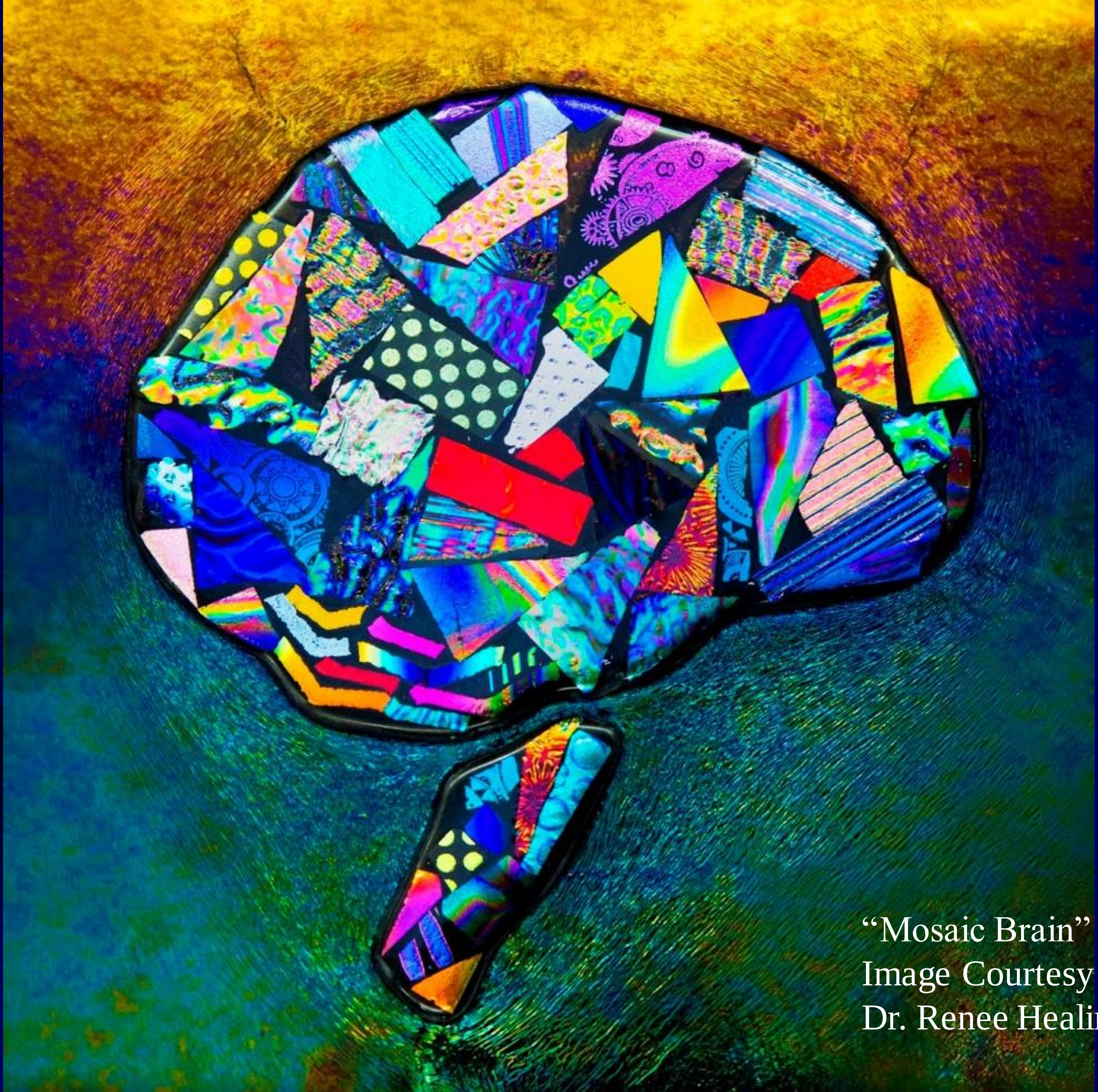
Carotid Ultrasound

Applied Principles and Physics, and Foundation for Interpretation

Charles H. Tegeler, MD
Professor and Chair, Department of Neurology
McKinney-Avant Chair in Neurosonology
Director, Ward A. Riley Ultrasound Center
Medical Director, Neurosonology Lab
Wake Forest School of Medicine



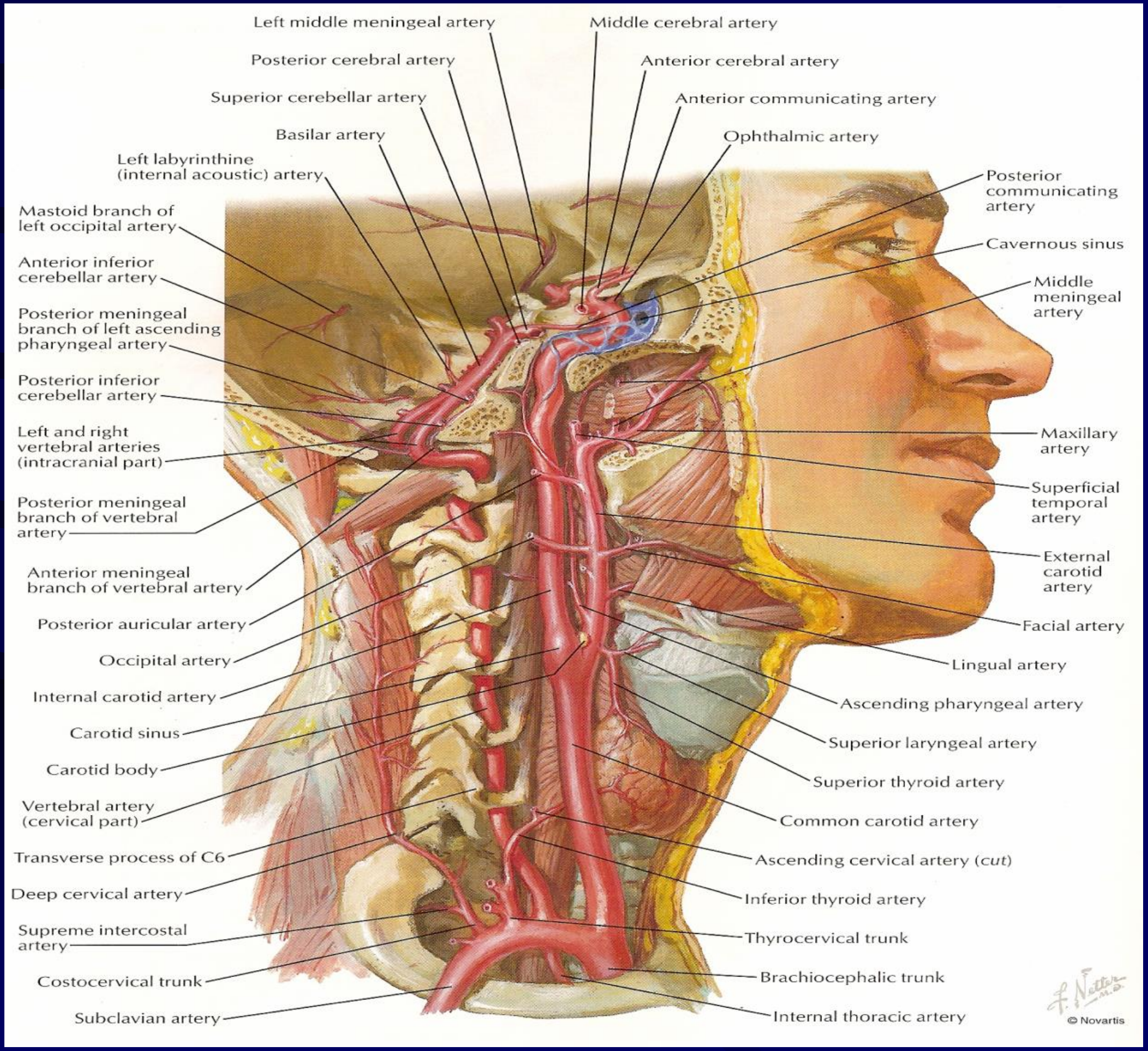
"Mosaic Brain"
Image Courtesy of
Dr. Renee Healing Art

Carotid Ultrasound
Applied Principles and Physics, and Foundation for Interpretation

- Doppler
- B-mode
- Color flow

Disclosures/Conflicts: None

Key Anatomy/Structures



Sound

- Sound is a wave: Propagating variations in acoustic variables of pressure, density, particle motion and temperature
  - Waves transmit energy from one place to another
  - Sound waves require a medium to travel through - Sound cannot pass through a vacuum

Describing a Wave

Terms to Understand

- Frequency
- Wavelength
- Period
- Amplitude
- Intensity
- Propagation Speed

Frequency

- The number of complete cycles (variations) in one second
- Expressed in hertz (Hz) and megahertz (MHz)
- Human hearing: 20Hz to 20 kHz

< 20 Hz = infrasound

> 20 kHZ = ULTRASOUND

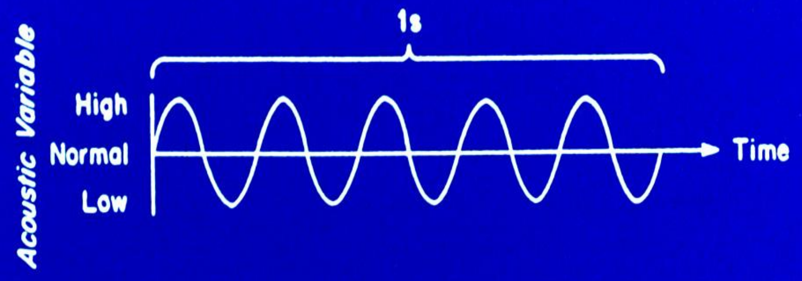


Figure 2.2. Frequency is the number of complete variations (cycles) that an acoustic variable goes through in 1 s. In this figure, five cycles occur each second; the frequency is five complete variations per second, or 5 Hz.

Relationship between Frequency and Wavelength

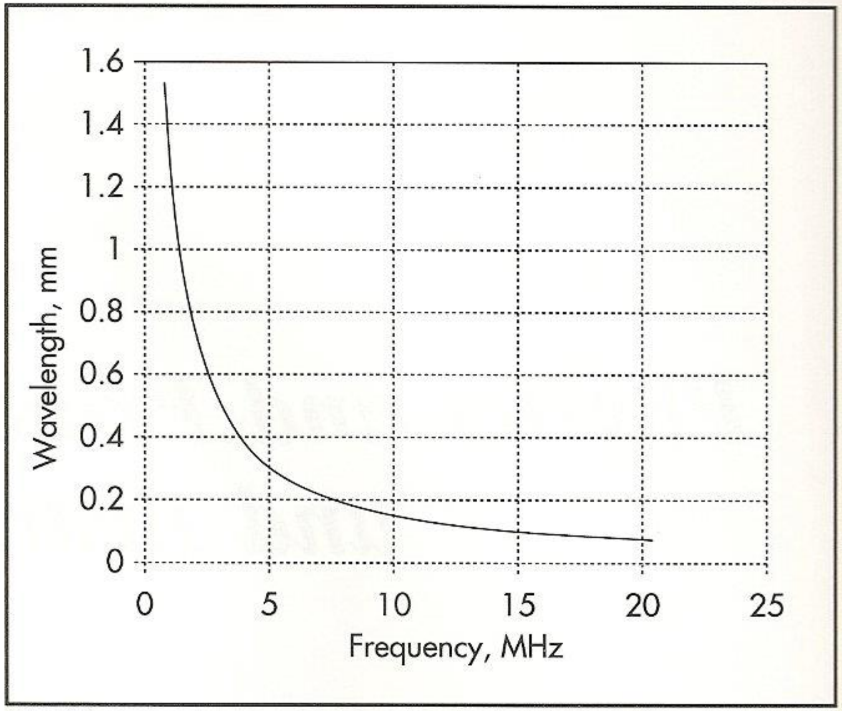


Fig. 1-1. The wavelength of ultrasound decreases as the transducer frequency increases. This graph shows the inverse relationship between wavelength and frequency in soft tissue, where the average propagation speed is assumed to be 1540 m/s.

