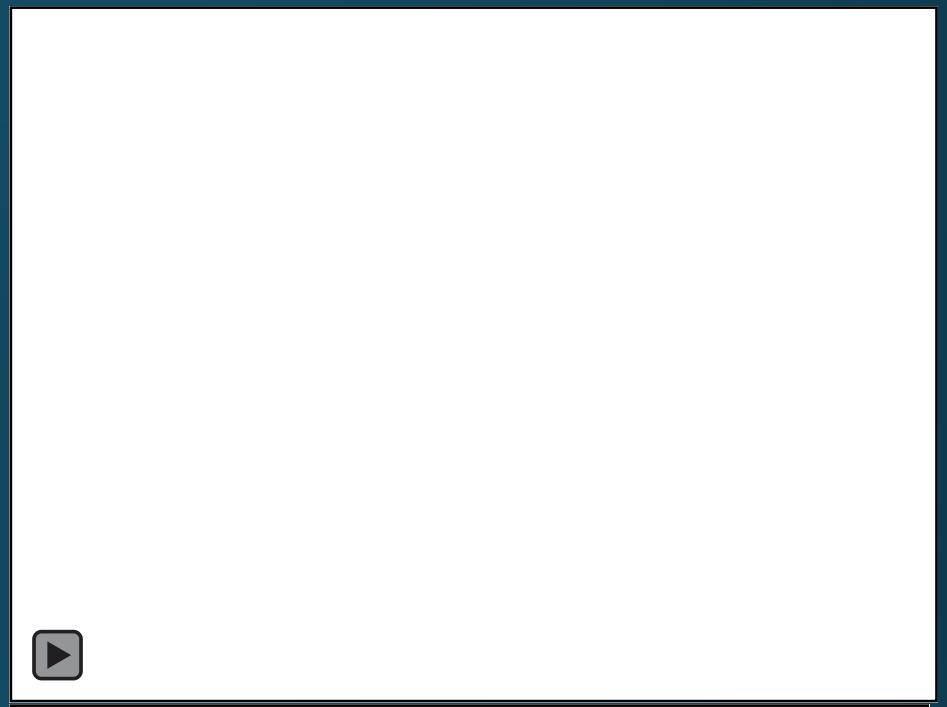
Right Left

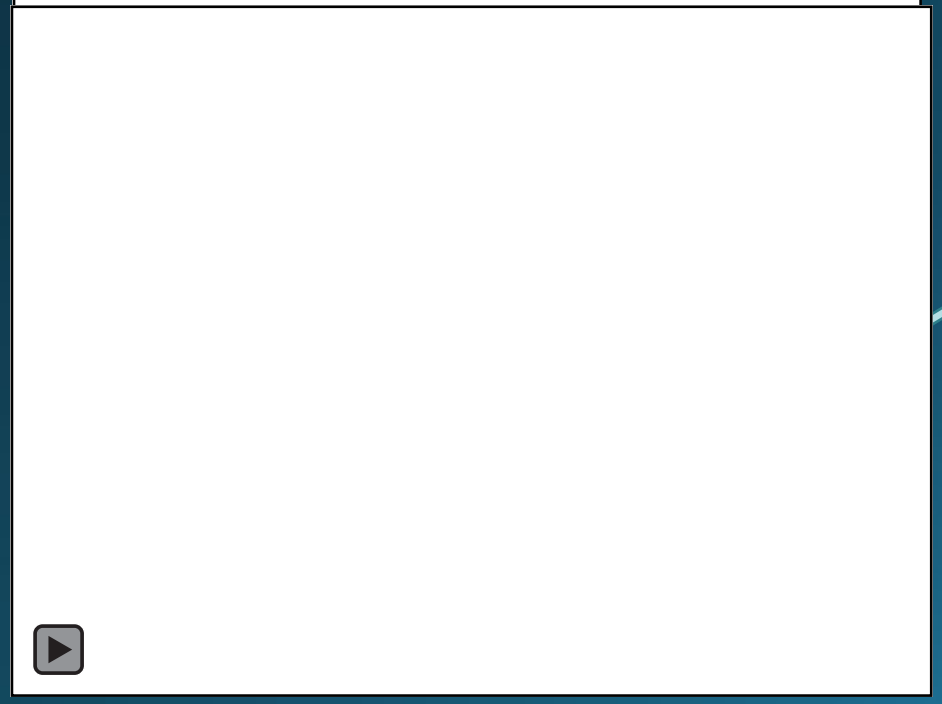


Foramen Magnum



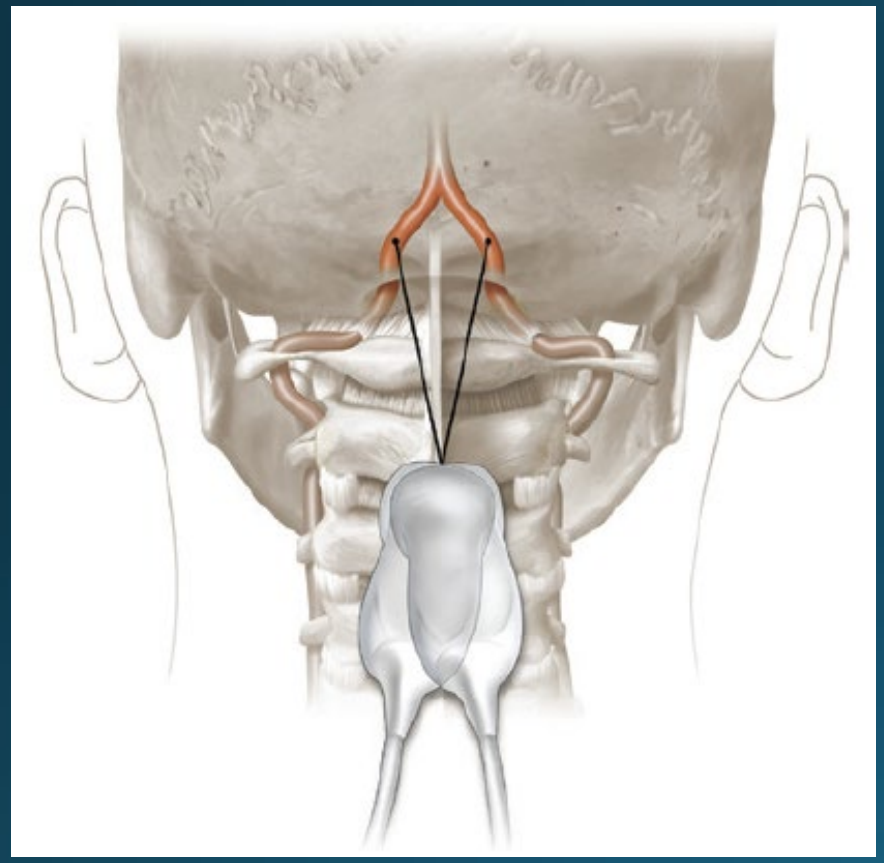
Medulla





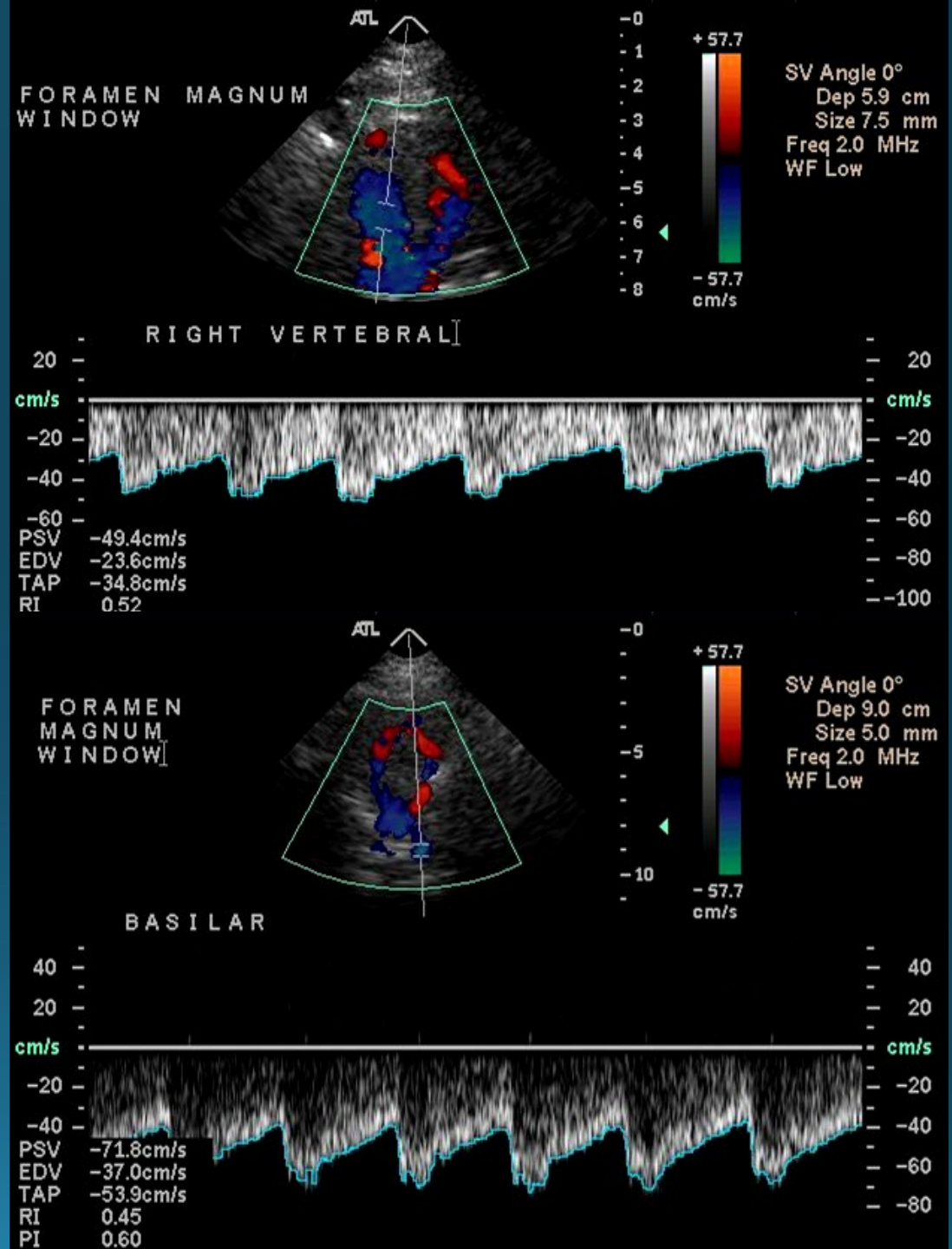
Basilar Artery

Vertebral (V4) Basilar



