# Carotid Duplex Ultrasound: Instrumentation and Technique

ASN Annual Meeting

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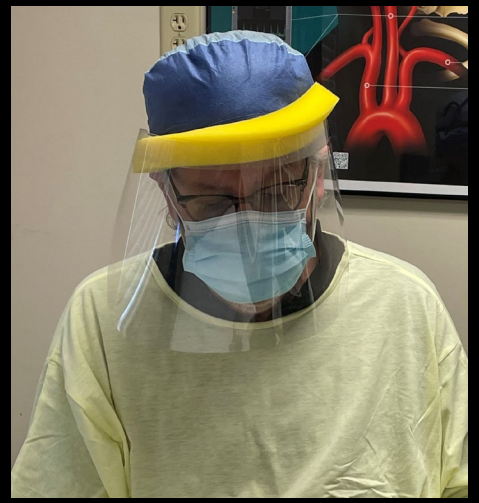


# Disclosures

- DWL
- Global Blood Therapeutics

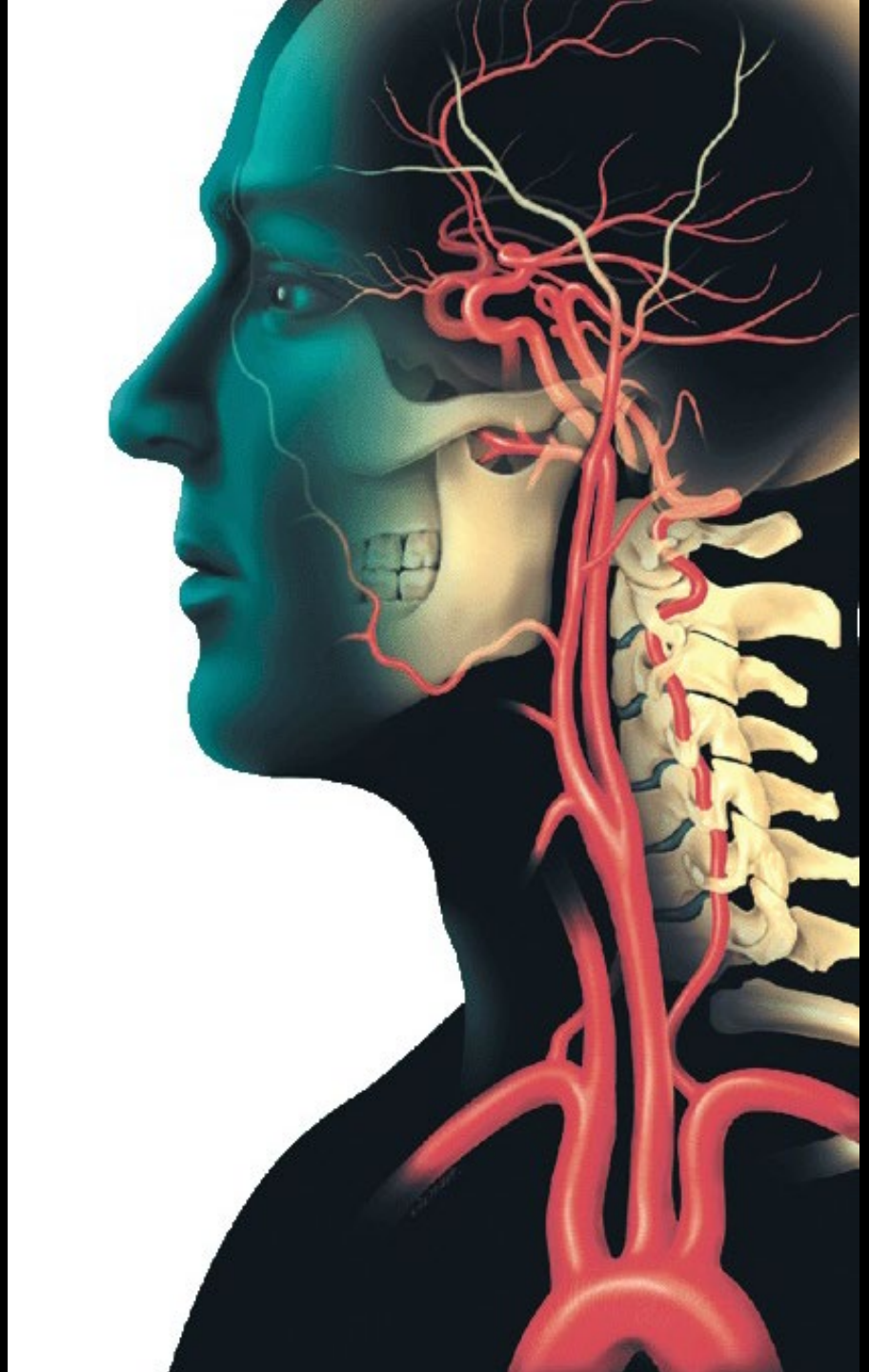
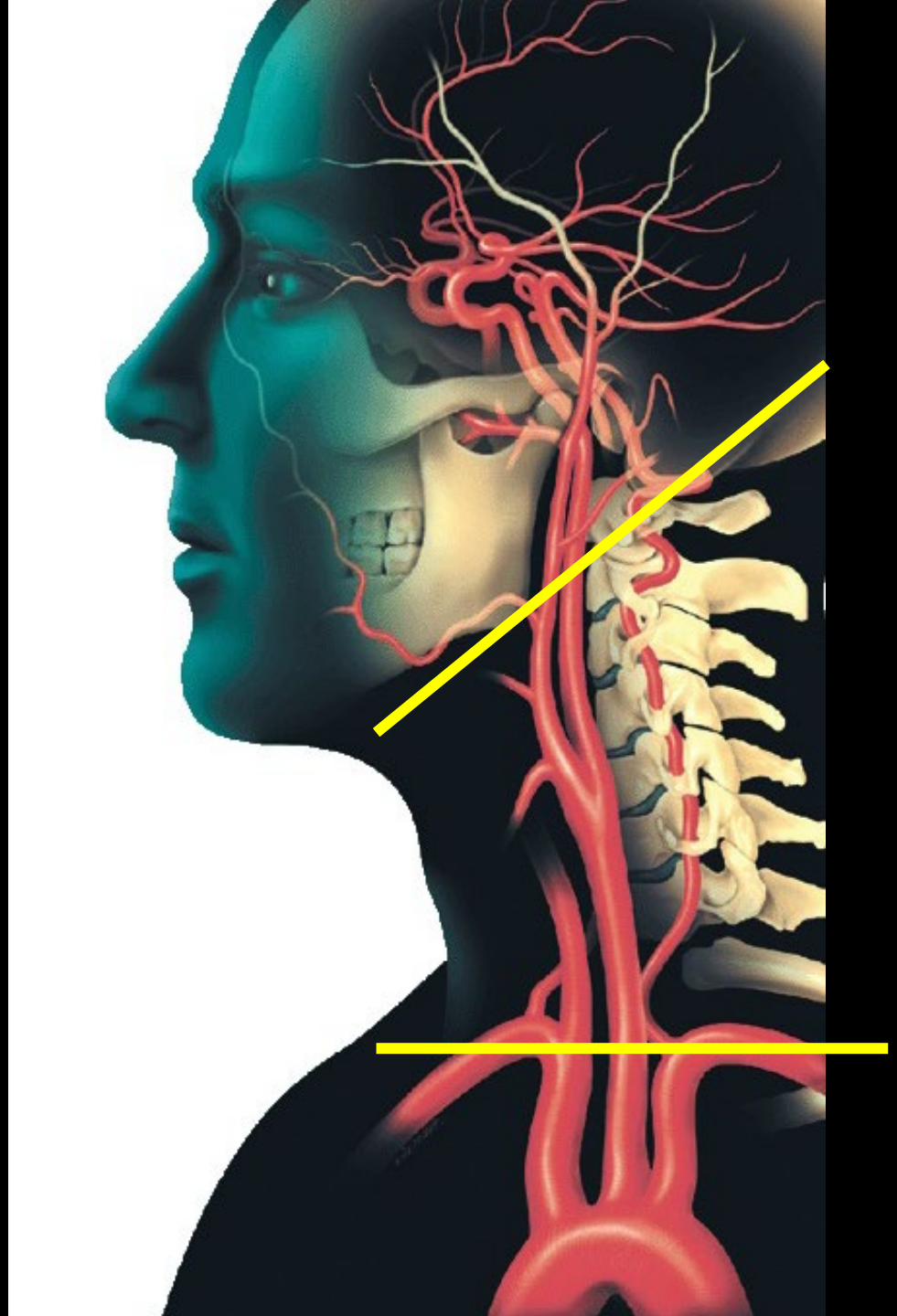


Image Courtesy of DWL



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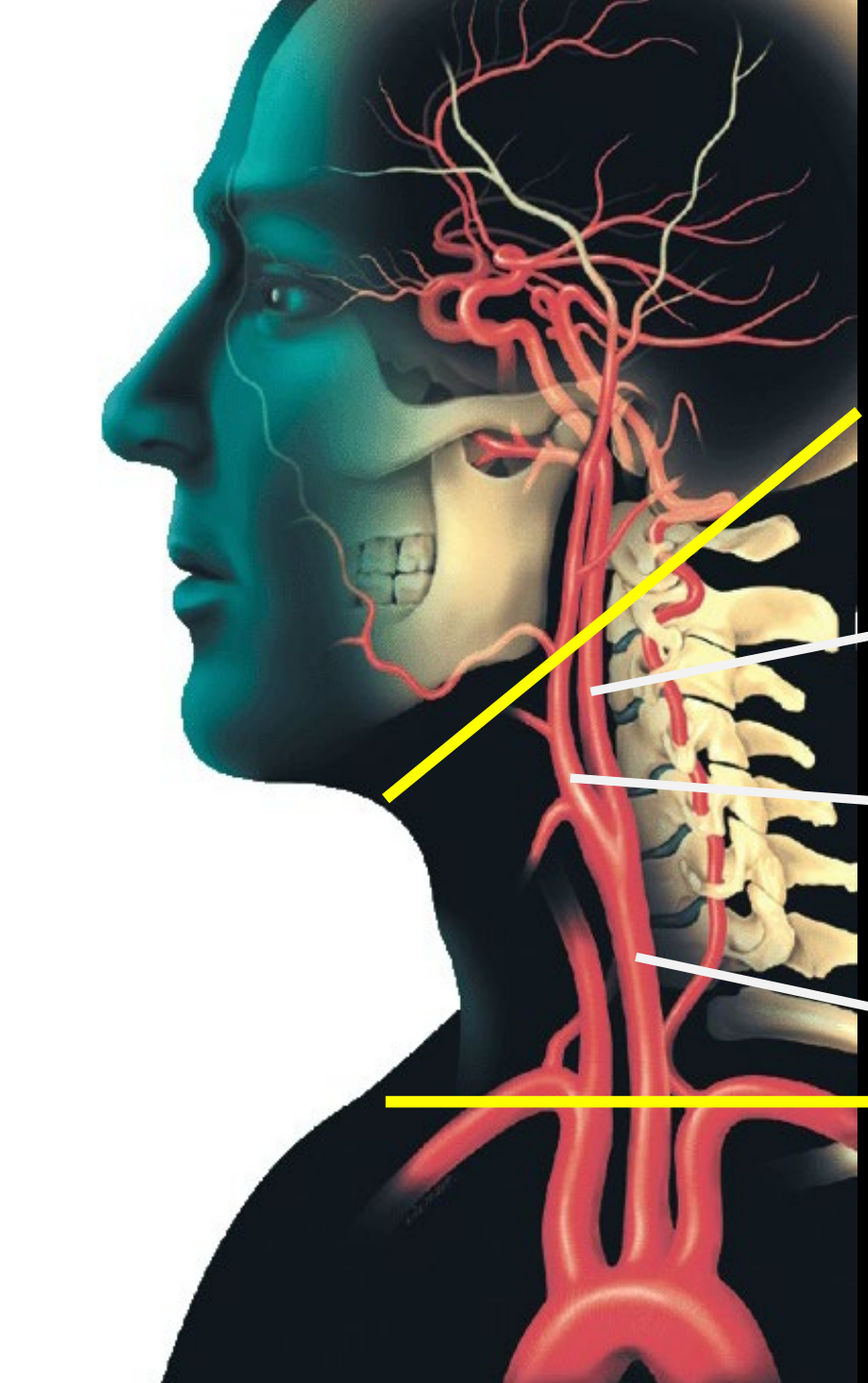
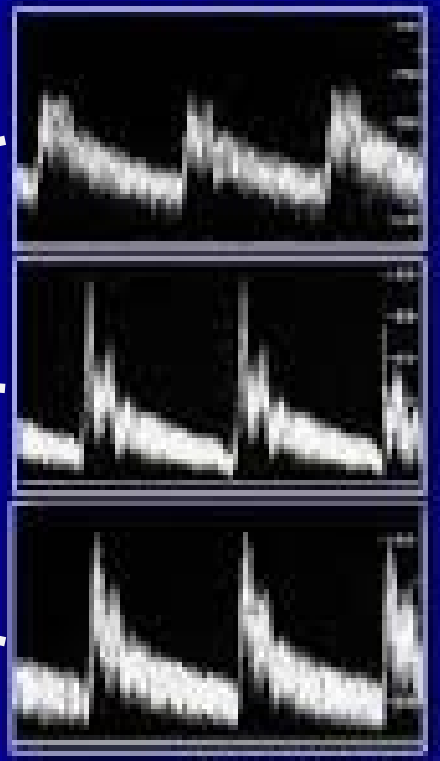