Riley WA, Neurosonology

Propagation Speed

- Speed of the sound wave as it travels
  - Independent of the frequency and amplitude of the wave and determined by the stiffness and density of the medium
  - In general, sound travels slowest in gaseous media, faster in liquid, and fastest in solids.
- Average speed of sound in soft tissues is 1540m/s or 1.54mm/μs
  - Speed of sound in air = 330m/s

Pulse Echo Principle

Range Equation allows determination of depth of echo: depth = prop speed x time / 2

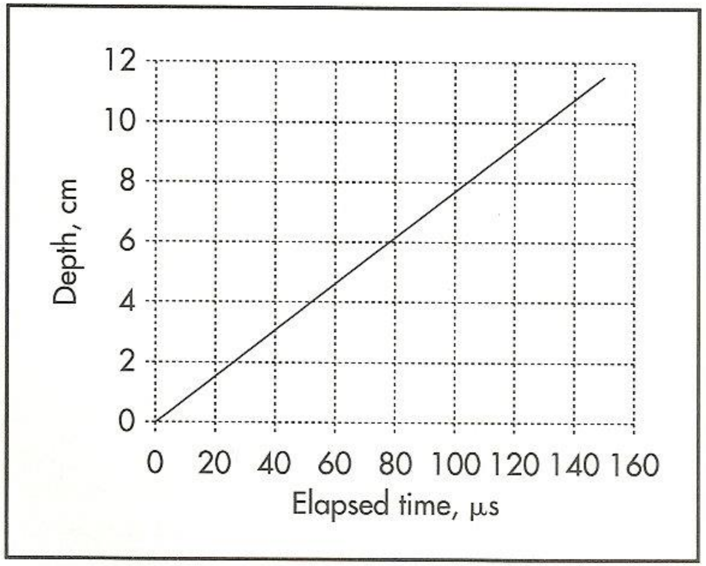


Fig. 1-3. The pulse-echo principle permits the depth (distance of a tissue boundary from the transducer) to be computed if the elapsed time from transmission to reception of the echo is measured. This graph shows the depth computed for different elapsed times, assuming a value for the average ultrasound propagation speed in soft tissue of 1540 m/s. For example, if the elapsed time for a boundary is approximately 80 μs, the depth is computed to be 6.2 cm and the boundary is assumed to be located 6.2 cm from the transducer.

1.54 mm/microsecond (13 microseconds per cm for round trip)

Transmission/Reflection Scattering

- Reflection occurs at smooth interfaces (rare in living tissues)
- Scattering/transmission depends on difference in acoustic impedance
- Can be physiological interface, as with boundary layer separation in flowing blood
- Beam is bent/refracted if not perpendicular

Ultrasound Interaction at Interfaces
Reflection, Transmission, Refraction, Scattering

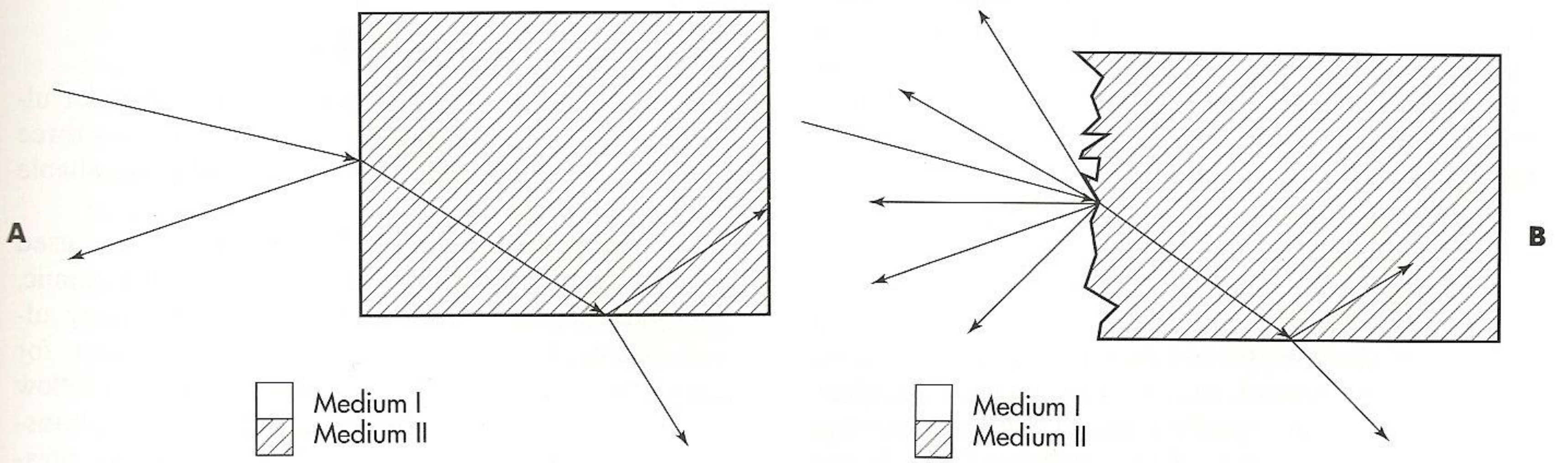


Fig. 2-2. Transmission, reflection, scattering. **A,** An ultrasound beam at a regular interface between two media will be partly transmitted and reflected at the same angle of incidence. **B,** At an irregular interface, the beam will be partly transmitted and scattered.

Riley WA, Neurosonology

Attenuation

- Intensity of an ultrasound beam decreases as it travels through tissue as a result of reflection, scattering and absorption (the most important cause of attenuation)

  Attenuation = 1/2 x path length x f (MHz)

- Decibels are the units of attenuation.

  There is ~ 1/2 dB attenuation/cm/MHz

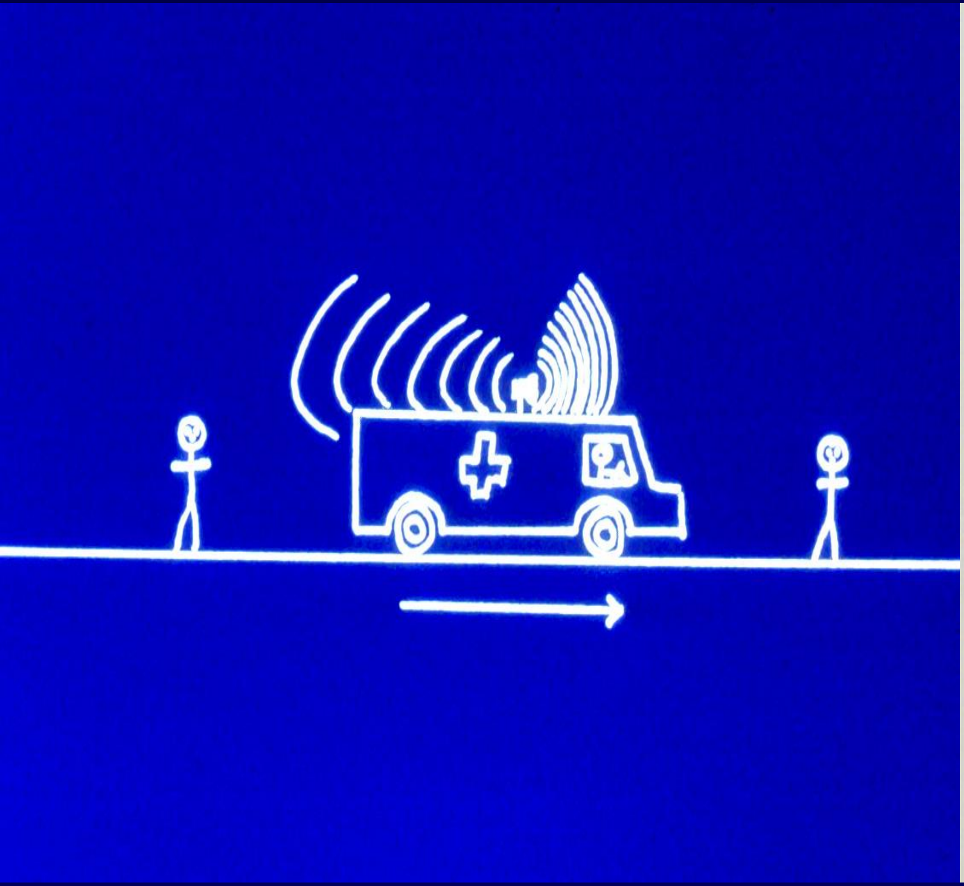
Ultrasound Transducers

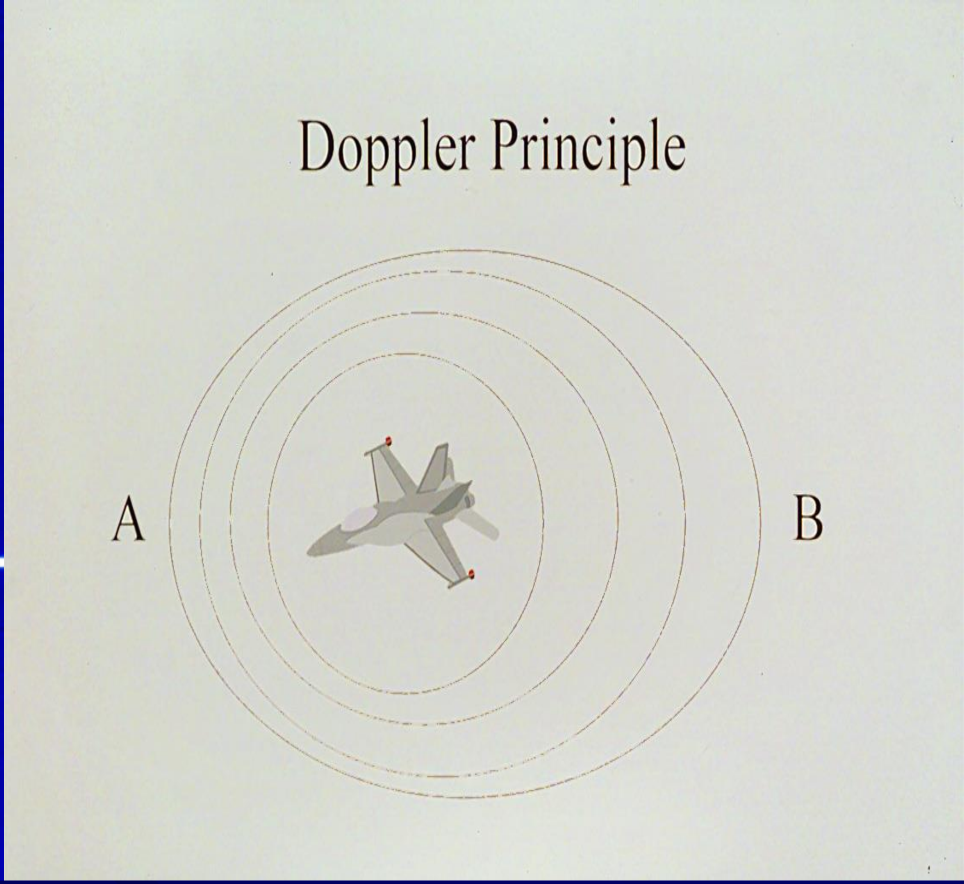
- Devices which produce ultrasound via the piezoelectric effect
  - Electrical energy causes the crystal or ceramic material to contract and expand, creating a sound wave
  - Sound energy received by the transducer makes the crystal vibrate, which can then create an electrical current to be analyzed

Doppler Principle

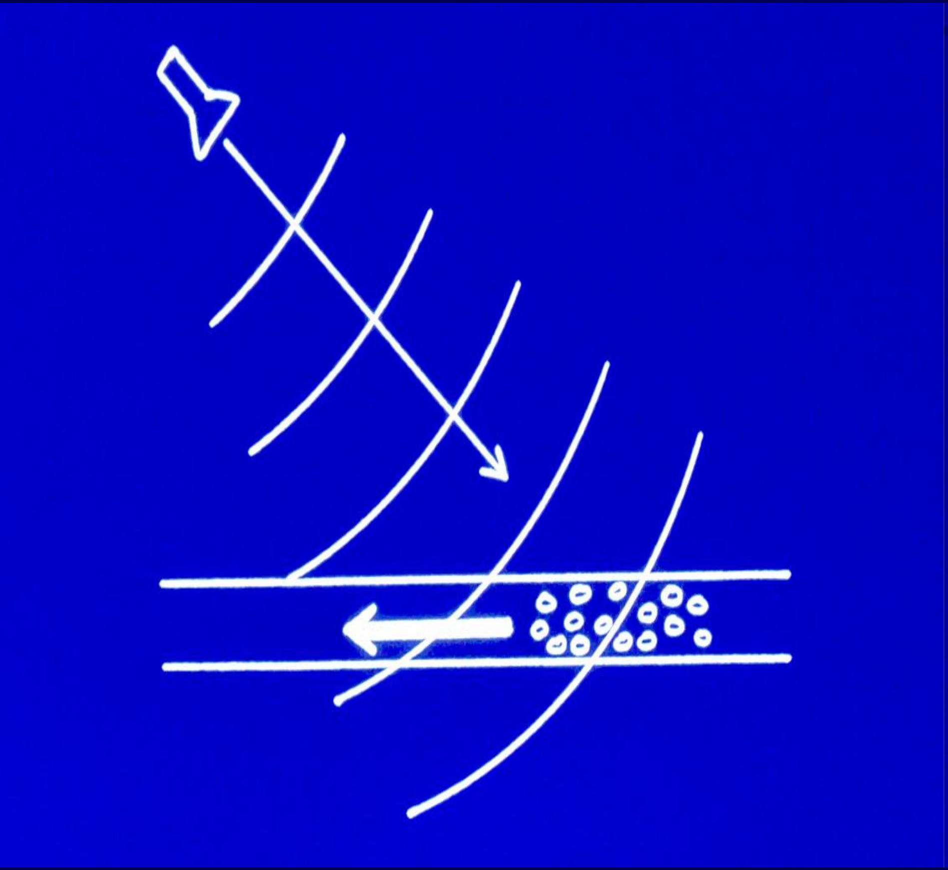
- Christian Andreas Doppler – 1842 – described basis for color shifts in double stars
- Change in echo frequency produced by a moving reflector is called the Doppler shift
  Doppler shift = reflected frequency - transmitted frequency
  - Directly related to the speed of the reflector/scatterer and the transmitted frequency
  - Inversely related to the angle of insonation