V4 TAMV
33-44 cm/sec

BA TAMV
35-50 cm/sec

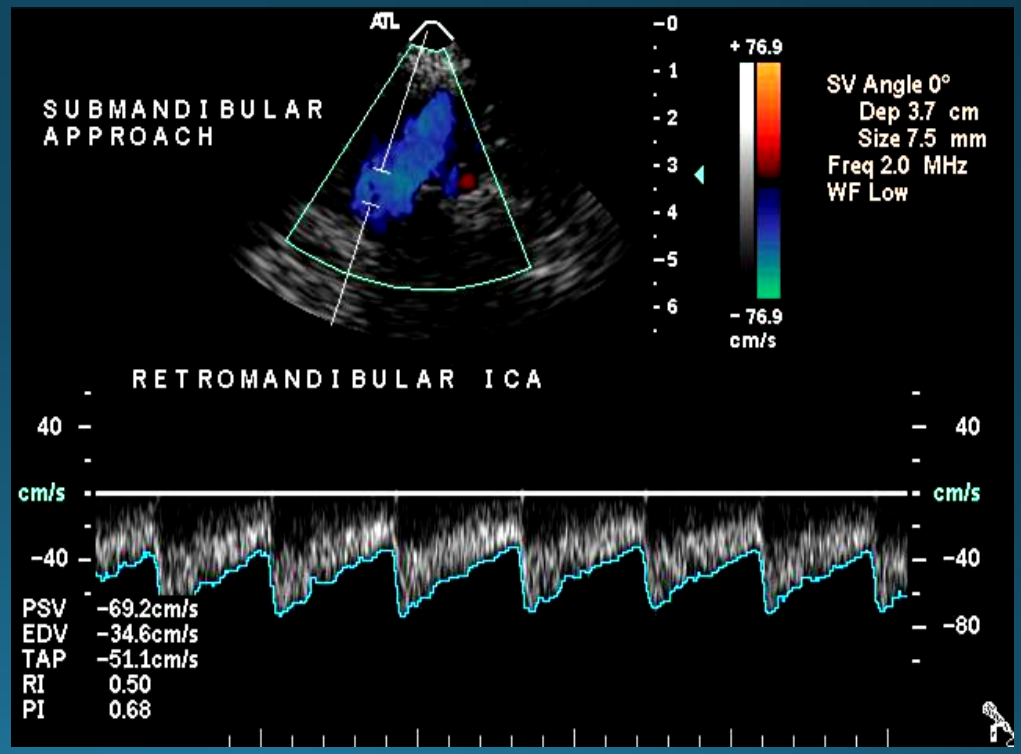


Submandibular Approach
Extracranial ICA

Reduce Power
Orientation marker up/anterior
Do NOT use a lateral approach
Utilize Doppler angle of zero