## Typical normal Doppler spectra



Internal carotid artery

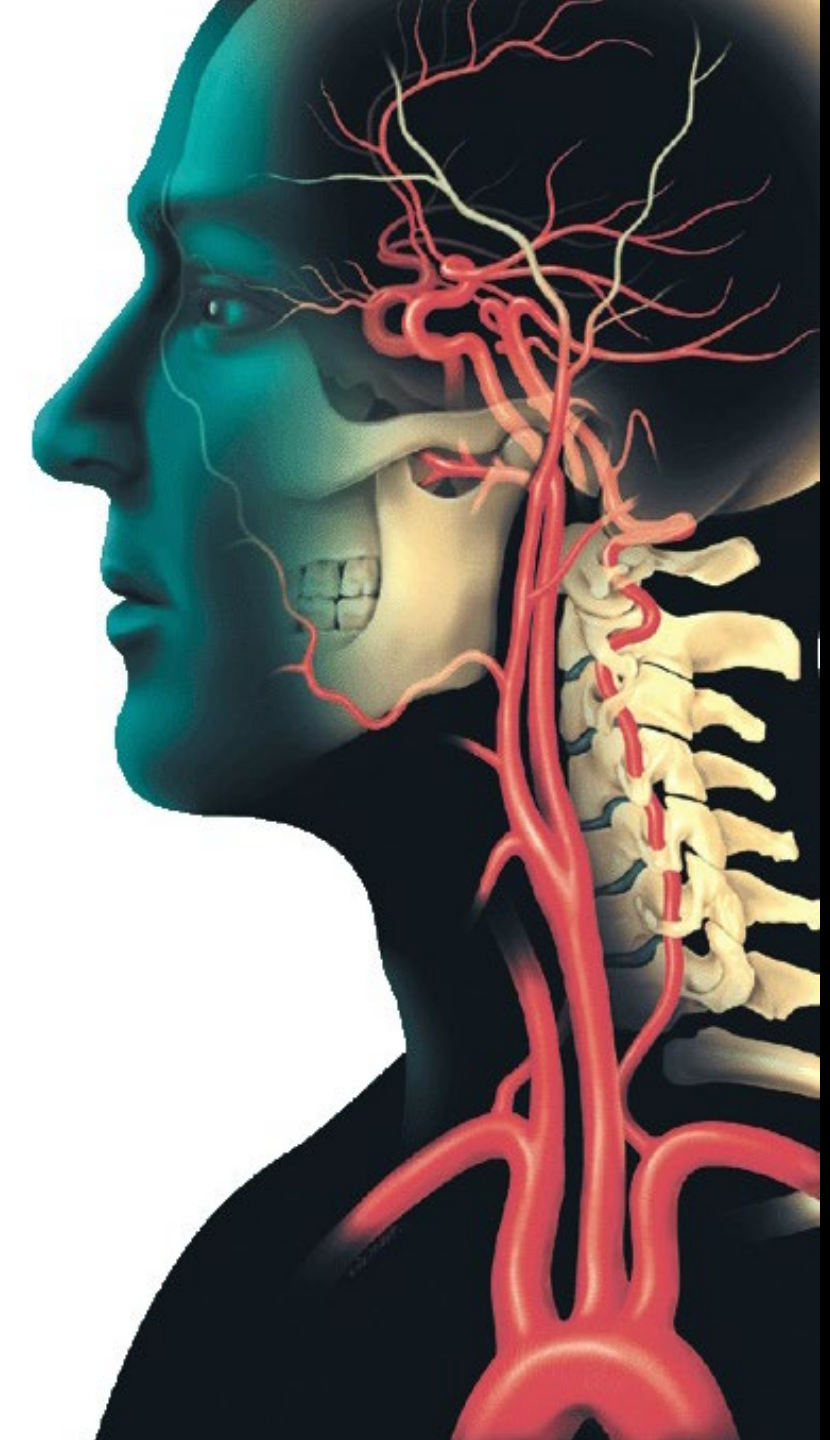
PSV: 45 – 125 cm/sec

Difference between 2 sides < 15 cm/sec

External carotid artery

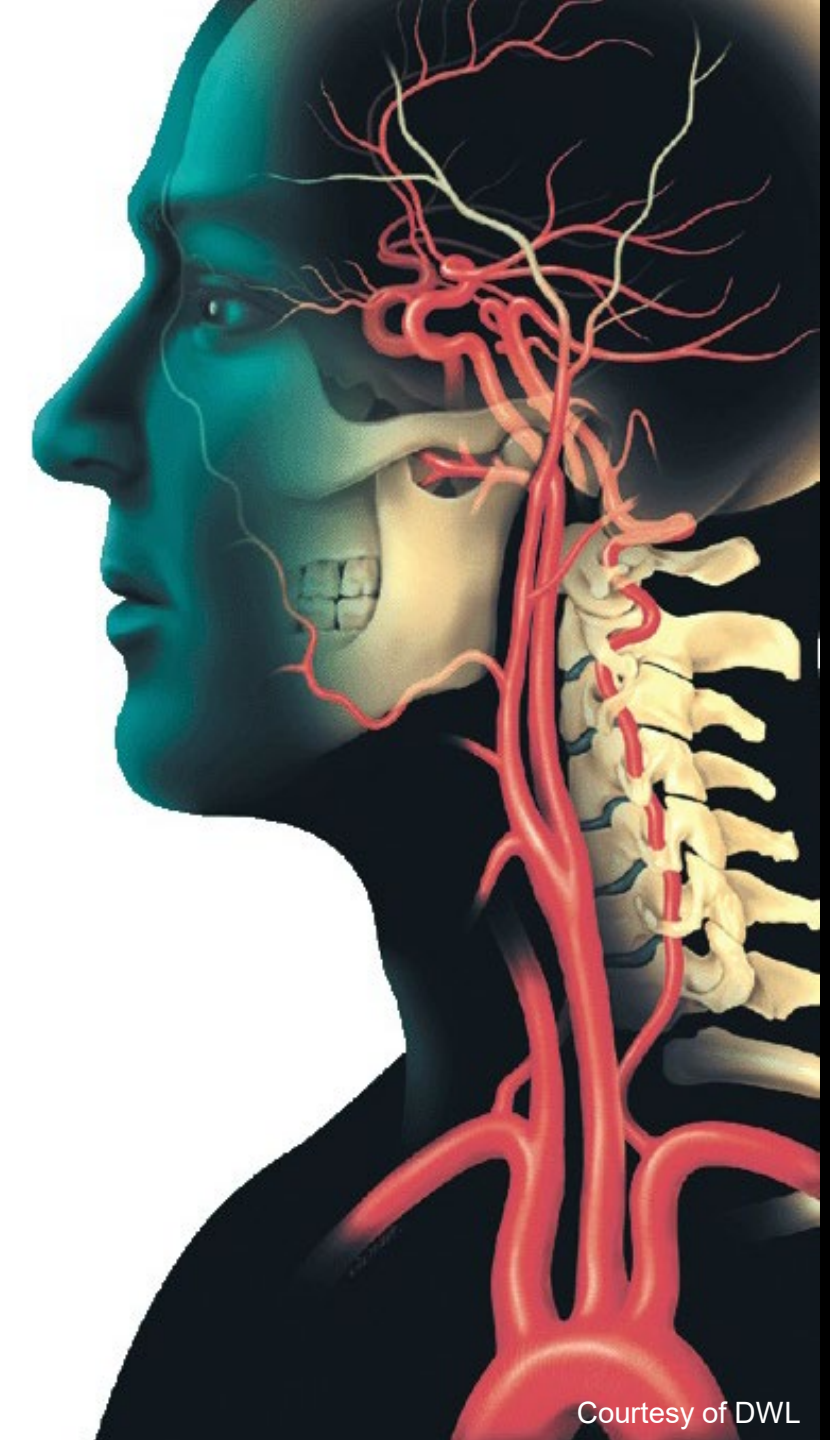
Common carotid artery

Zwiebel WL. Introduction to vascular ultrasonography. W.B. Saunders. Philadelphia. USA. 4th edition. 2000.



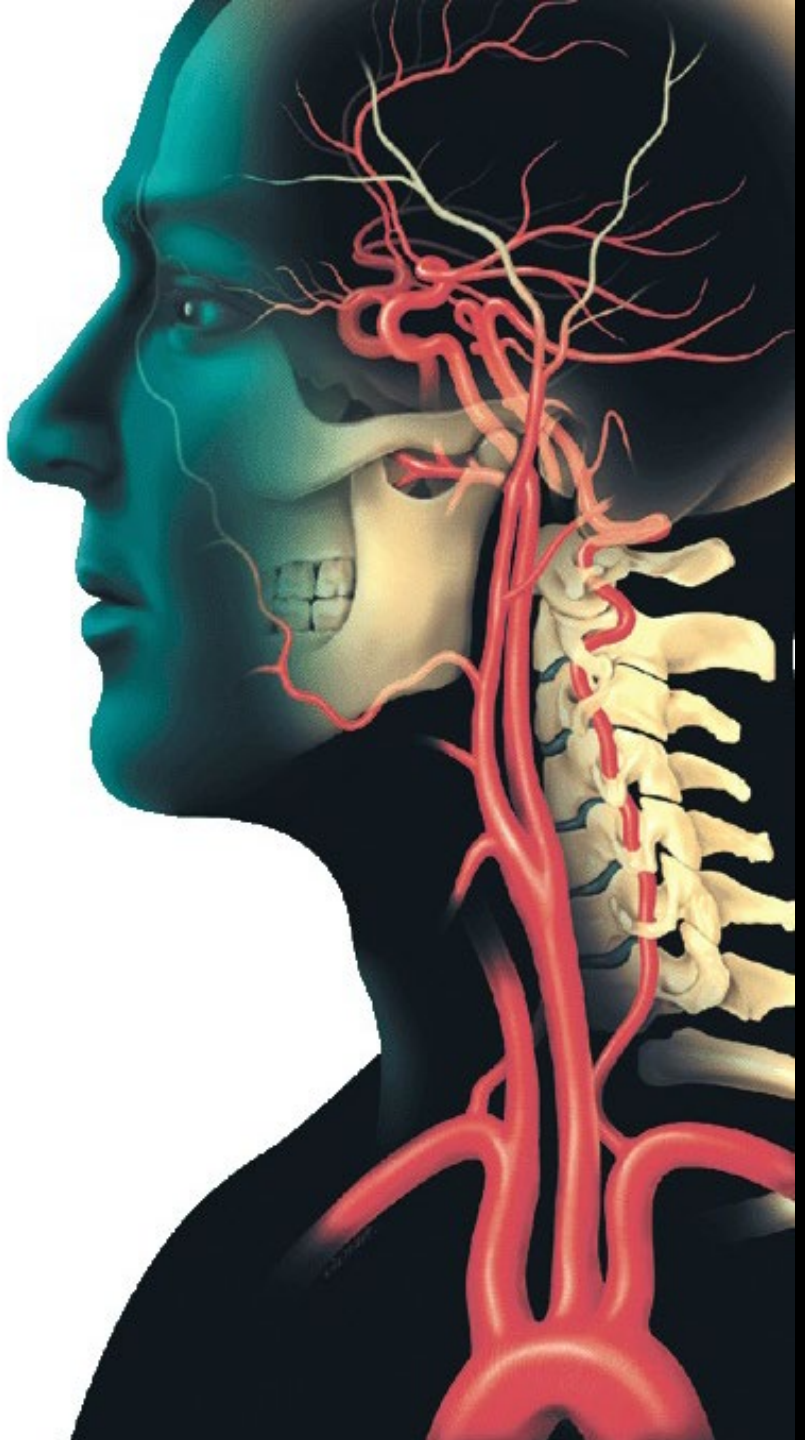
# Carotid Ultrasound
# Why do we do it?