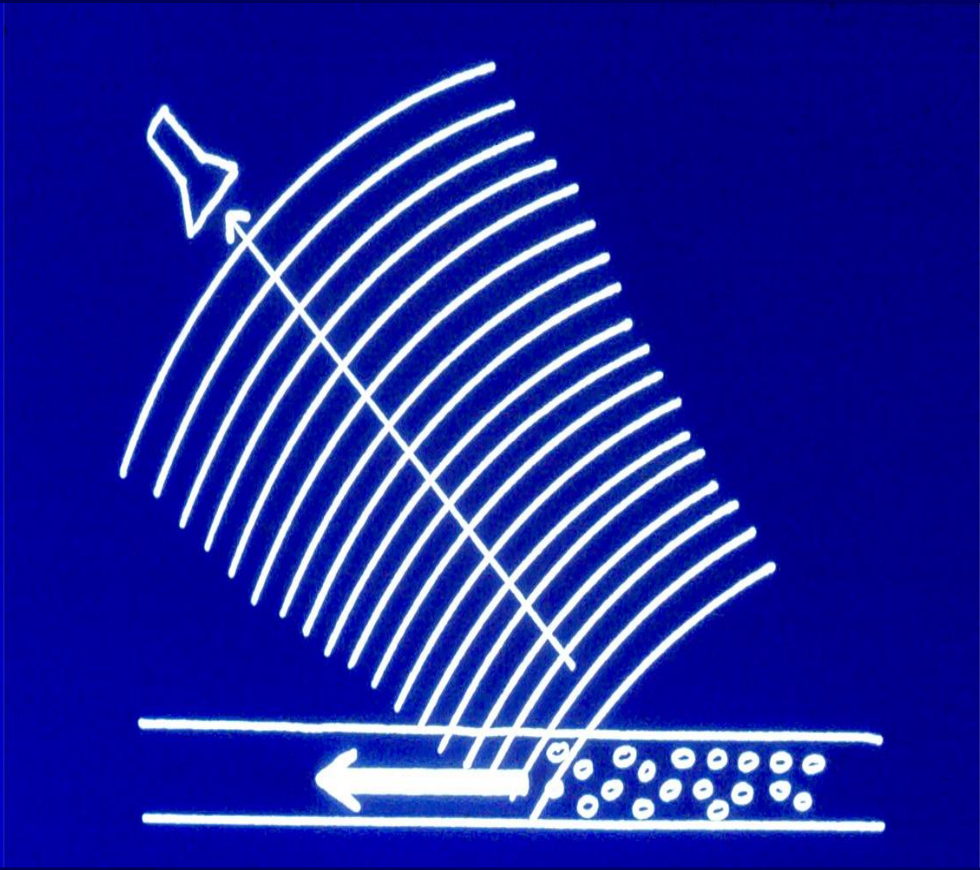
Doppler Principle





Vascular Doppler



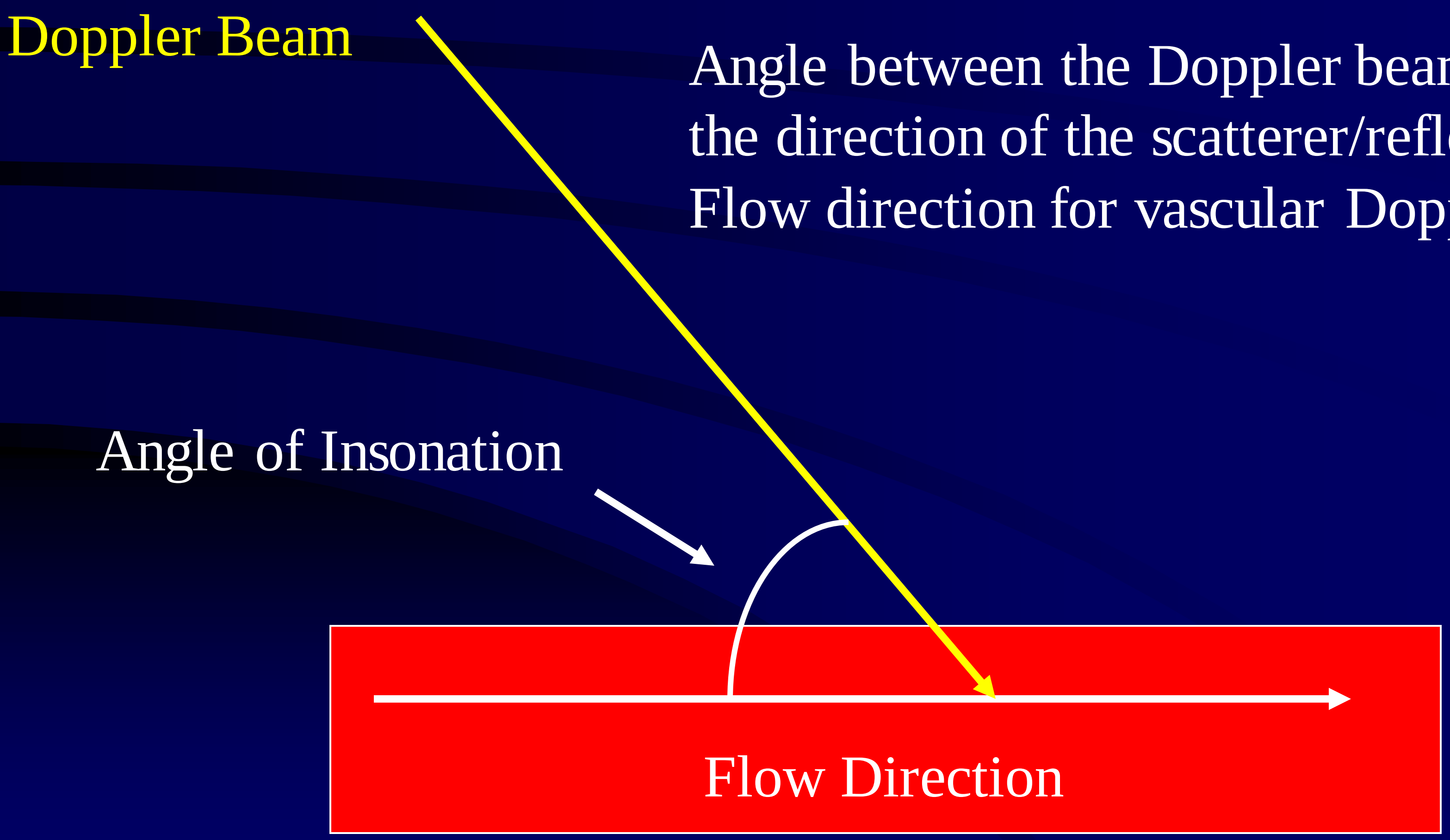


Vascular Doppler

- Blood cells/components act as moving scatterers (reflectors)
- Imparts frequency shift to scattered Doppler beam (higher or lower)
- Instrument can determine magnitude of Doppler shift in cycles/sec (Hz)
- With AOI can get velocity (cm/s)
- Provides a common language across labs/instruments

Doppler Angle of Insonation

Angle between the Doppler beam and the direction of the scatterer/reflecter; Flow direction for vascular Doppler

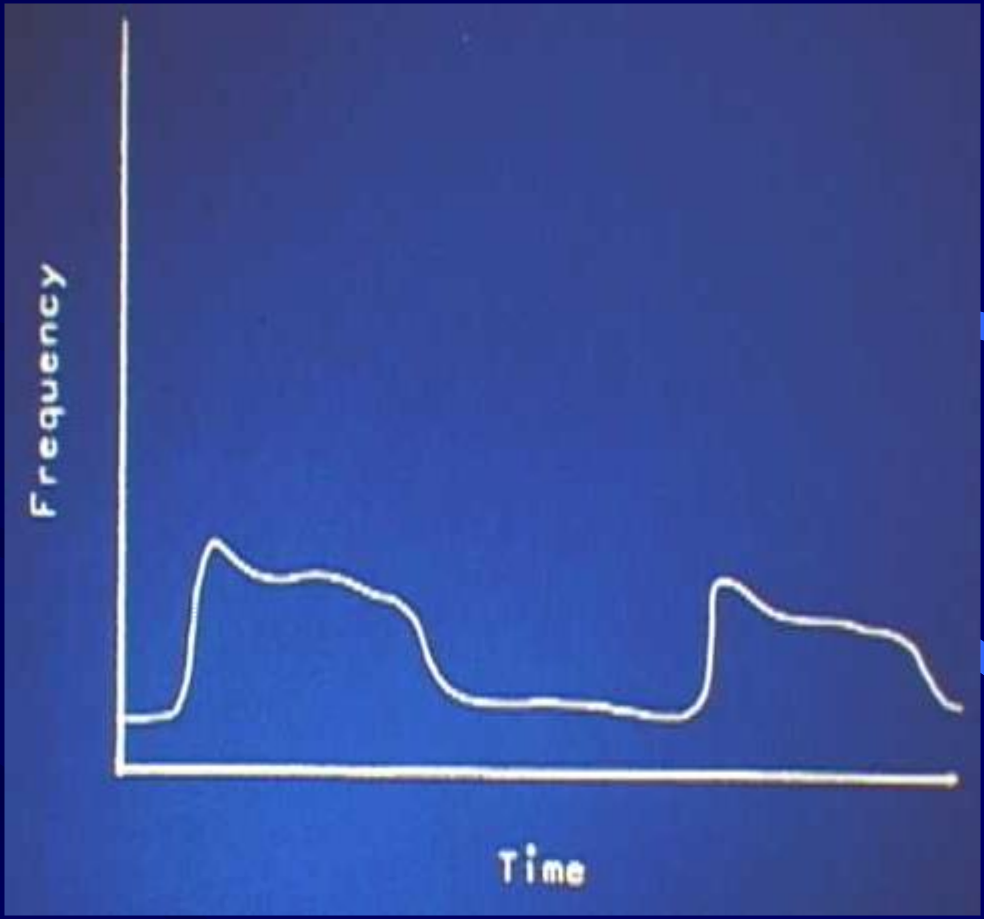


Pulsed Wave Doppler

- A transducer emits short pulses of sound at a fixed rate (PRF) and then waits for the echo before emitting the next pulse
- “Range-gate” to sample at specific depths
- Distance = Speed X Total Time/2
- To accurately evaluate the Doppler shift of the echoes accurately, there must be at least 2 pulses for each cycle of the Doppler Frequency Shift

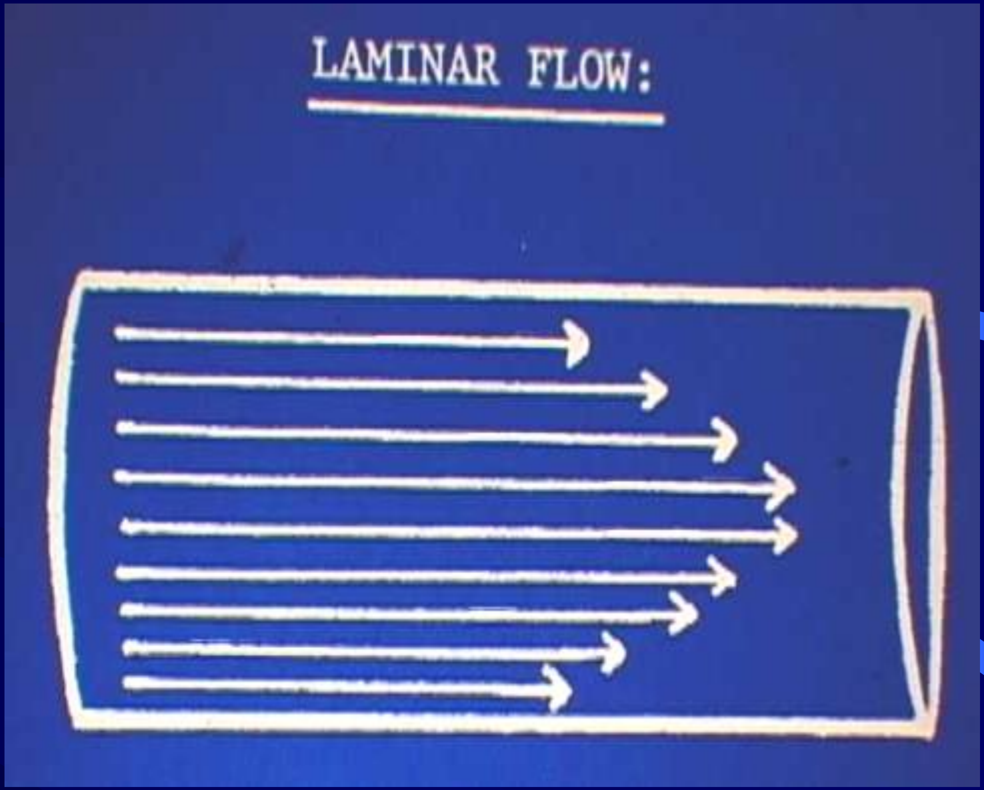
Doppler Spectral Analysis

- Higher frequency shift/velocity in systole; lower diastole
- If plug flow, or single giant red cell would see single tracing over cardiac cycle