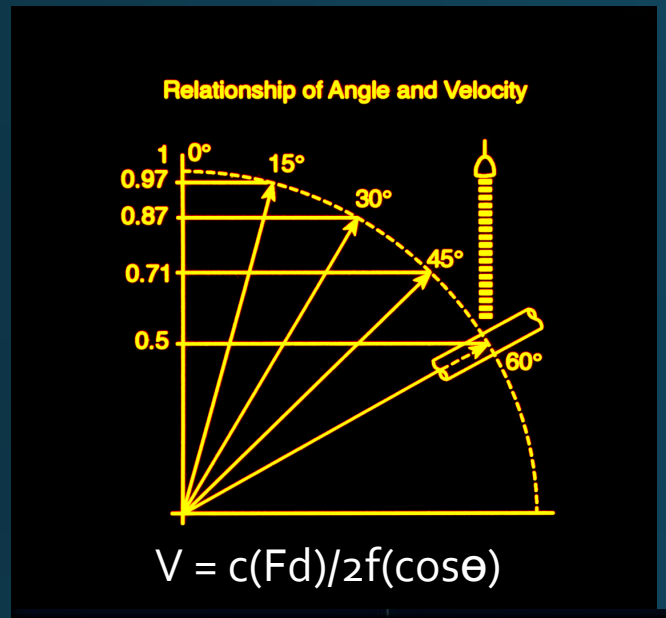
- Calculation of Lindegaard Ratio for vasospasm
- Corrects for velocity increases due to *high flow volume states (due to hyperemia, autoregulation, hypertension, hypervolemia)* versus high velocities due to vasospasm
- High volume flow: EC-ICA high velocity, MCA high velocity = low Lindegaard Ratio
- Vasospasm: EC-ICA low velocity, MCA high velocity = high Lindegaard Ratio

Normal Lindegaard/Hemispheric Ratio = 1.7 (1.1 – 2.3)