- Carotid/Vertebral disease is the most commonly identified stroke mechanism
- Carotid/Vertebral atherosclerosis/stenosis is marker of increased stroke risk
- Established surgical benefit for (>70%) symptomatic carotid stenosis (NASCET)
    - and tight asymptomatic stenosis (ACAS




# Questions to Answer

- Presence
  - Is there plaque (or other narrowing) ?
- Distribution / Location
  - Diffuse, focal, tandem ? Indirect ?
- Characteristics
  - Plaque features influence decision
- Severity
  - Percent stenosis remains the primary end point of the exam



# Objectives

- Assess Flow Dynamics Across Segment
- Identify and Describe Anatomy and Pathology

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- Assess Flow Dynamics Across Segment
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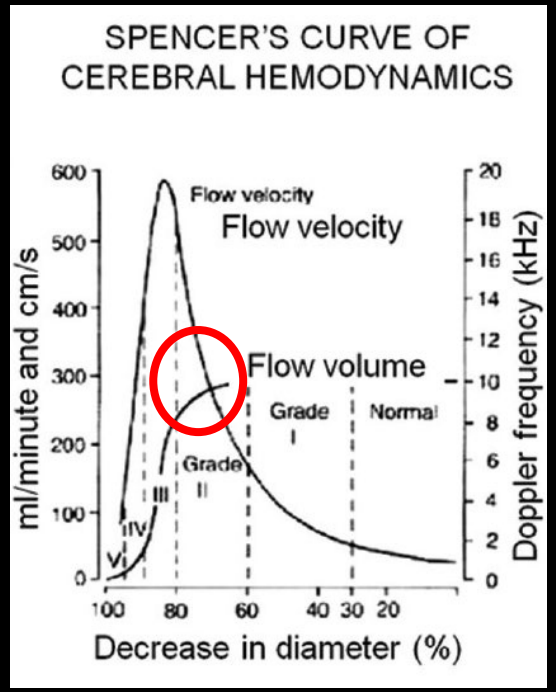
# Doppler

- Quantitative (Spectral Doppler)
  - Velocity (PSV, EDV)
    - ICA/CCA Ratio
  - Stenosis Range / Where along Spencer's Curve
  - Waveform Morphology
  - Proximal / Inflow
  - Distal / Outflow
- Big Picture View (Color):
  - Location, size, course of vessels
  - Presence of Flow, Distribution, Relative Speed and Character



# SRU Consensus Criteria (Post NASCET)

**Degree of ICA Stenosis in Doppler US***

**Consensus Criteria – NASCET criteria**

| ICA stenosis (%) | ICA PSV cm/sec | ICA EDV cm/sec | PSV ratio ICA/CCA |
|---|---|---|---|
| Normal | < 125 | < 40 | < 2.0 |
| < 50% | < 125 | < 40 | < 2.0 |
| 50 – 69% | 125 – 230 | 40 – 100 | 2.0 – 4.0 |
| > 70% | > 230 | > 100 | > 4.0 |
| Near occlusion | variable | variable | variable |
| Total occlusion | undetectable | undetectable | not applicable |

* Diameter reduction

Grant EG et al. Radiology 2003 ; 229 : 340 – 346.

# University of Washington Criteria (Pre-NASCET)

**Table 1 – University of Washington (Strandness) carotid duplex interpretation criteria.**

| Stenosis (DR) | $PSV_{ICA}$ (cm/s) | ~~Spectral broadening~~ | $EDV_{ICA}$ (cm/s) | Plaque imaging |
|---|---|---|---|---|
| Normal | <125 | None | NA | None |
| 0–19% | <125 | None | NA | Minimal lumen reduction |
| 20%–49% | <125 | Mild | NA | Moderate lumen reduction |
| 50%–79% | >125 | Moderate | <140 | Significant lumen reduction |
| 80%–99% | >125 | Severe | >140 | High-grade stenosis |
| Occlusion | No flow | NA | No flow | Lumen filled with plaque and thrombus |

DR, diameter reduction; $EDV_{ICA}$, end diastolic velocity of internal carotid artery; NA, not applicable; $PSV_{ICA}$, peak systolic velocity of internal carotid artery.

# Objectives

- Assess Flow Dynamics Across Segment
- Identify and Describe Anatomy and Pathology

# B-mode

- Big Picture View:
  - Location, size, course of vessels
  - Plaque distribution and other pathology
- Specific / Focal View:
  - Plaque Features including:
    - Surface (smooth, irregular, ulcerated)
    - Echodensity (isoechoic, hyperechoic, hypoechoic
    - Pattern (homogeneous/heterogeneous, shadowing ?)

# AbuRhama et al (J Endovasc Surg 1999)

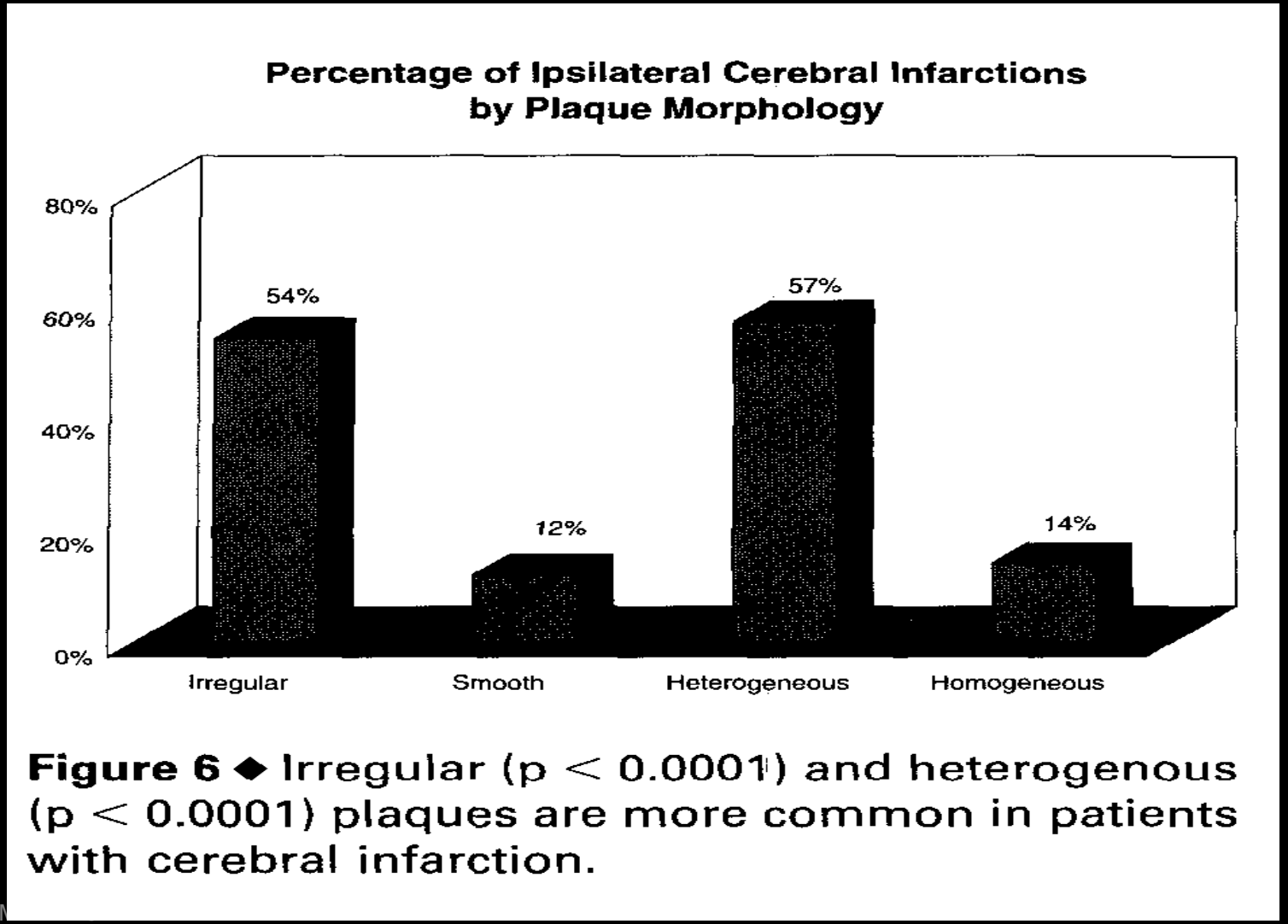



**Figure 6** ◆ Irregular ($p < 0.0001$) and heterogenous ($p < 0.0001$) plaques are more common in patients with cerebral infarction.

# Carotid Ultrasound: Over Forty Years in Evolution

- CW Doppler Spectral Analysis (1970's-1980's)
- CW & PW Doppler Imaging (1970's-1980's)
- Real-time B-Mode Imaging (1980's -
- **Duplex** (1982 - )
  - Color Doppler Imaging (1987 - )

# CEREBROVASCULAR DOPPLER SPECTRUM ANALYSIS EVALUATION

## NORMAL
INTENSITY CONCENTRATED IN UPPER ENVELOPE. REGULAR WAVEFORM AND WINDOW

## MILD 10-45%
INTENSITY OF LOWER FREQUENCIES INCREASED. REGULAR WAVEFORM, BUT SMALLER WINDOW

## MODERATE 50-75%
INTENSITY UNIFORM ACROSS FREQUENCY RANGE. ELEVATED PEAK FREQUENCY

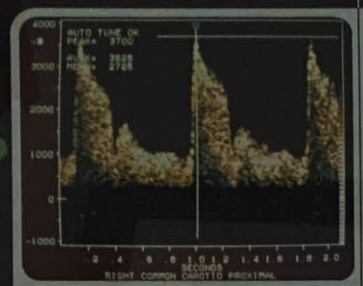
## SEVERE 76-99%
INTENSITY MARKED NEAR BASELINE. INDISTINCT PEAK, EXTREME PEAK FREQUENCY

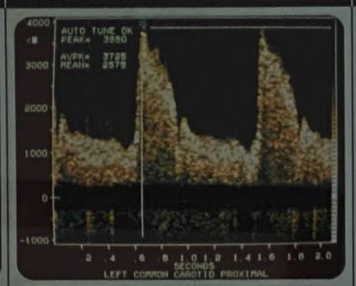
## OCCLUDED 100%
ABSENCE OF SIGNAL DISTAL TO STENOSIS