Doppler Spectral Analysis

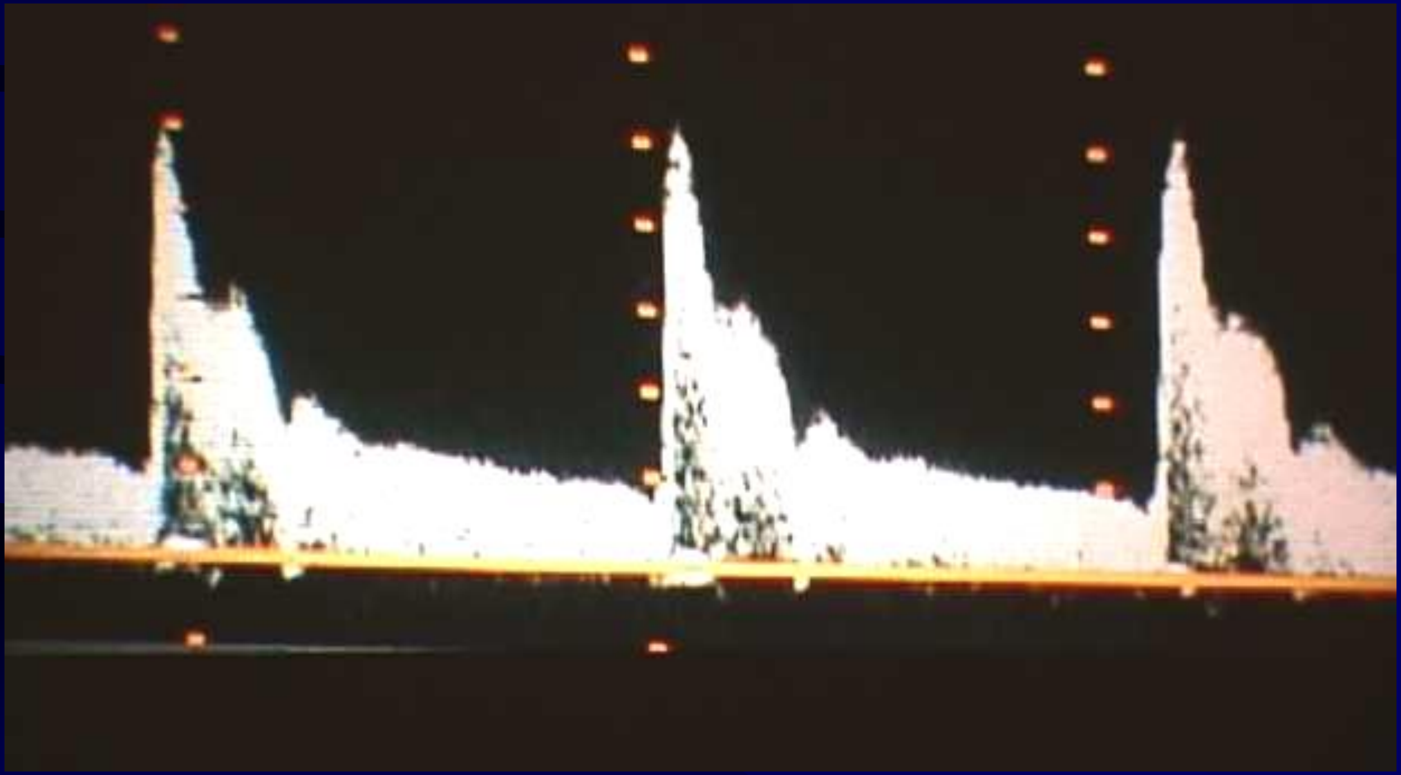
- Normal vessels have laminar flow
- Multiple speeds & directions of flow in any sample volume



Doppler Spectral Analysis

- At any point in time, there is a spectrum of different speeds and directions of flows (frequency shifts or velocities)

Doppler Spectral Analysis
FFT Spectral Display

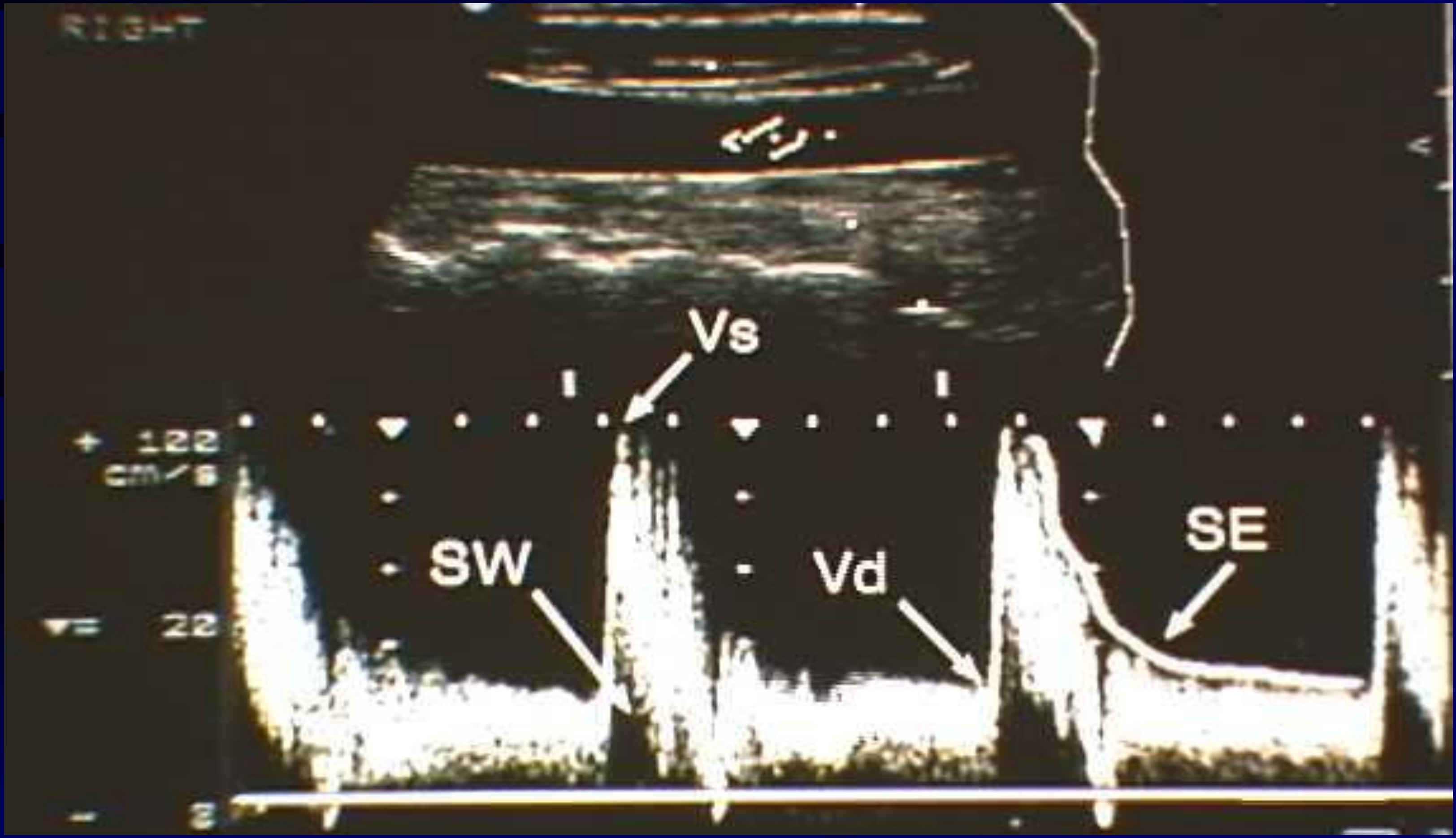


Vascular Doppler
Spectral Analysis Parameters

- Flow direction
- Peak systolic velocity
- End-diastolic velocity
- Spectral pattern (vessel fingerprint)
- Spectral broadening