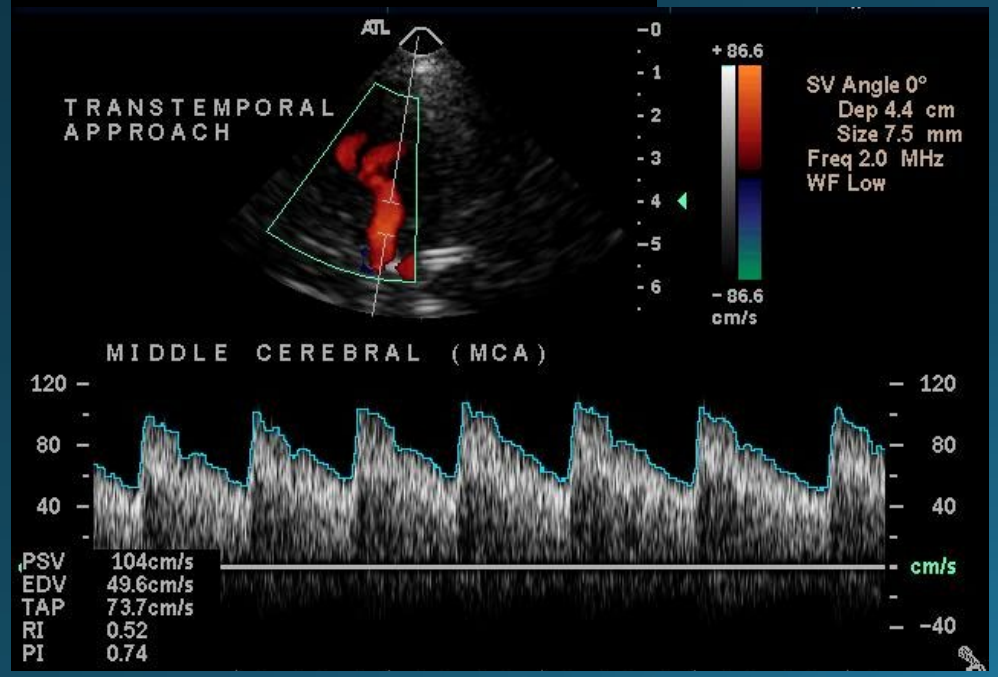


Lindegaard KF, et al. Acta Neurochir. 1999;72:59-71
Lindegaard KF, et al. Acta Neurochir. 1989;100:12-24

Angle Correction?



$V = c(Fd)/2f(\cos\theta)$



TCD, TCI Velocity Comparison

- Lower velocities **w/o angle correction** due to use of color Doppler *image* to obtain highest velocity
- Improved using highest *audible* Doppler "pitch" (TCD)
- Higher velocities **w angle correction**
- Use vessel segment long enough to determine the course
- Use vessel segments where the correction needed is less that 45°, to reduce over correction errors

* Angle correction not usually used for sickle cell studies

Kirsch JD et al. Advances in transcranial Doppler Us: imaging ahead. *Radiographics* 2013; 33:E1-E14.

Padayachee et al. *PediatrRadiol.* 2012;(42):470–474.

Aaslid R. Transcranial Doppler Sonography. New York: Springer-Verlag,1986;25.

Applications

TCD-Imaging

- Sickle cell determine stroke risk
- Stenosis/occlusion, potentiation of thrombolytic therapy
- Vasospasm (SAH)
- Collateral pathways
- Cerebral circulatory arrest (adjunct)
- AVM assessment

TCD (Monitoring)