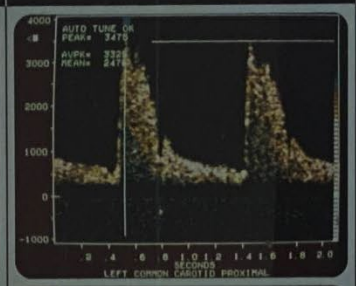
COMMON CAROTID C

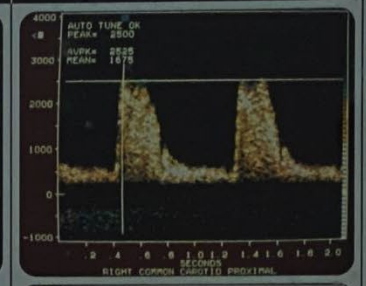
EXTERNAL CAROTID E

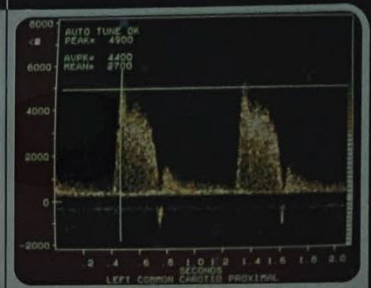
INTERNAL CAROTID 1 PROXIMAL

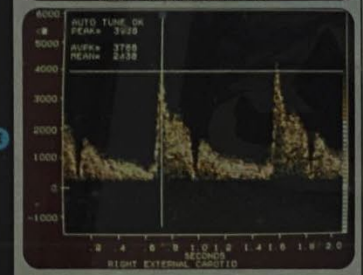


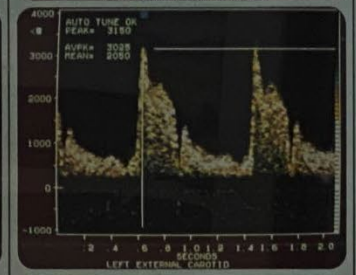



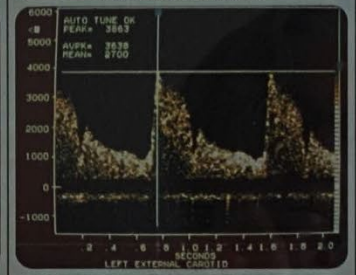



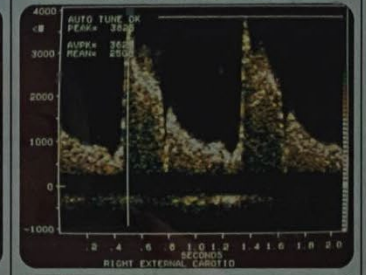



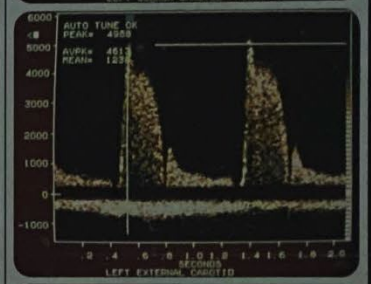



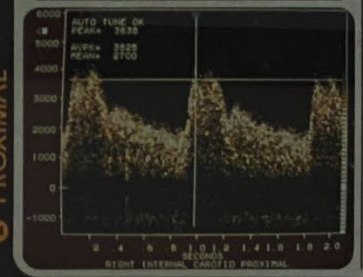



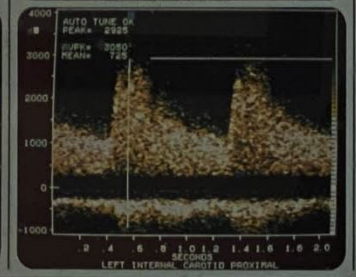



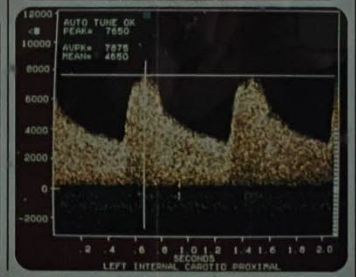



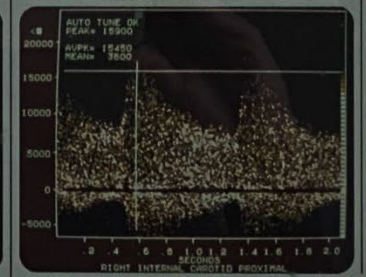



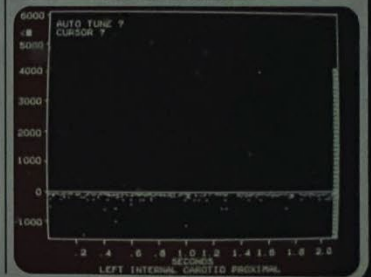



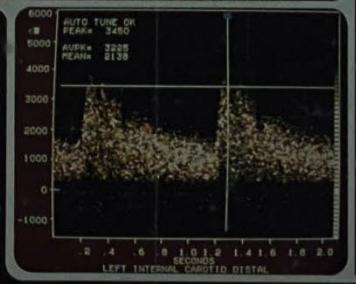



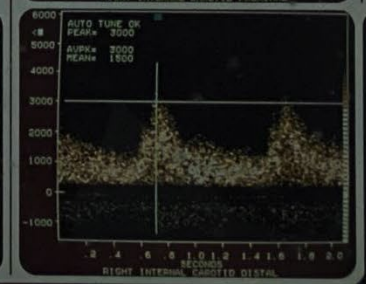



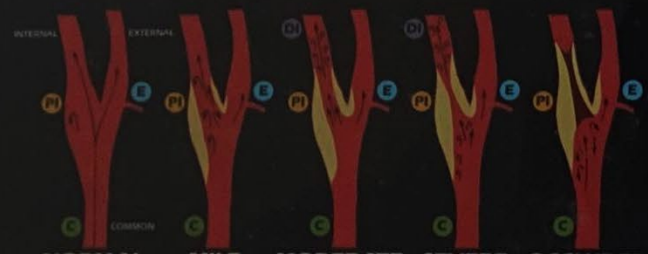




INTERNAL CAROTID 3 DISTAL



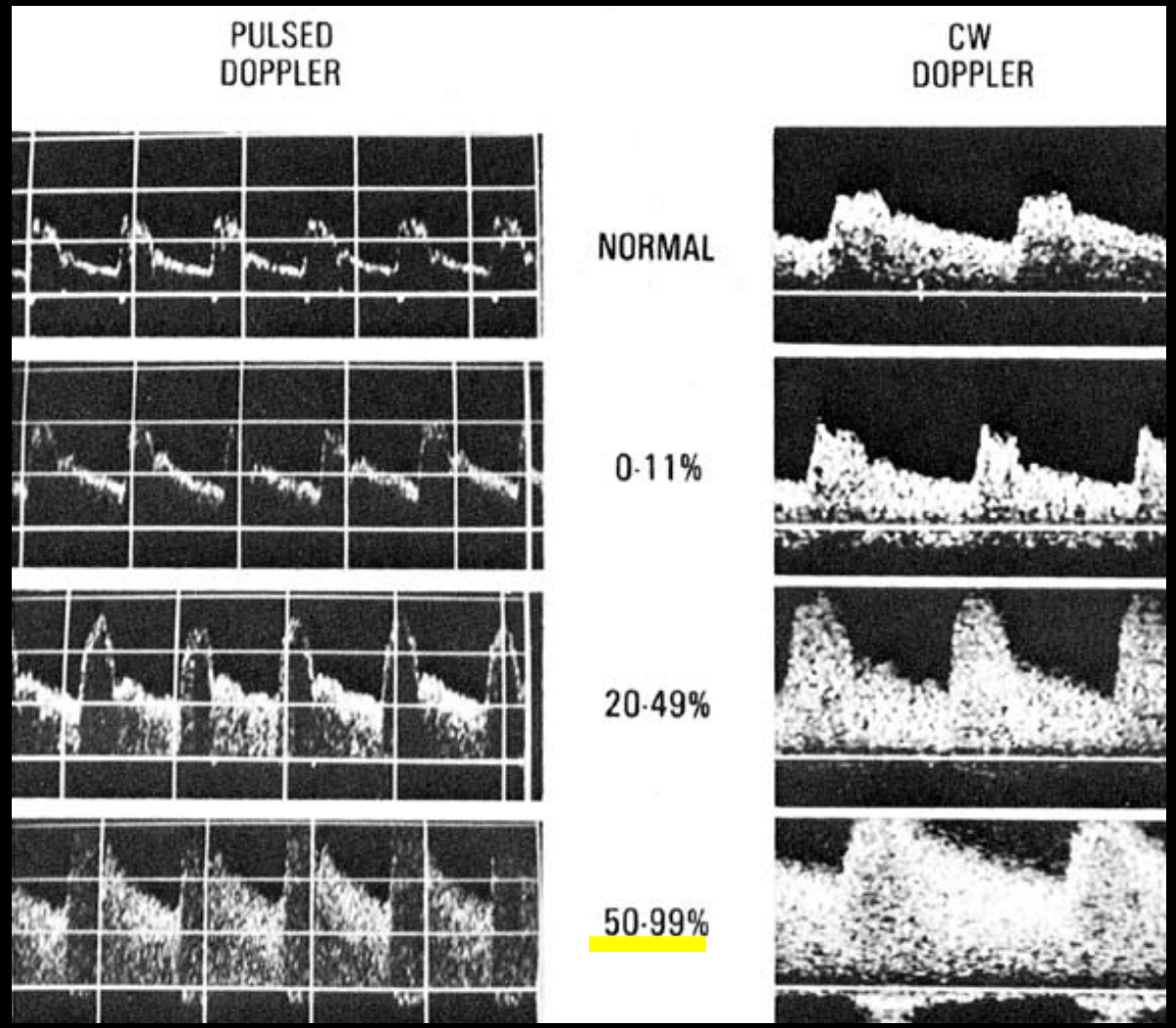

NOTES:
- SPECTRAL INTENSITY CONCENTRATION AND PEAK FREQUENCIES TAKEN FROM IPSILATERAL AND CONTRALATERAL CAROTID SITES MUST BE COMPARED TO ACCURATE DIAGNOSTIC ERROR.
- INCREASE IN INTENSITY OF LOWER FREQUENCIES CAN BE CAUSED BY TECHNICAL ERROR.
- SHIFT IN DOPPLER FREQUENCY IS PROPORTIONAL TO PROBE FREQUENCY AND PROBE ANGLE. USE SAME PROBE FREQUENCY AND CONSISTENT ANGLE THROUGHOUT EXAM.