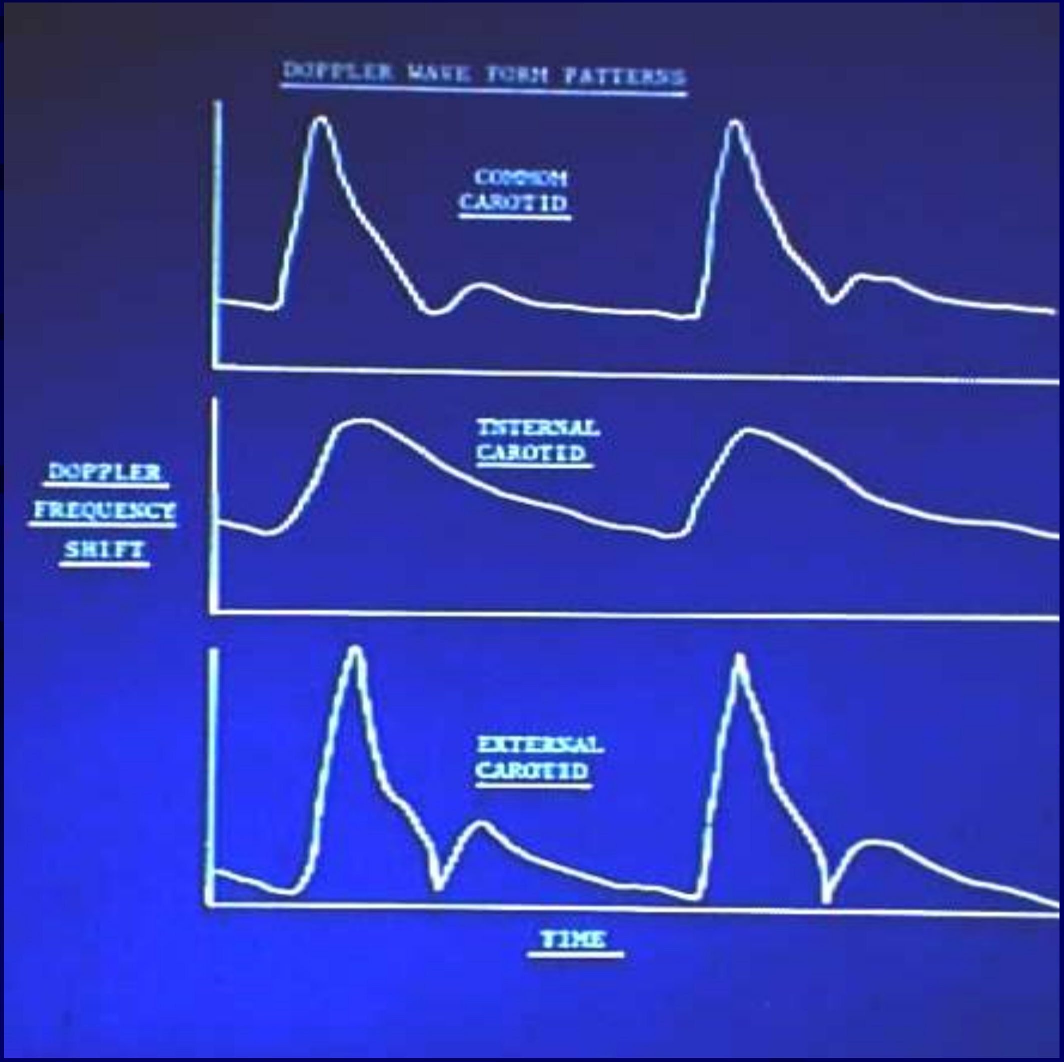
Doppler Spectral Analysis

Parameters

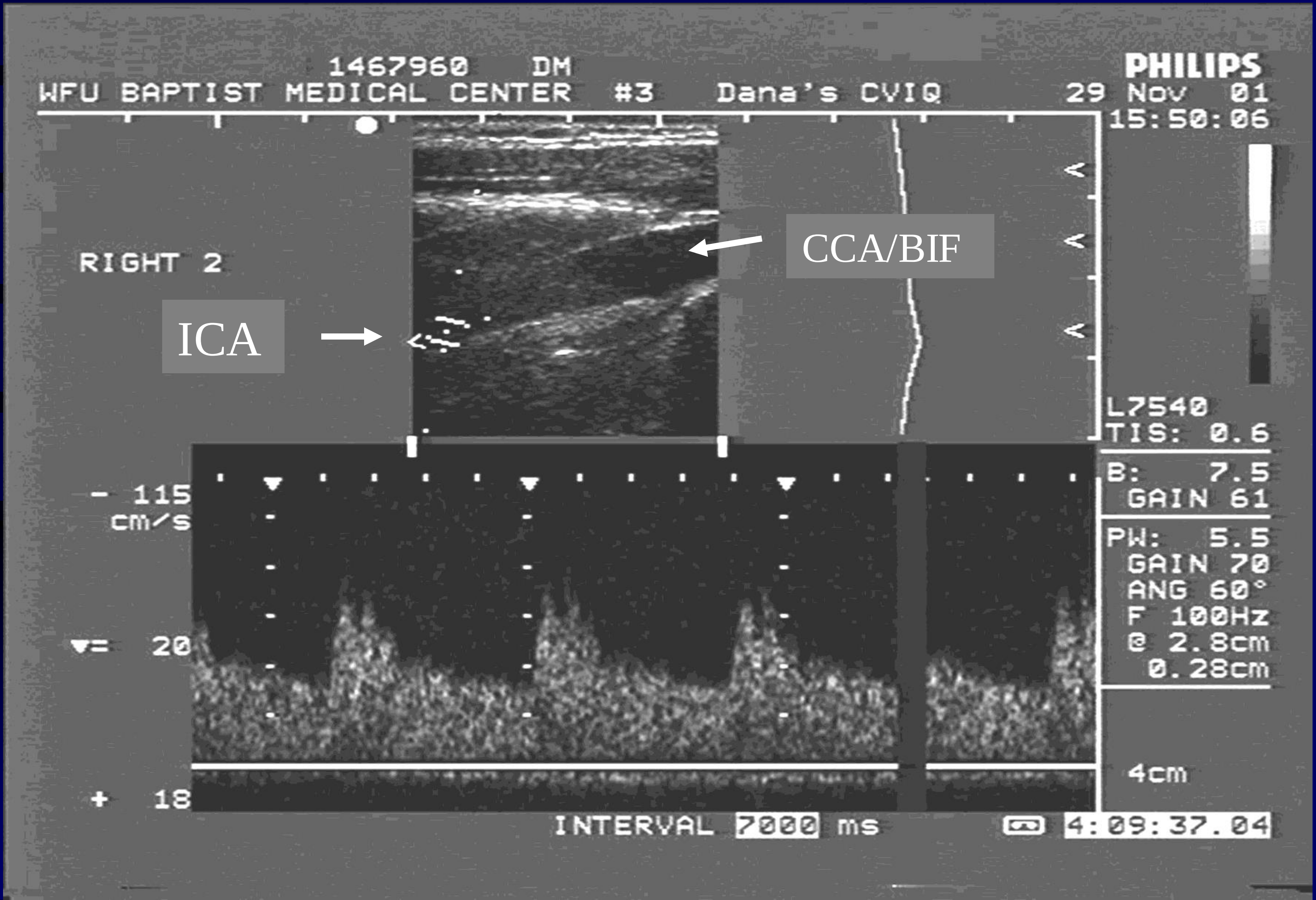


Doppler Spectral Analysis

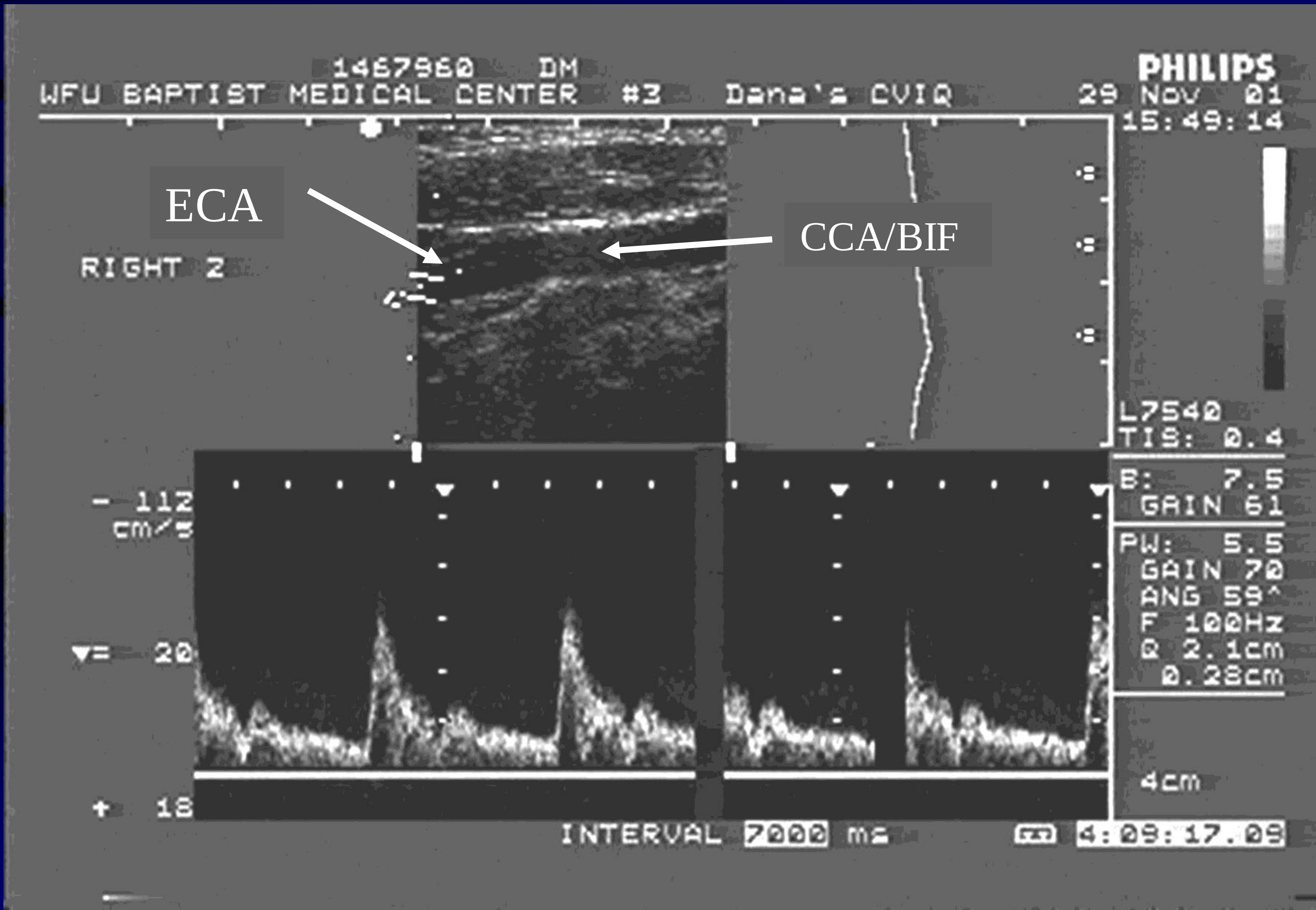
Spectral Fingerprints

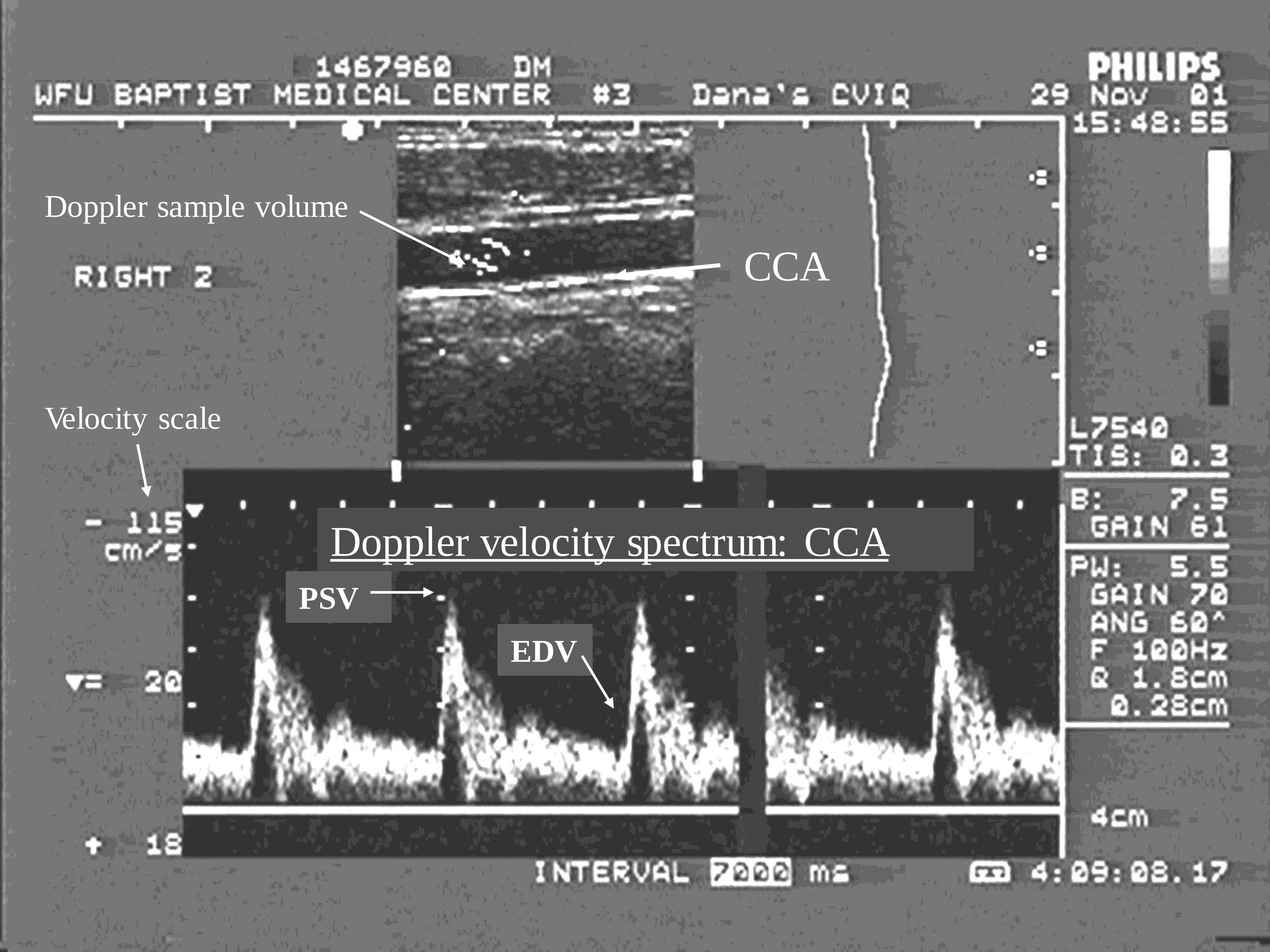


Doppler Velocity Spectrum: ICA



Doppler Velocity Spectrum: ECA

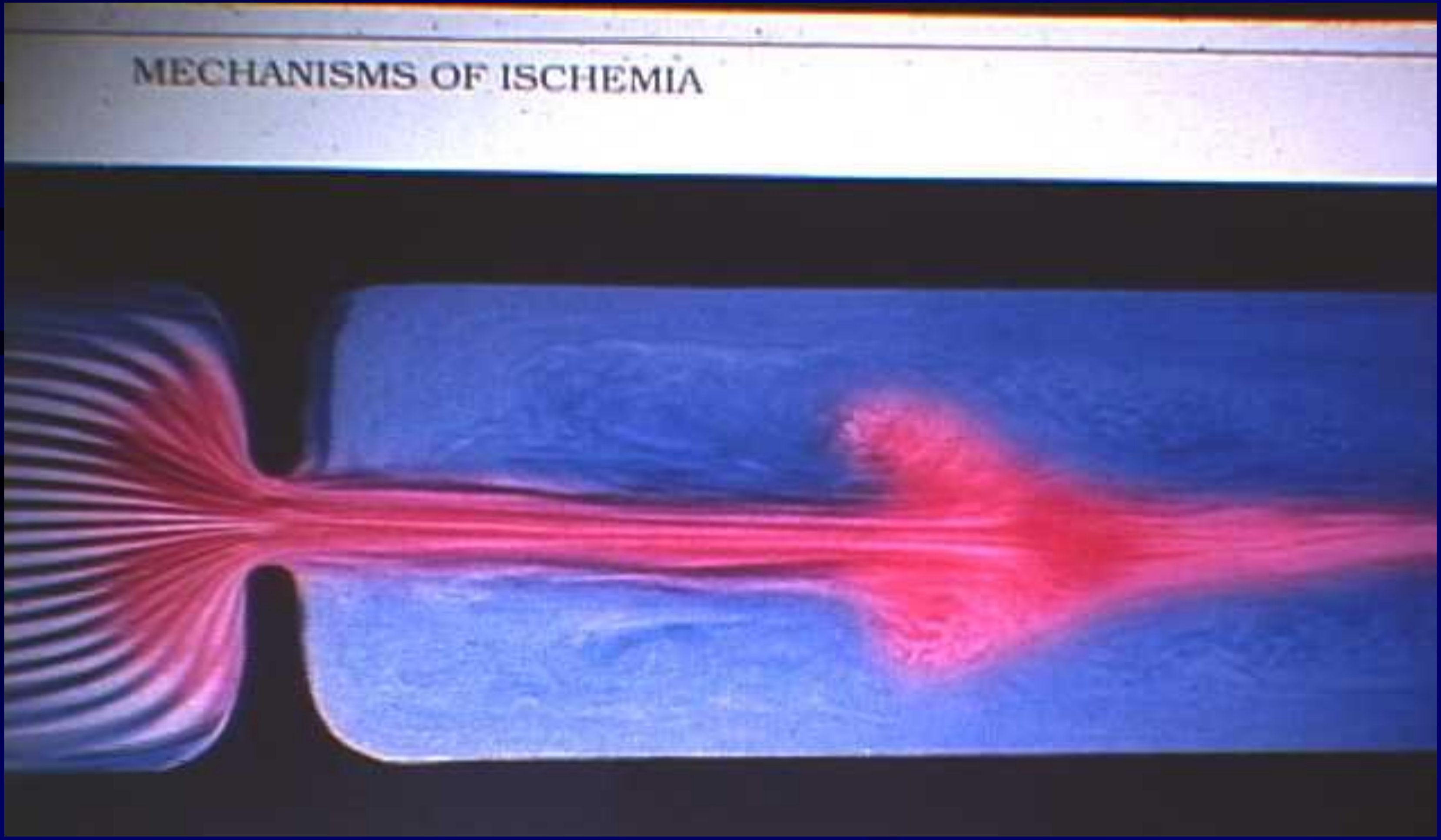



1467960 DM
WFU BAPTIST MEDICAL CENTER #3 Dana's CVIQ
PHILIPS
29 NOV 01
15:48:55
Doppler sample volume
RIGHT 2
CCA
Velocity scale
- 115
cm/s
Doppler velocity spectrum: CCA
PSV
EDV
▼= 20
+ 18
L7540
TIS: 0.3
B: 7.5
GAIN 61
PW: 5.5
GAIN 70
ANG 60^
F 100Hz
@ 1.8cm
0.28cm
4cm
INTERVAL 7000 ms
4:09:08.17