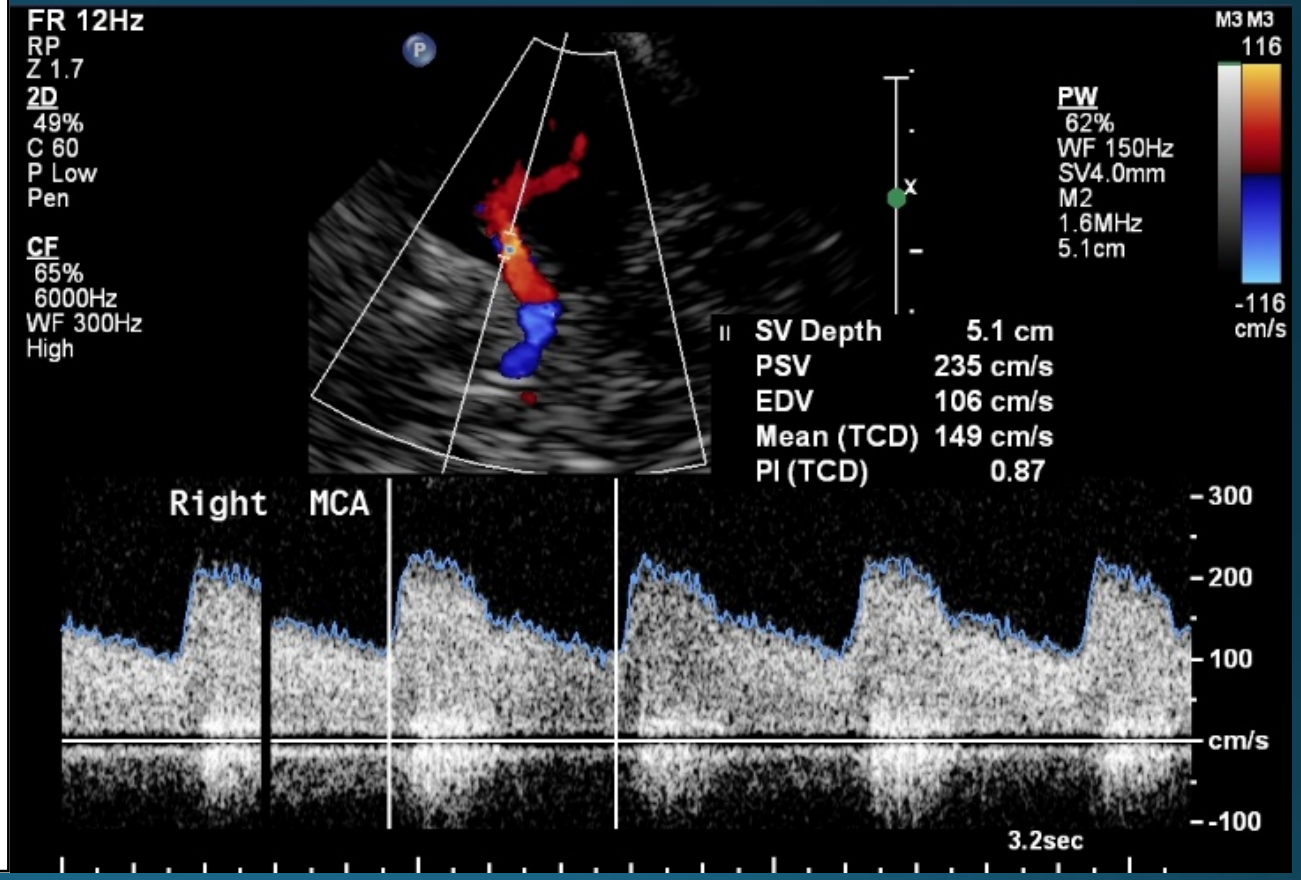
- Detection of microemboli
- PFO detection & grading
- Vasomotor reactivity – CO_2 challenge
- Evaluation of positional vertigo
- Intraoperative & periprocedural monitoring to detect
  - Thrombosis
  - Embolization
  - hypoperfusion and hyperperfusion

Anatomical Road Map:

Guides placement of spectral Doppler

Spectral Doppler Waveform:

Interpretation of blood flow



Intracranial stenosis > 70%

Thank you

ASN 2021

TCD Interpretation Skills

Saturday: 1/30/2021

08:45 - 14:10 Mountain Time