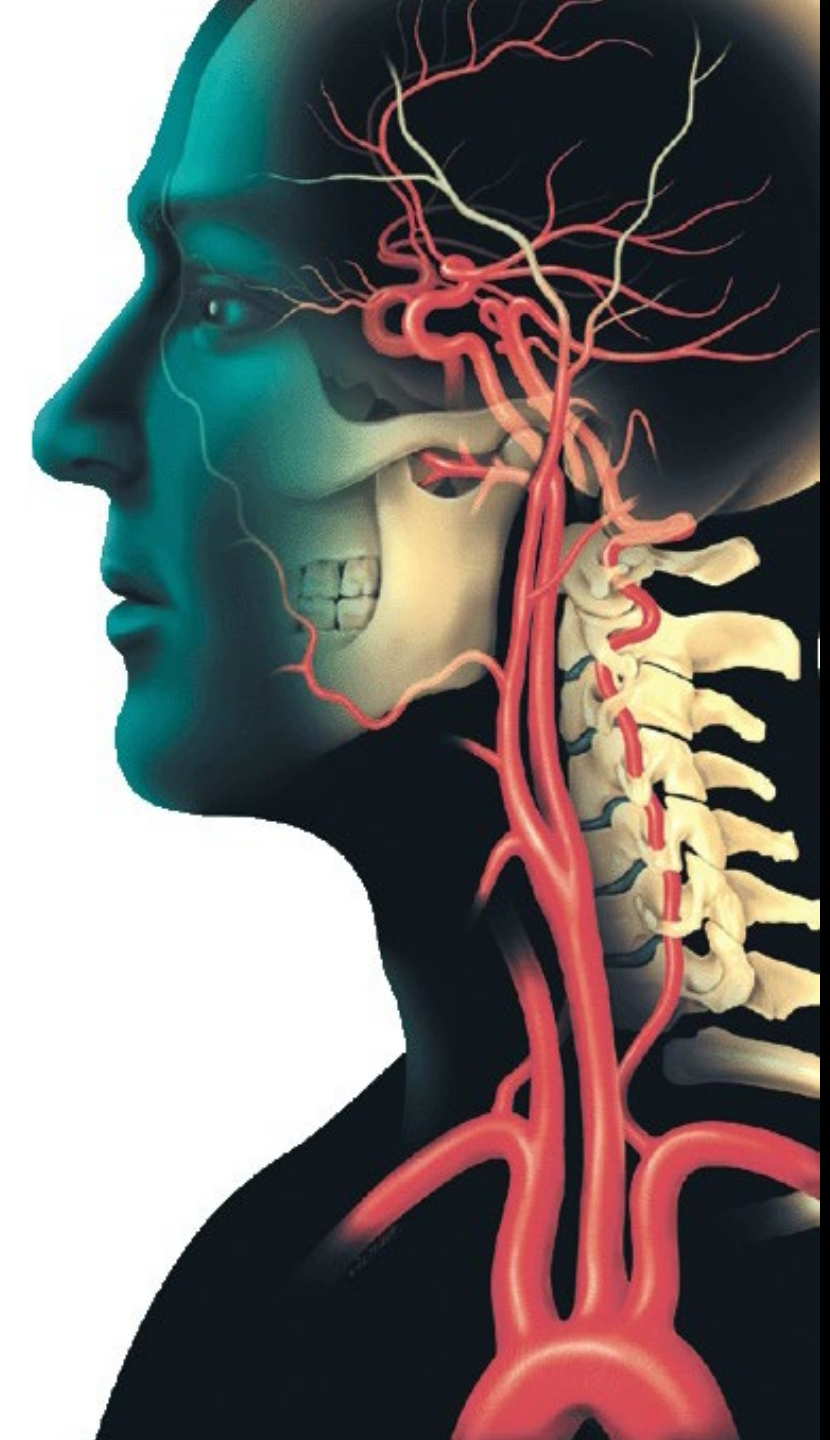
MEDA SONICS

SPECTRUM ANALYZER SYSTEM

VASCULAB SA

# Evolution of Doppler Criteria





# Duplex

- **B-Mode** (Grayscale/Real-Time)

- **Doppler** (SIngle-gate)
  - **Audio**
  - **FFT Spectral Waveforms**

  - Color Doppler Imaging (Multi-gate, scanning)
    - Color
    - Power

Courtesy of DWL

# IAC Standards and Guidelines for Vascular Testing Accreditation

## Extracranial Cerebrovascular Testing

IAC Standards and Guidelines for Vascular Testing Accreditation (Published July 15, 2019)

# STANDARD – Techniques
# (Standard 1.4B)

"Appropriate techniques must be used for the evaluation of the extracranial cerebrovascular system to assess for the presence of any abnormalities and to document their severity, location, extent and whenever possible etiology"

IAC Standards and Guidelines for Vascular Testing Accreditation (Published July 15, 2019)

# Elements of Proper Technique include, but are not limited to: (Standard 1.4B)

- performance of an examination according to the facility specific, written protocol
- proper patient positioning
- patient preparation
- appropriate equipment and transducer selection
- appropriate transducer positioning
- proper sample volume size and positioning
- optimization of equipment gain and display settings
- a spectral Doppler angle of 60 degrees or less with respect to the vessel wall and/or direction of blood flow when measuring velocities
- proper measurement of spectral velocities as required by the protocol
- identification of vessels by imaging and Doppler

IAC Standards and Guidelines for Vascular Testing Accreditation (Published July 15, 2019)

# Each Examination Performed in the Facility

must provide documentation as required by the protocol that is sufficient to allow proper interpretation, including but not limited to: (Standard1.5B)

- Grayscale Images
- Color Doppler Images
- Doppler Waveforms
- Velocity Measurements
- other images and waveforms as required by the protocol *

IAC Standards and Guidelines for Vascular Testing Accreditation
(Published July 15, 2019)

# Long Axis (longitudinal)) Grayscale Images (minimum)

- Common Carotid Artery
- Bifurcation
- Internal Carotid Artery
- Carotid Artery Stent (if present) including proximal and distal ends

Standards and Guidelines for Vascular Testing Accreditation. 2019

# Doppler Spectral Waveforms and Measurements (minimum)

- Proximal Common Carotid Artery
- Mid/Distal Common Carotid Artery
- Proximal Internal Carotid Artery
- Distal Internal Carotid Artery
- External Carotid Artery (one site)
- Vertebral Artery (one site)

Standards and Guidelines for Vascular Testing Accreditation. 2019

# In Addition:

- “Abnormalities will require additional images and waveforms that demonstrate the severity, location, extent and whenever possible etiology of the abnormality present.”

- “Areas of suspected stenosis or obstruction must include representative Doppler waveforms and velocity measurements recorded at and distal to the stenosis or obstruction.”

- Limitations of the study must be documented in the final report

# Additional Doppler If Stent Present

- Native Artery at the Proximal End of the Stent
- Proximal Stent
- Mid Stent
- Distal Stent
- Native Artery at the Distal End of the Stent

# Transducer – Phased Linear Array


## Broad Band

- incorporate multiple frequencies
  - Higher for imaging/resolution
  - Lower for Doppler/penetration

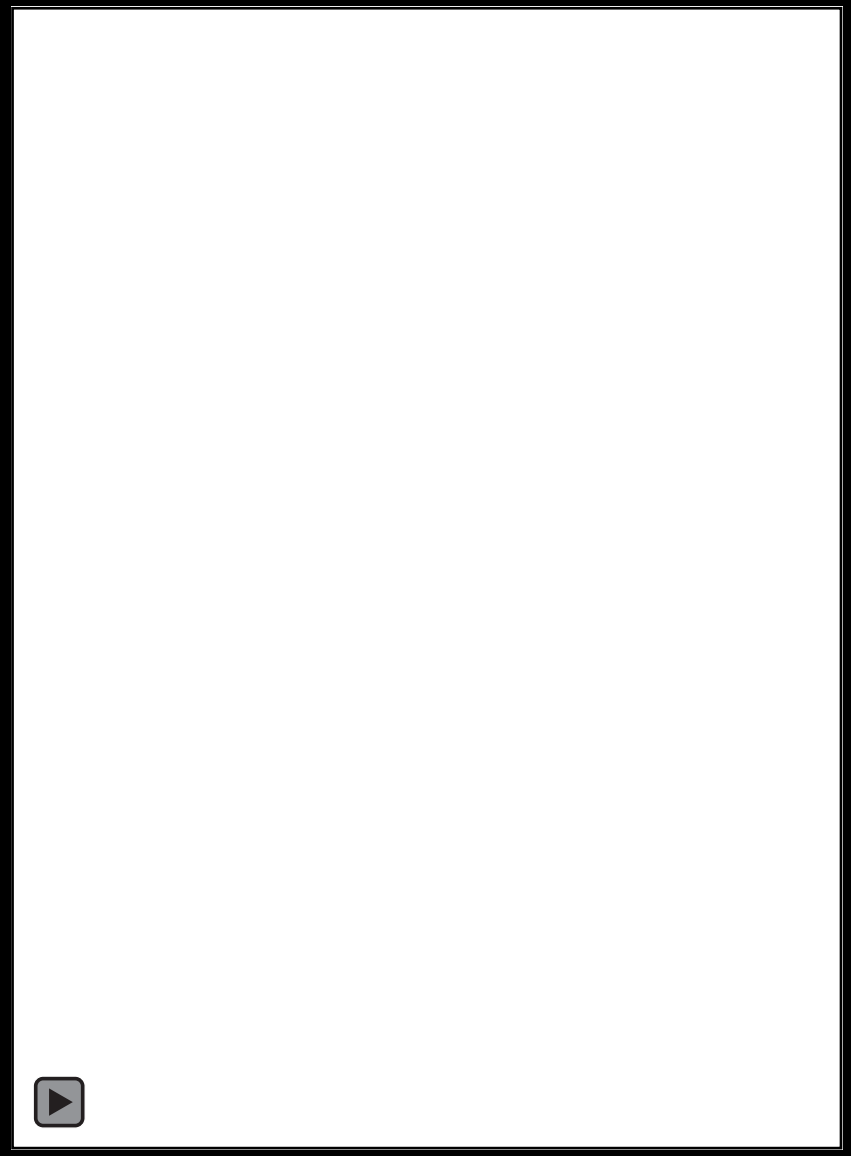
- variety of frequency ranges

## Higher Frequency:

- higher resolution
- less penetration

# Transducer Orientation

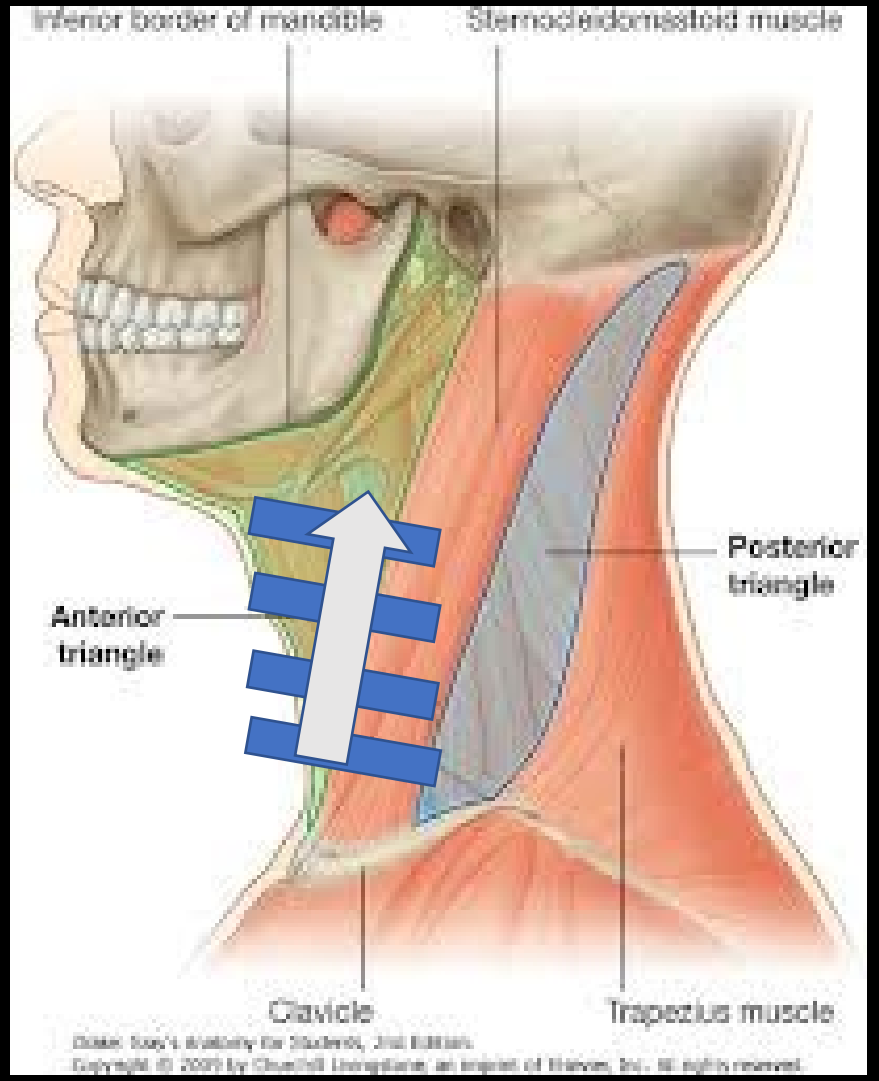
- Transverse
  - Left is Right
- Longitudinal
  - Left is Head