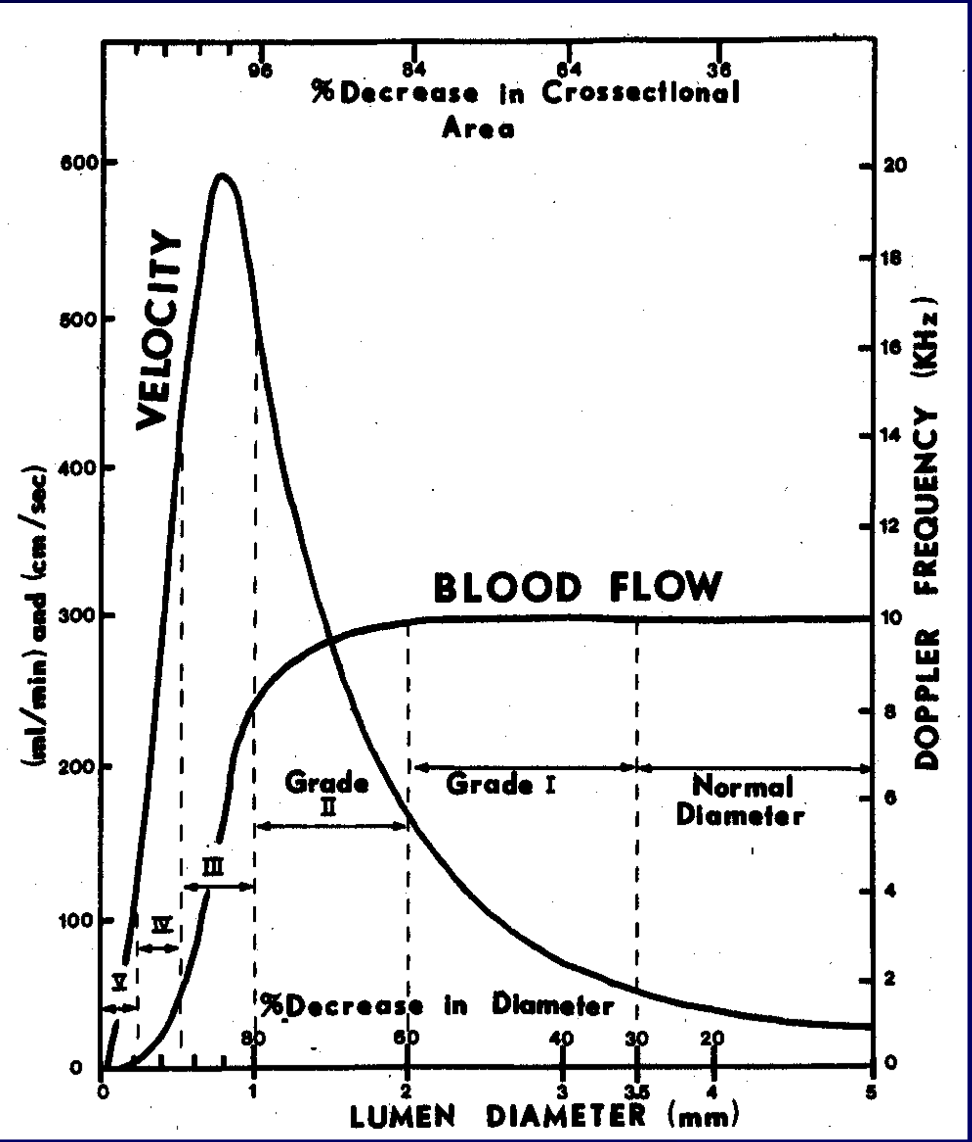
Hemodynamic Principles
Key Factors Affecting Flow

- Pressure difference
- Resistance
  - Tube/stenosis length
  - Fluid viscosity
  - Radius (residual lumen) – Changes have exponential effect – 4th power
- Brain tries to maintain flow