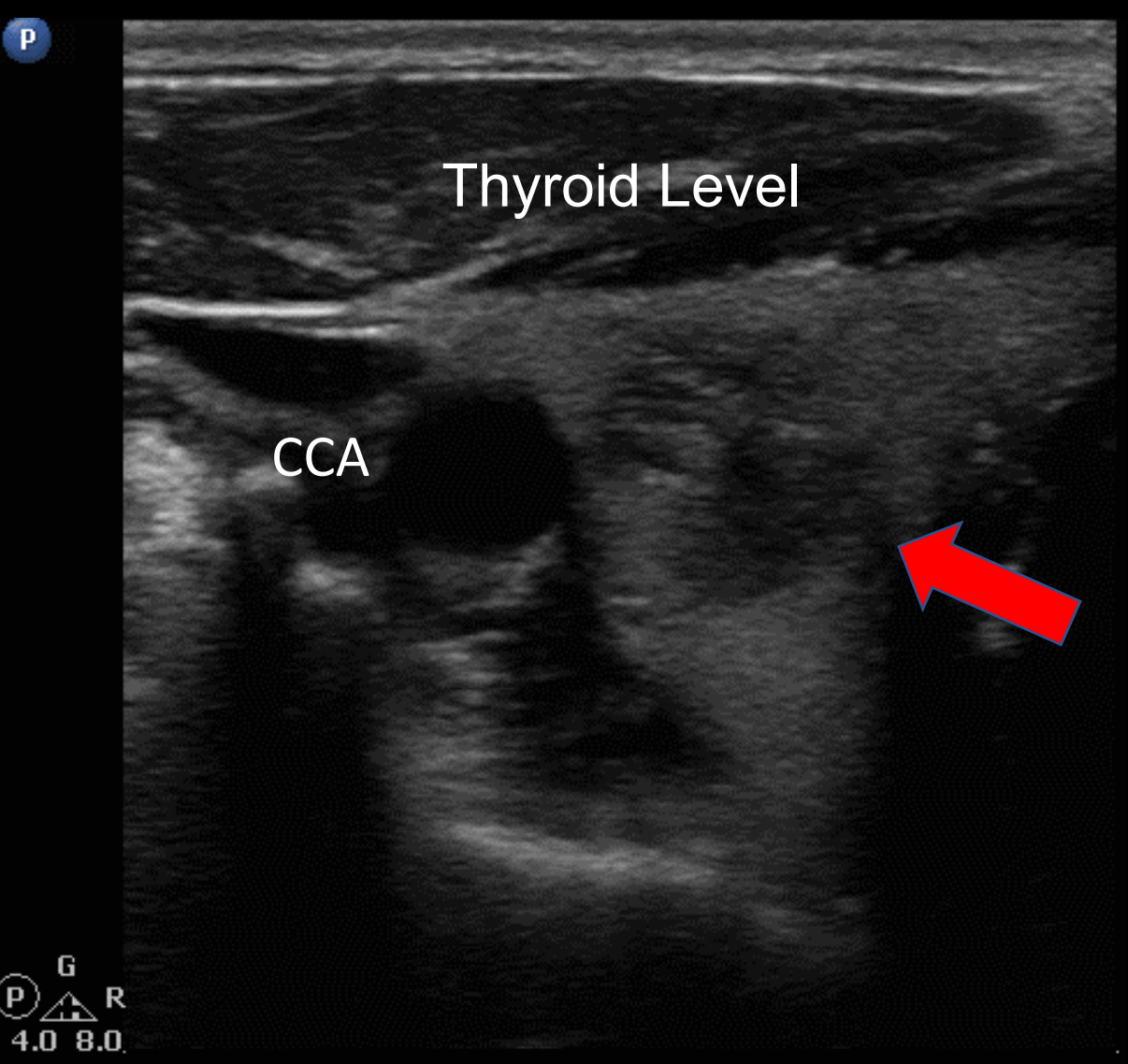
## Jugular Groove

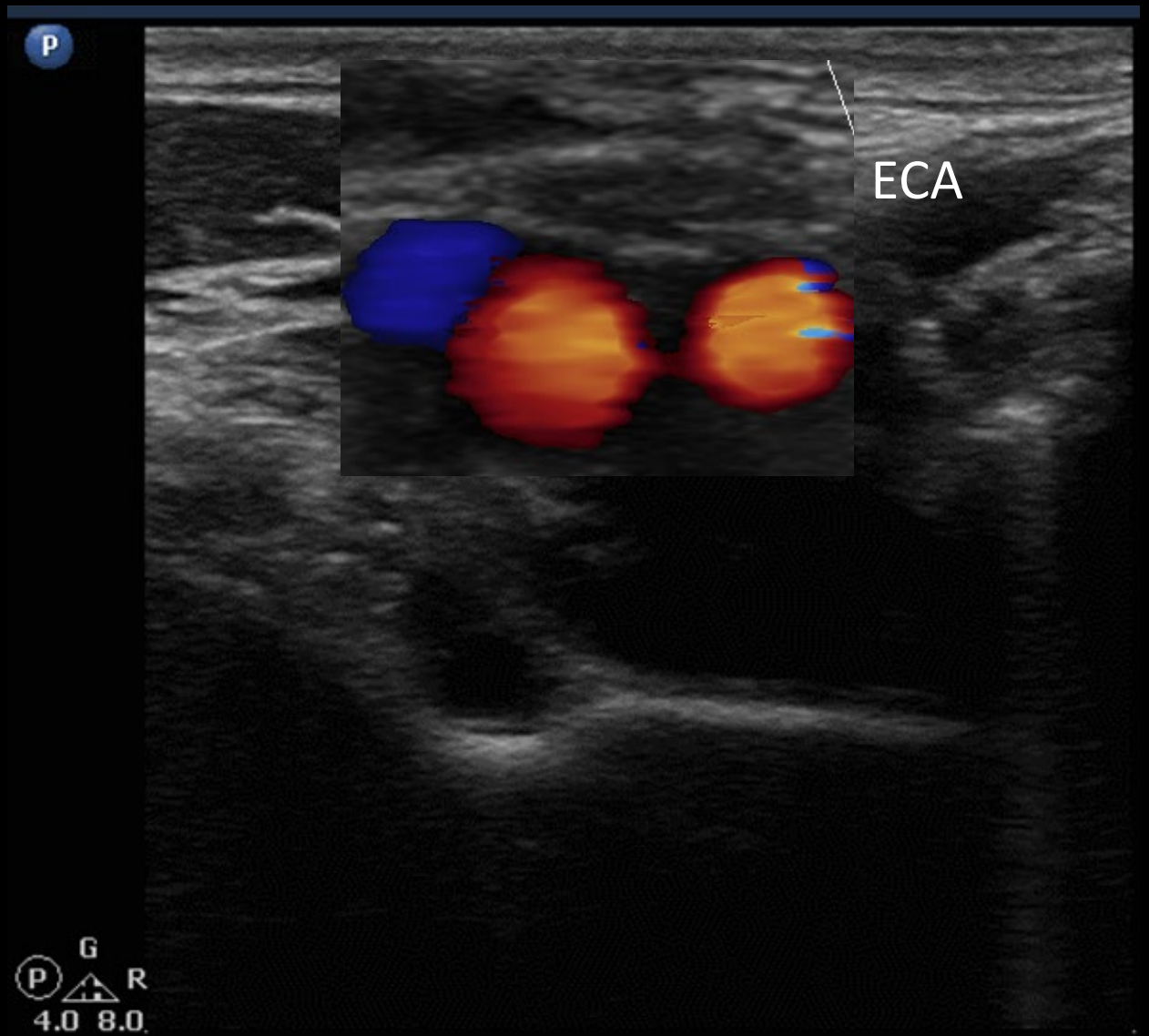
## Preparation / Ergonomics

# Transducer Orientation - Transverse



# Transverse

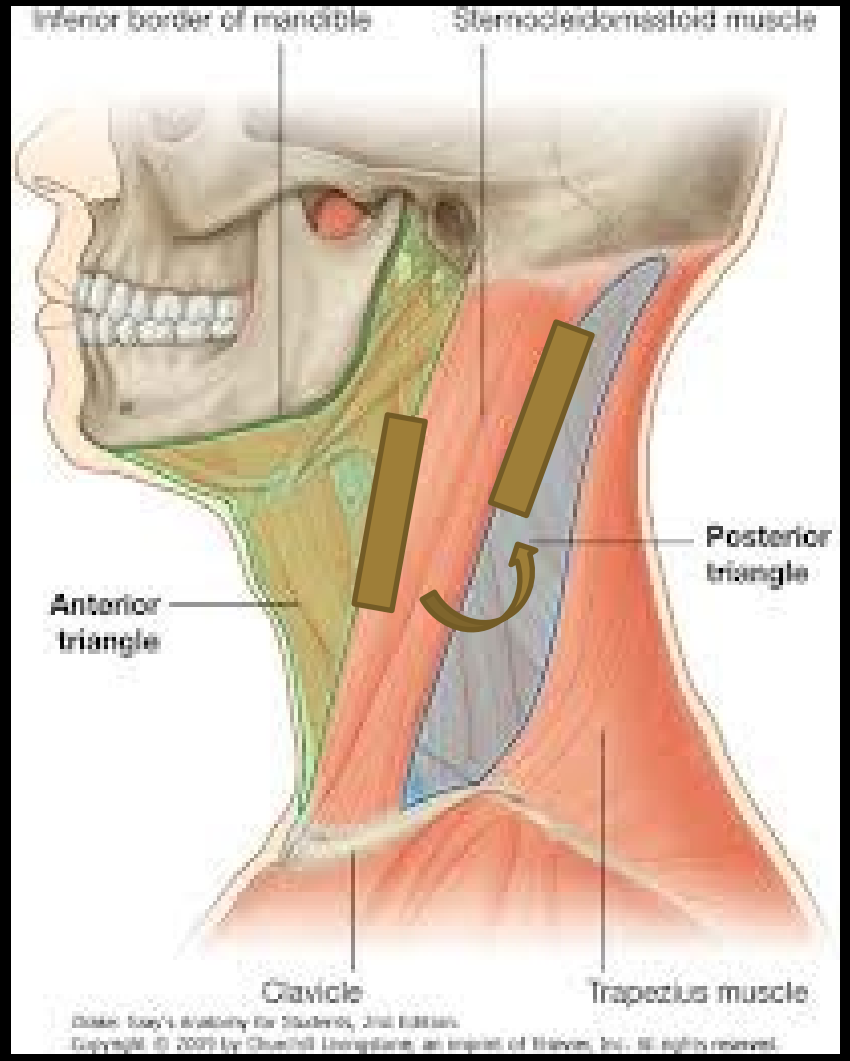


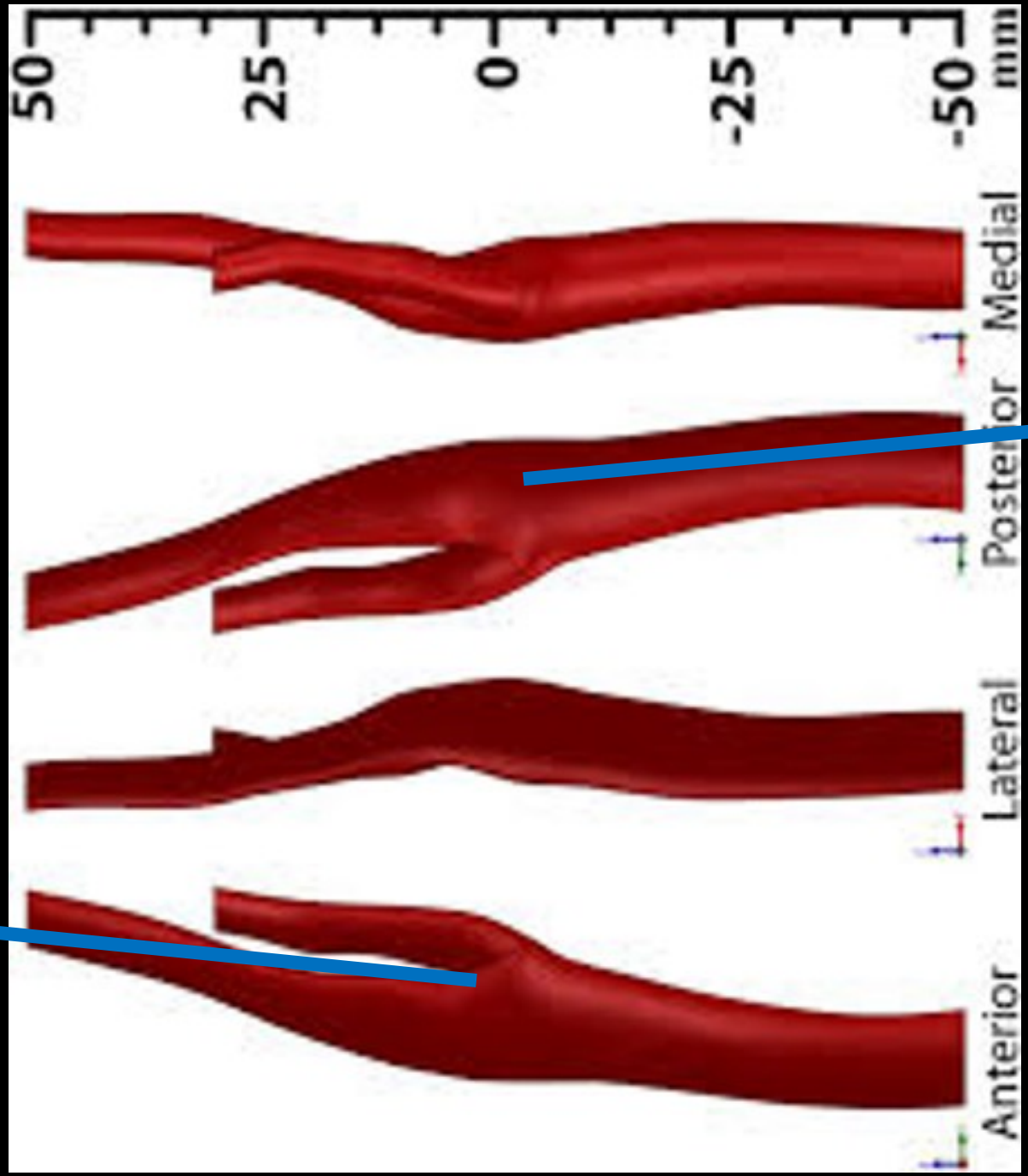



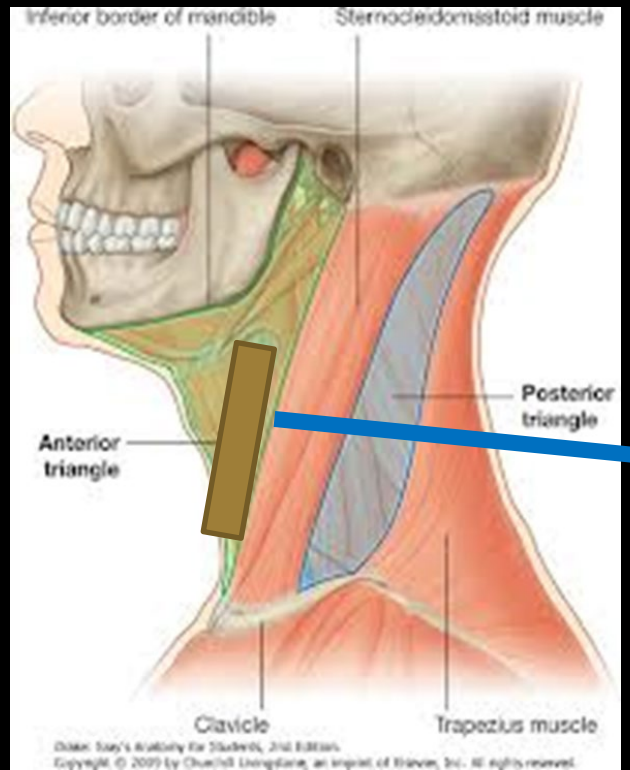
# Transducer Orientation –Longitudinal

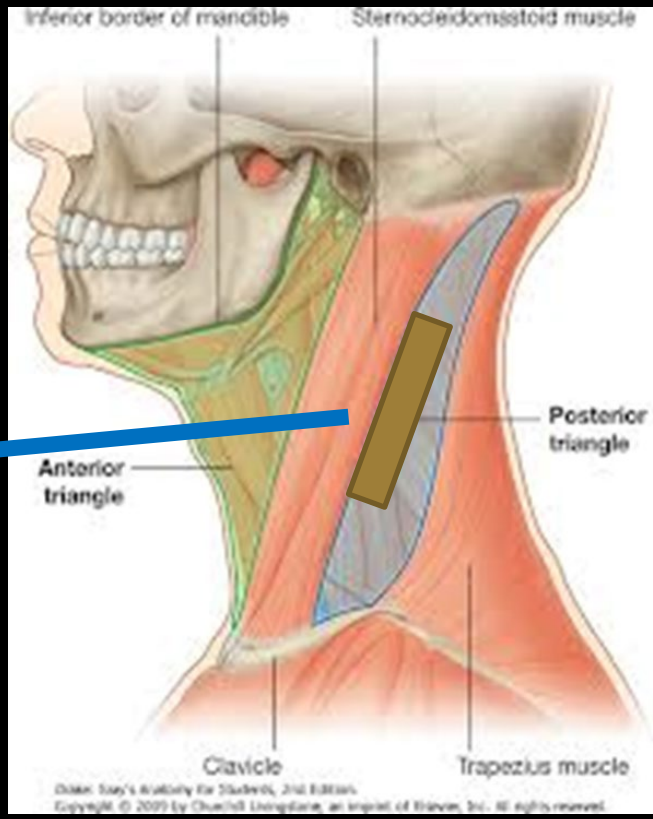
Anterior

Posterolateral

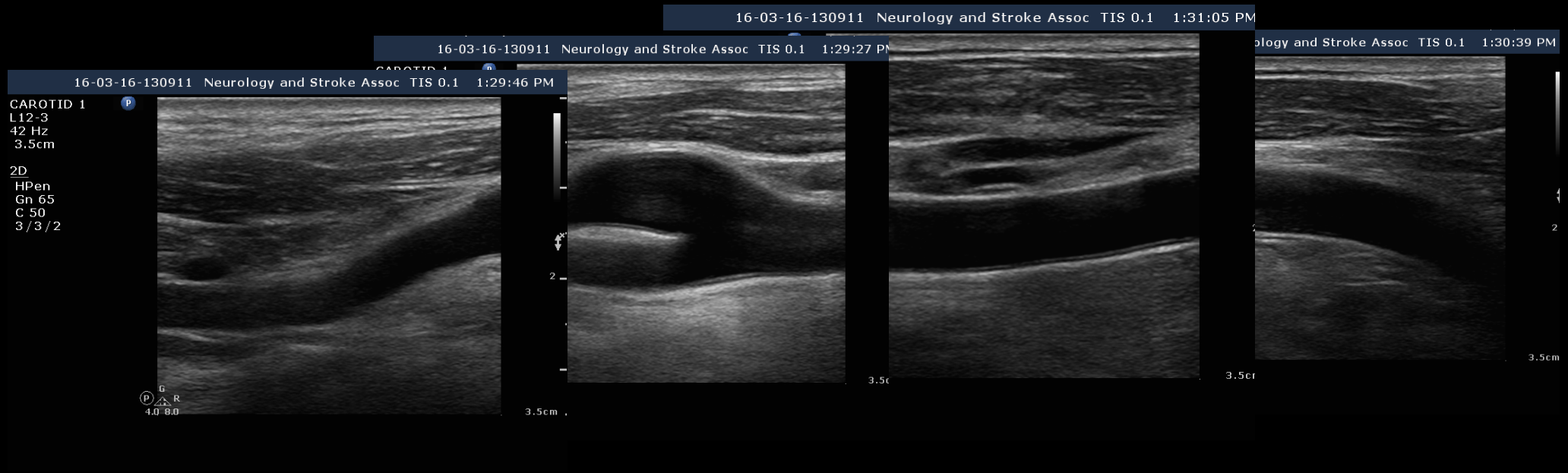



50
25
0
-25
-50
mm
Medial
Posterior
Lateral
Anterior

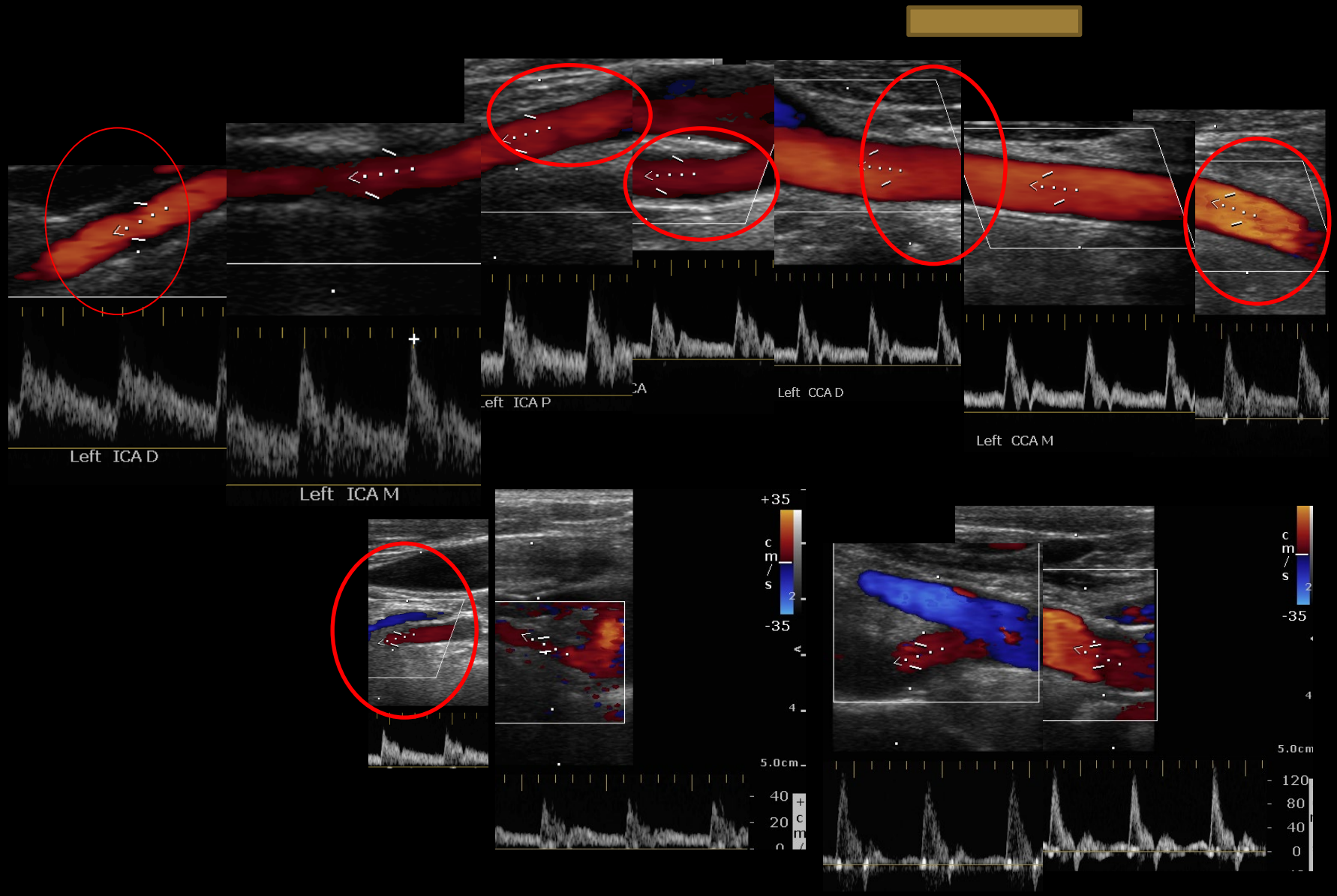

Inferior border of mandible
Sternocleidomastoid muscle
Posterior triangle
Anterior triangle
Clavicle
Trapezius muscle