Hemodynamic Effect Of Stenosis

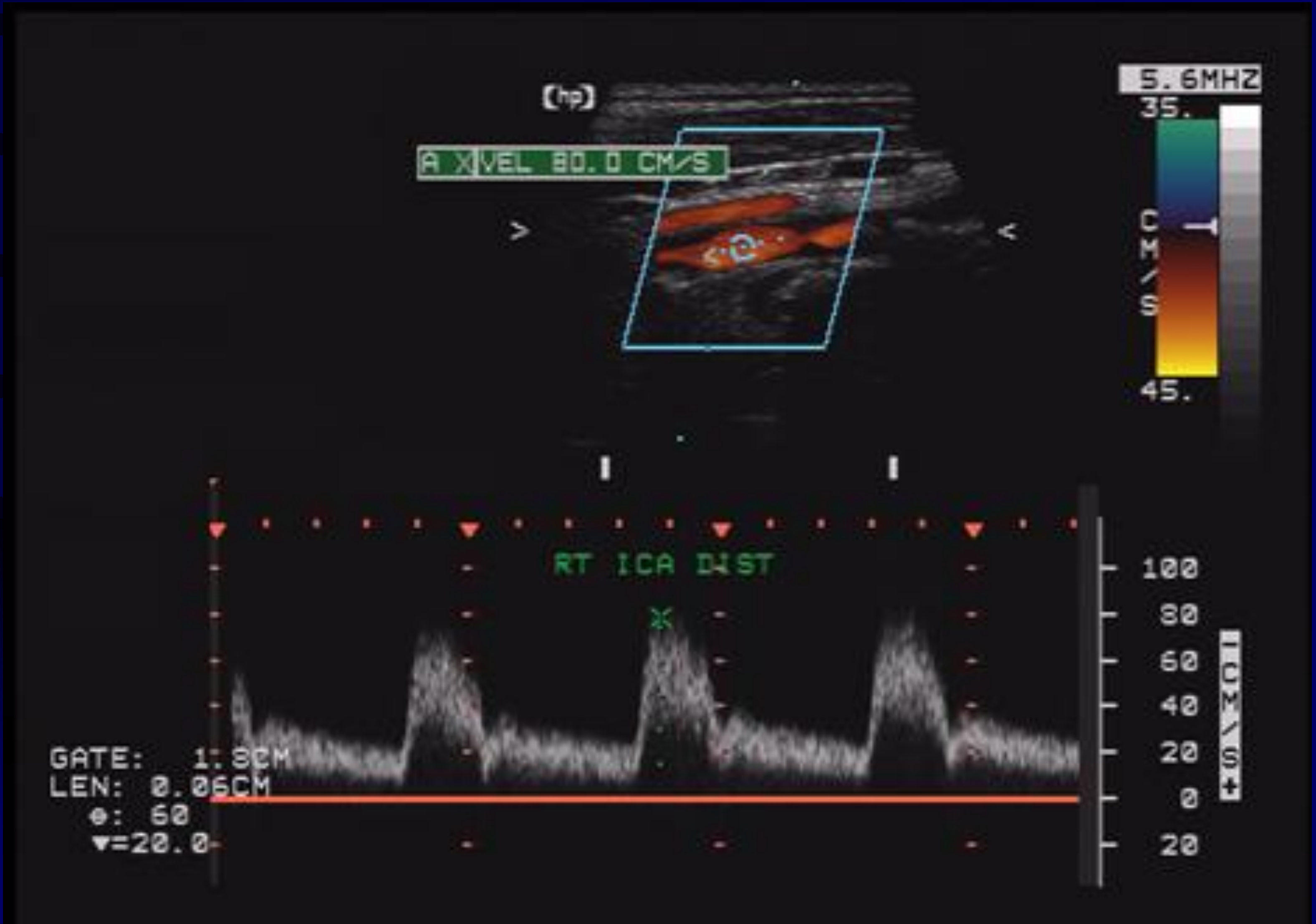


Hemodynamic Effect of Stenosis



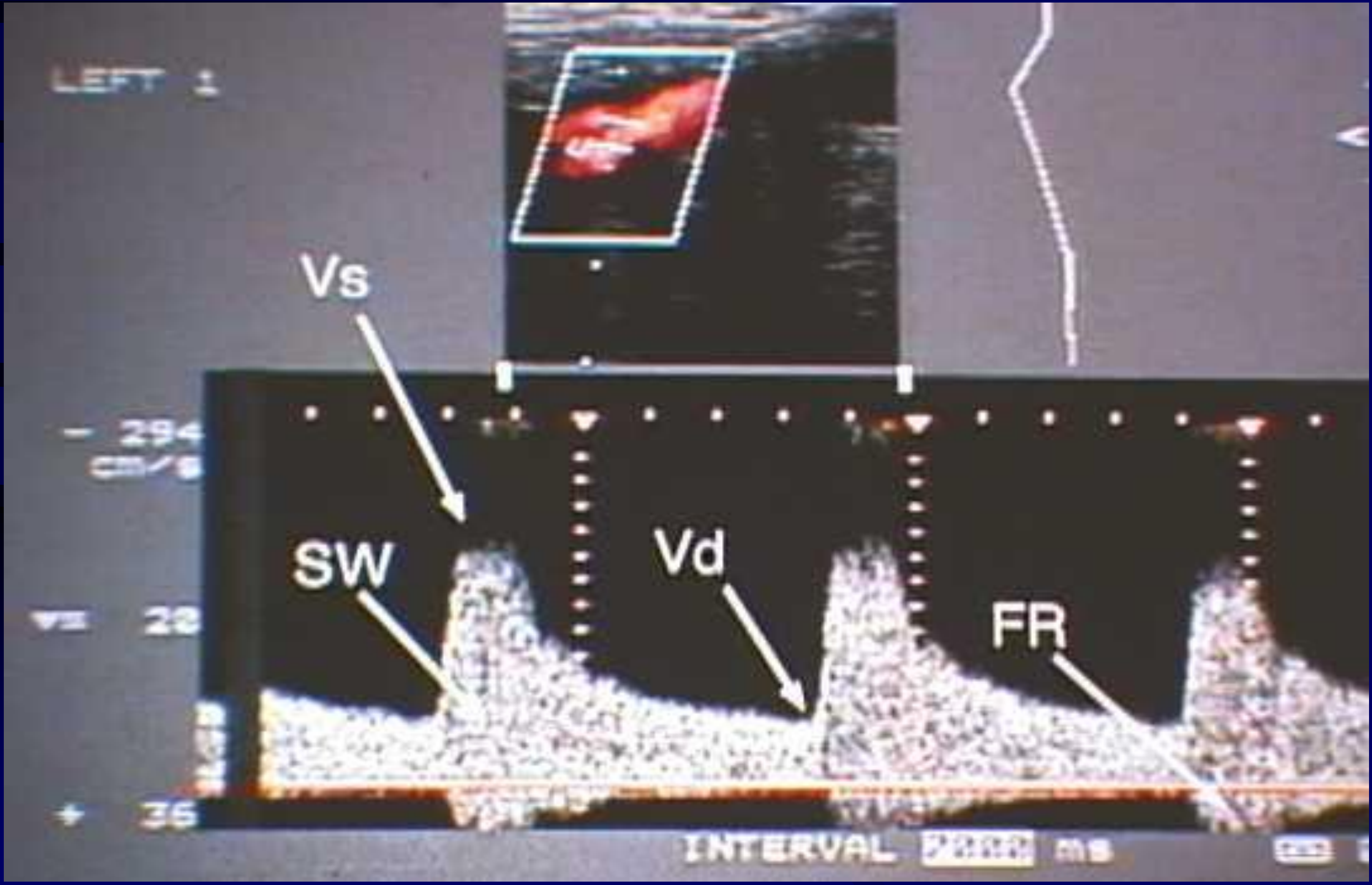
Doppler Velocity Spectral Analysis

Normal ICA Velocity



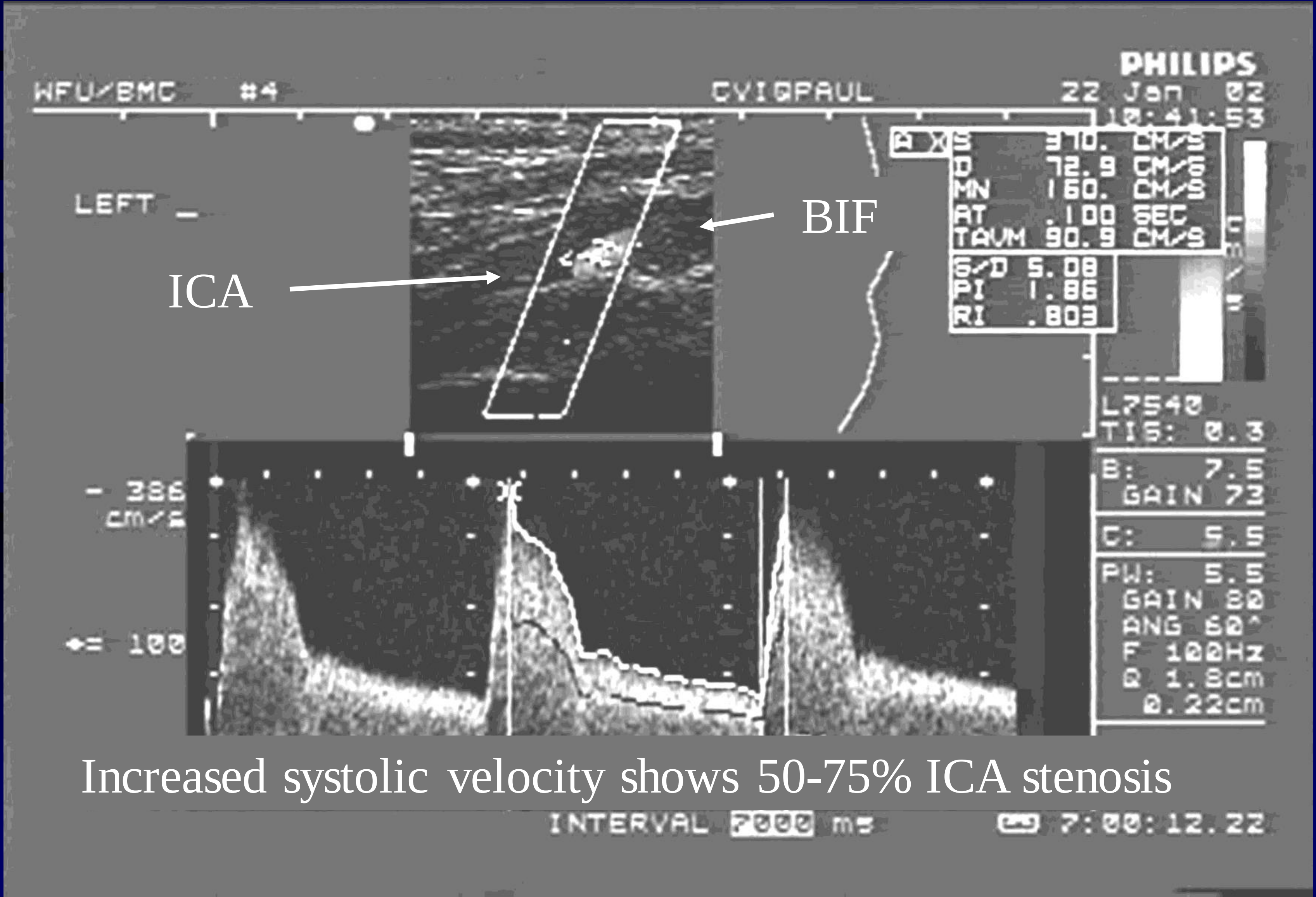
Doppler Spectral Analysis

Changes with Moderate Stenosis



Doppler Spectral Analysis

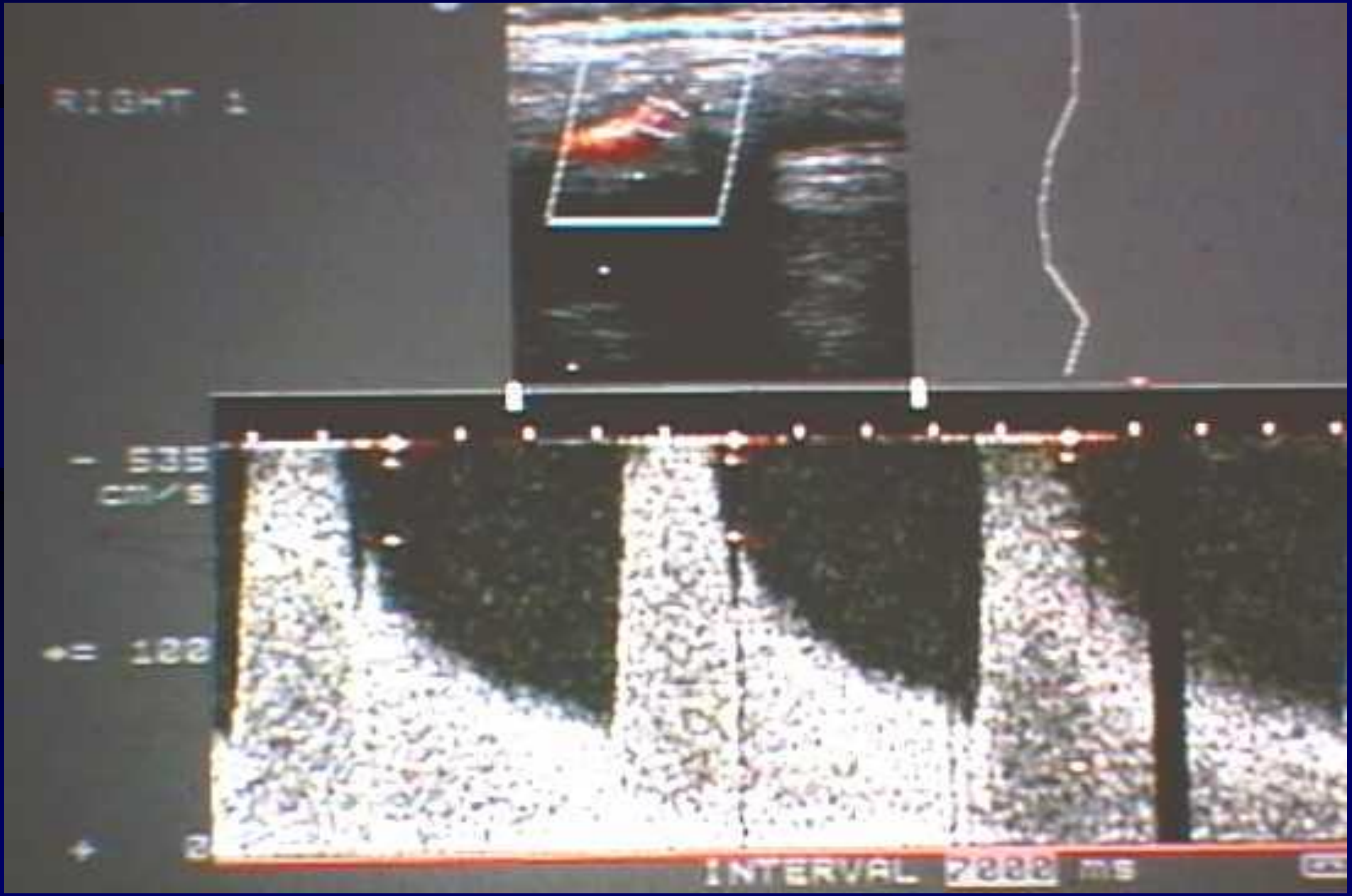
Moderate Stenosis



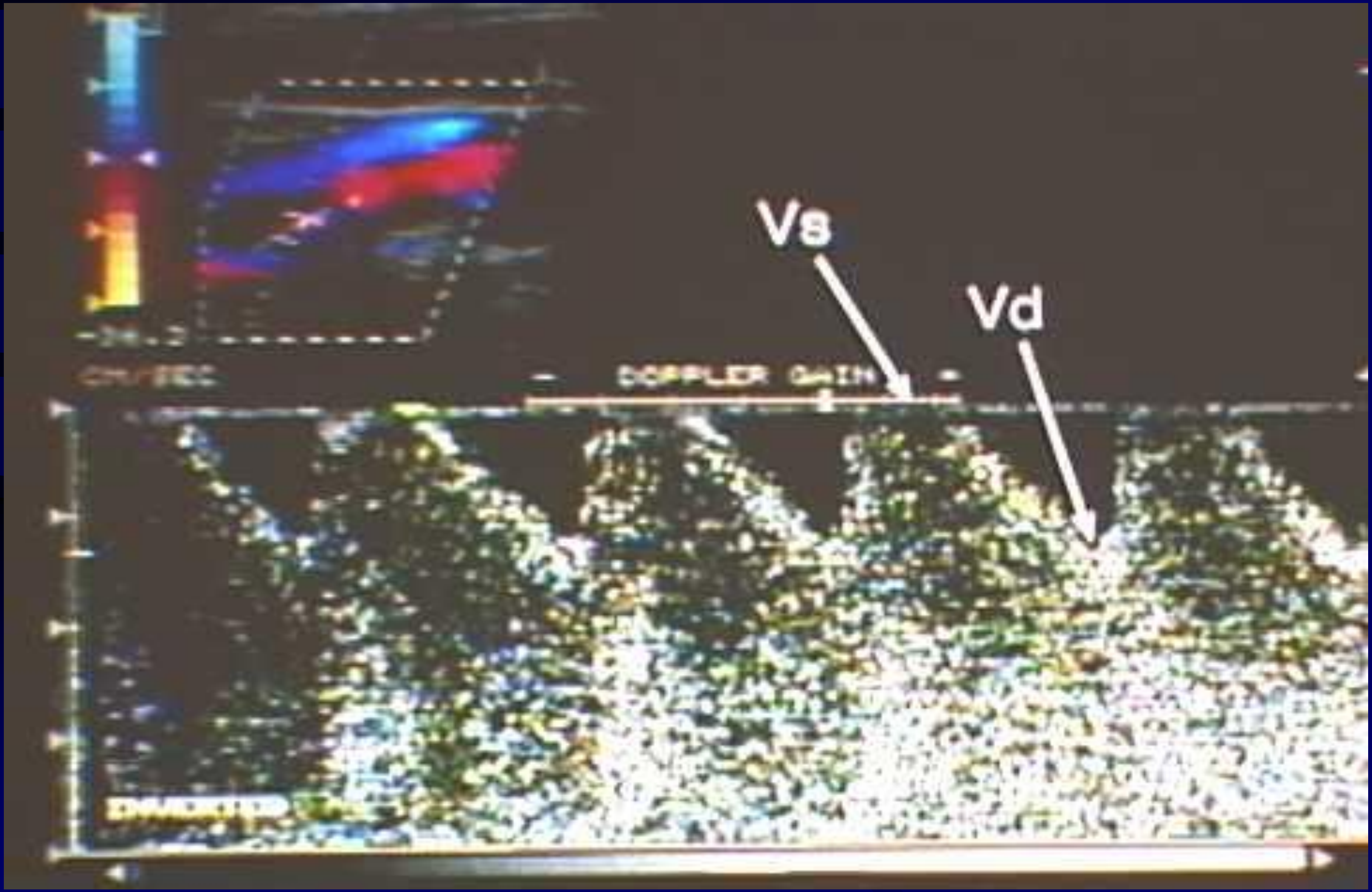
Increased systolic velocity shows 50-75% ICA stenosis