Inferior border of mandible
Sternocleidomastoid muscle
Posterior triangle
Anterior triangle
Clavicle
Trapezius muscle

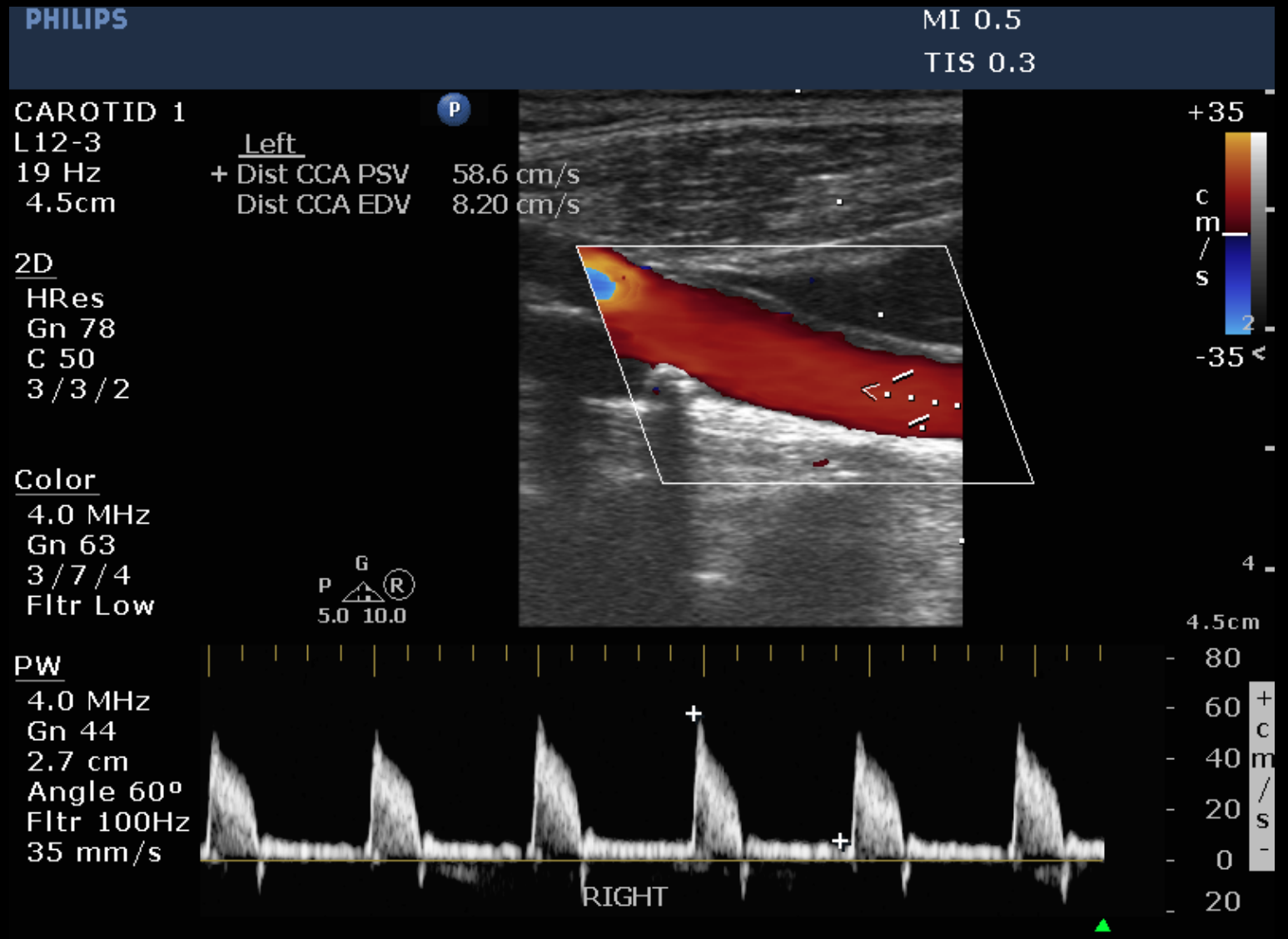
# Composite B-mode - Longitudinal



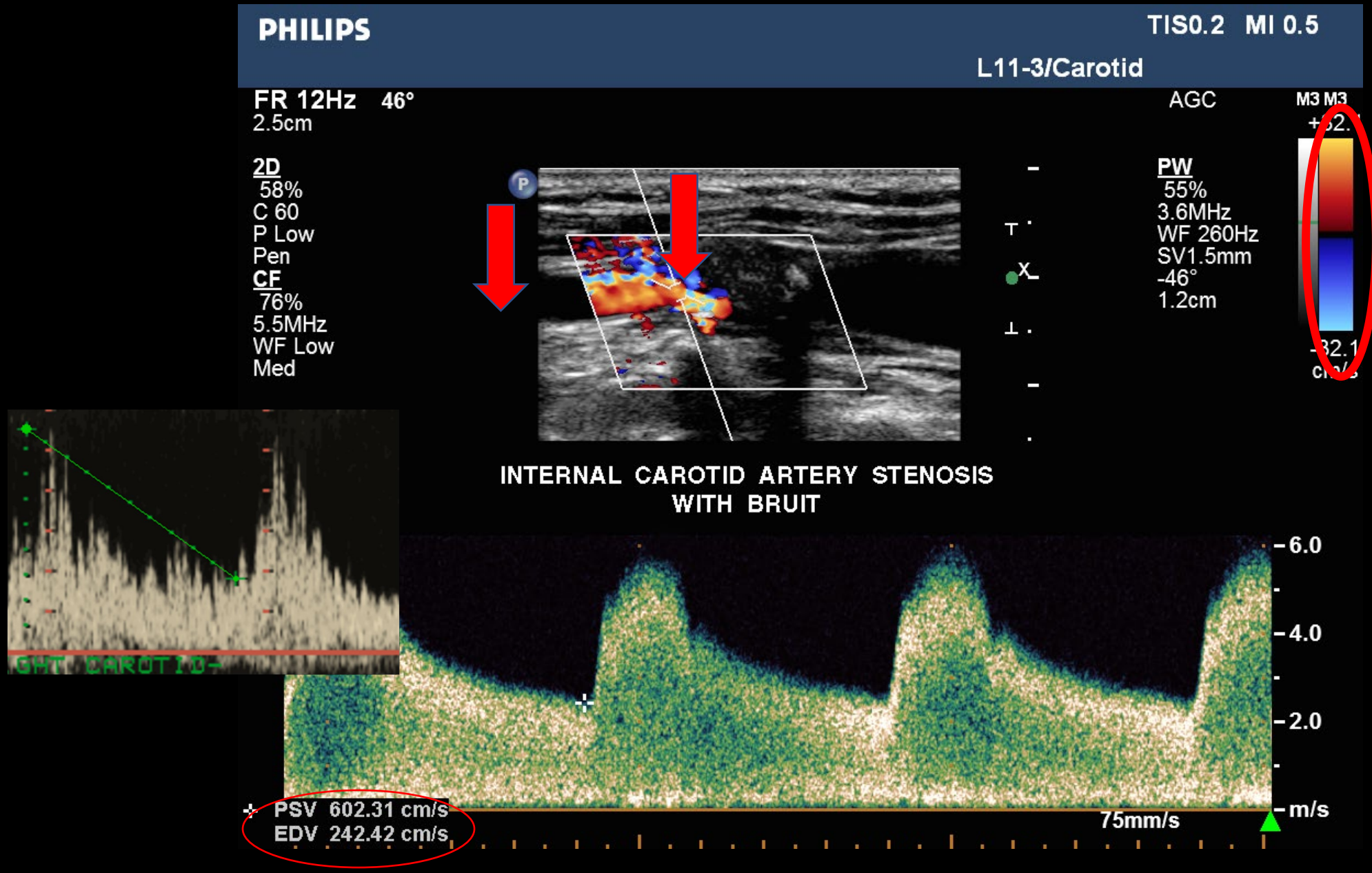
# Minimum Spectral Doppler Sites



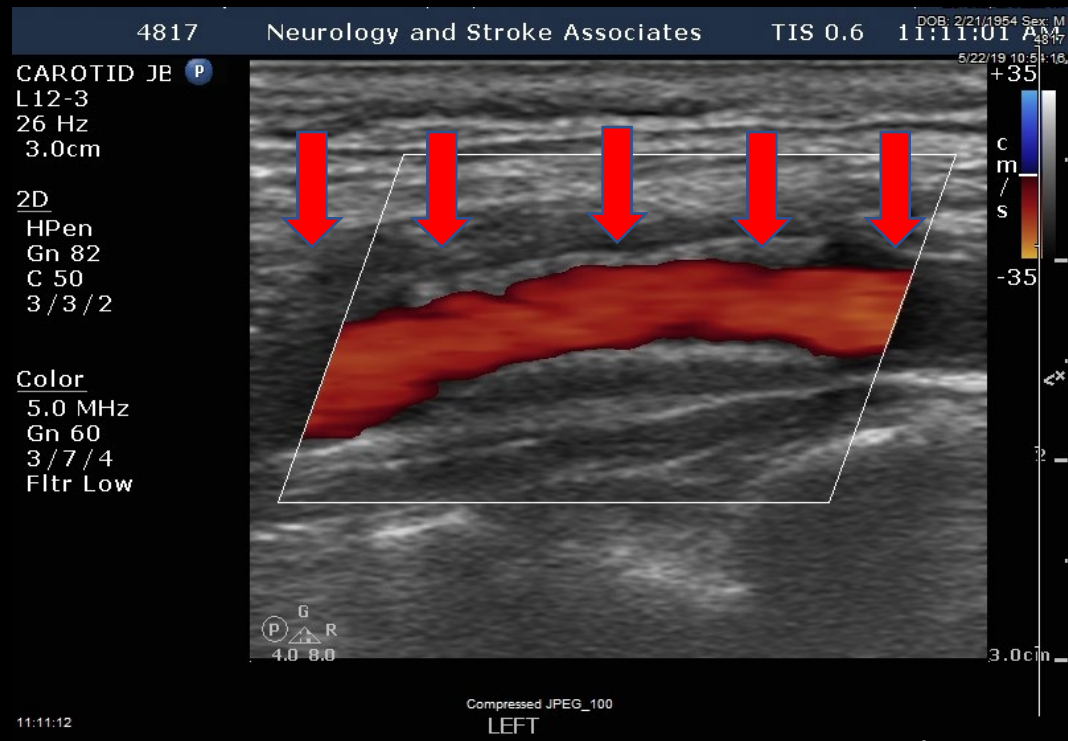
# Sample Volume Placement – CCA Mid/Distal



# Additional - Stenosis



# Additional - Carotid Artery Stent (CAS)


Obtain Additional Doppler Waveforms/Velocities:

- Native Artery at the Proximal End of the Stent
- Proximal Stent
- Mid Stent
- Distal Stent
- Native Artery at the Distal End of the Stent

# Stent Re-stenosis

| % Stenosis | PSV (cm/s) | EDV (cm/s) | Ratio |
|---|---|---|---|
| 50 - 69 | 175 – 299 | | |
| ≥ 70 | ≥ 300 | ≥ 140 | 4.0 |

Setacci C, et al., Stroke, 2008;39;1189-96

# Gain and Other Options
## (to Compensate for Attenuation)

- Optimize Scan Plane*
  - Big Picture
  - Small Picture
- Optimize Focus
- Optimize Overall Gain
  - & TGC
- Experiment with Compression
- Optimize Frequency
  - Resolution/Penetration
  - Change Transducer
- Power (ALARA)
- Don’t forget the monitor