Doppler Spectral Analysis

Severe Stenosis

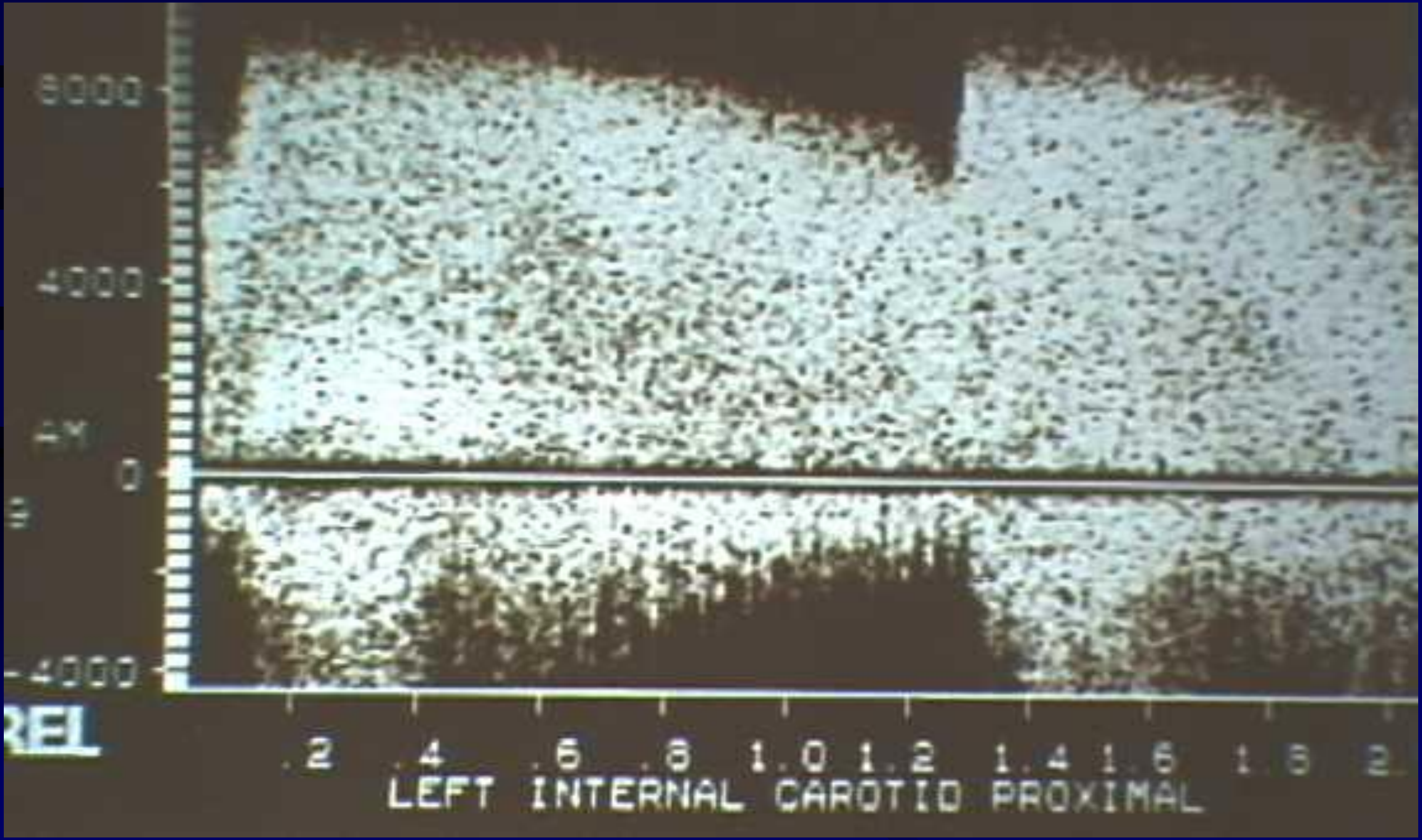


Doppler Spectral Analysis
Severe Stenosis/Near Occlusion



Doppler Spectral Analysis

Severe Stenosis/Near Occlusion



Vascular Doppler
Correlating with Stenosis

- Use velocity and spectral pattern to determine presence/severity of stenosis
- Many sets of criteria in literature
- All only estimate range of stenosis
- Criteria chosen depend on equipment/goals
- <u>Must be validated for your laboratory</u>

Consensus Panel ICA Stenosis Criteria

	Primary	Parameters	Secondary	Parameters
% Stenosis	ICA PSV (cm/s)	Plaque % estimate	ICA/CCA PSV Ratio	ICA EDV (cm/s)
Normal	<125	None	<2.0	<40
<50	<125	<50	<2.0	<40
50-69	125-230	>50%	2.0-4.0	40-100
70-95	>230	>50	>4.0	>100
95-99	High, low, or none seen	Visible	Variable	Variable
Total occlusion	Undetectable	Visible, no lumen	N/A	N/A

Grant et al, 2003

Velocity Criteria at WFUSM

- PRIMARY CRITERIA
- Standard angle peak systolic velocity
- End-diastolic velocity
- SECONDARY PARAMETERS
- Spectral broadening/turbulence, ICA:CCA ratio, resistive pattern in CCA, side differences, extensive plaque on B-mode

Criteria for Carotid Stenosis

WFBMC

% Stenosis	PSV	EDV	ICA:CCA
< 50%	< 140 cm/s	< 40 cm/s	< 2.0
50-69%	> 140 cm/s	< 100 cm/s	2.0-4.0
70-99%	> 140 cm/s	> 100 cm/s	>4.0
Probable Occlusion	N/A	N/A	N/A

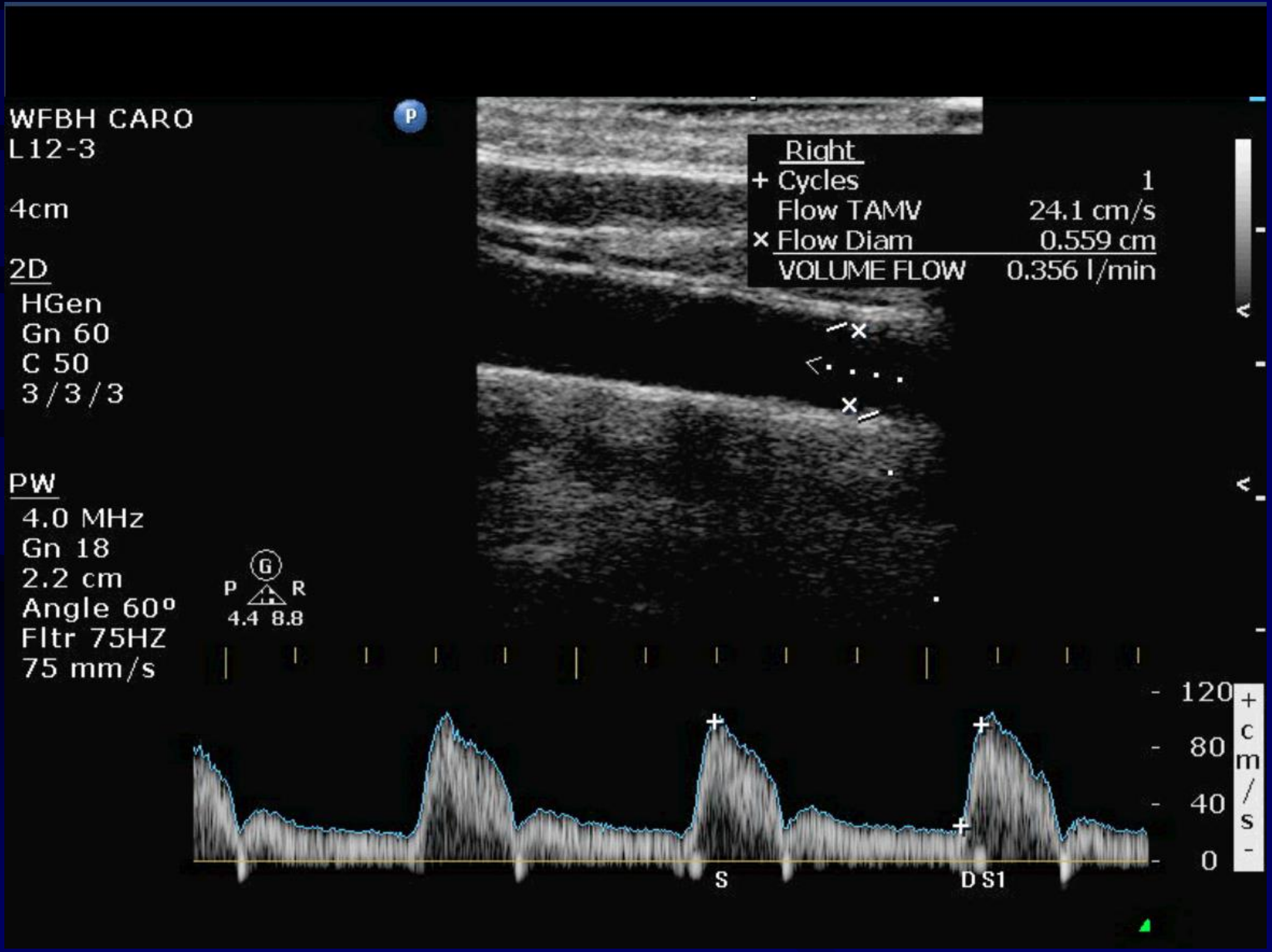
CREST – 2 Stenosis Criteria

Stenosis	Criteria
< 50%	PSV < 125 **OR** ICA/CCA < 2.0 **OR** EDV < 40
50-69%	PSV 125-230 **OR** ICA/CCA 2.0-4.0 **OR** EDV 40-100
≥70%	PSV > 230 + ICA/CCA > 4.0 **OR** PSV > 230 + EDV > 100
80-99%	PSV > 300 + ICA/CCA > 4.0 **OR** PSV > 300 + EDV > 140

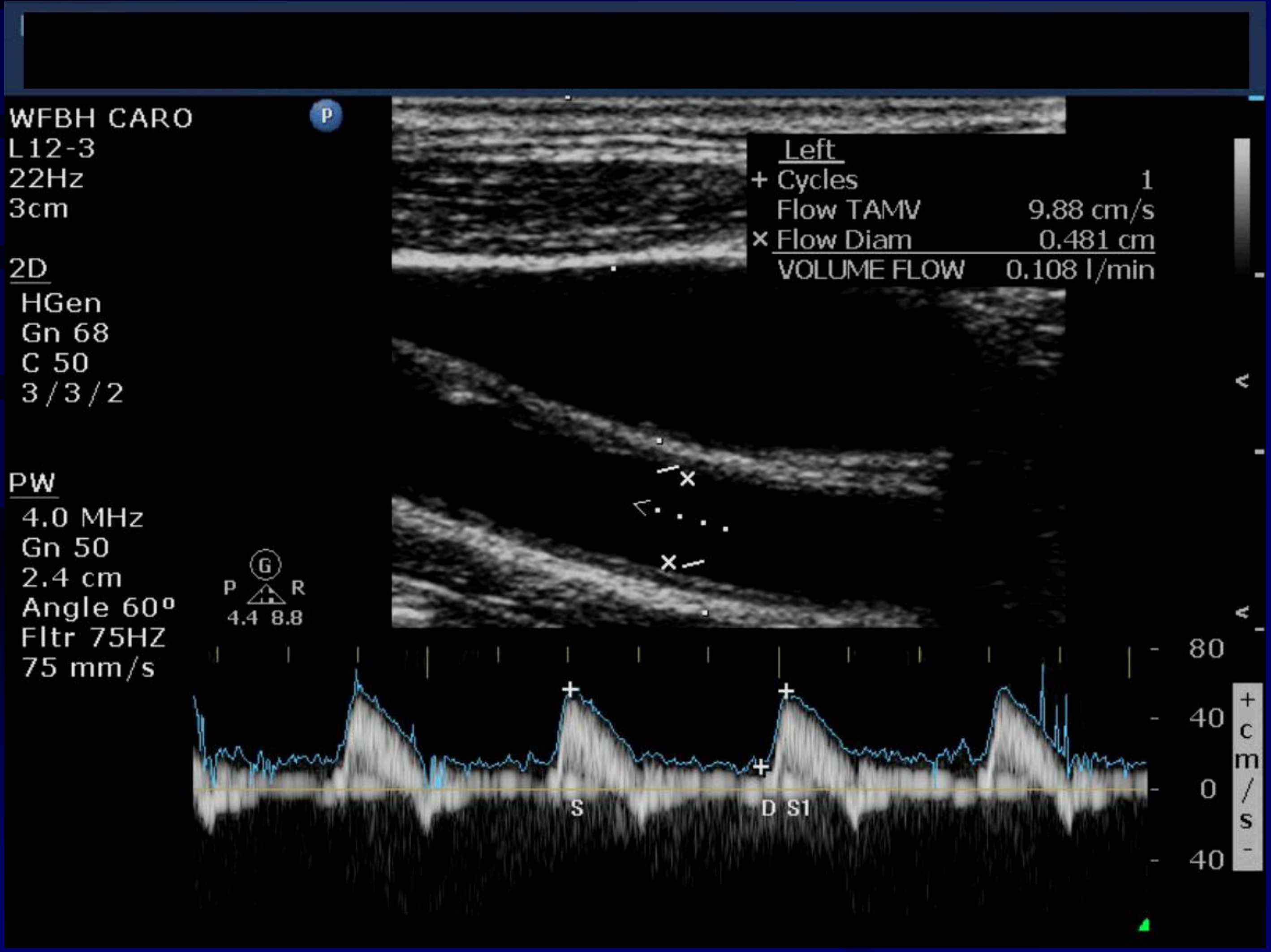
Velocity Criteria
Ratios

- Relationship between velocity at stenotic site and proximal or distal segments
- Higher stenosis, higher ratio
- Remains constant even if bad heart/pump so velocity not able to reach stenotic criteria
- ICA:CCA, ICA:Distal ICA validated
- Ratio can be systolic or diastolic velocity

Volume Flow Measurements

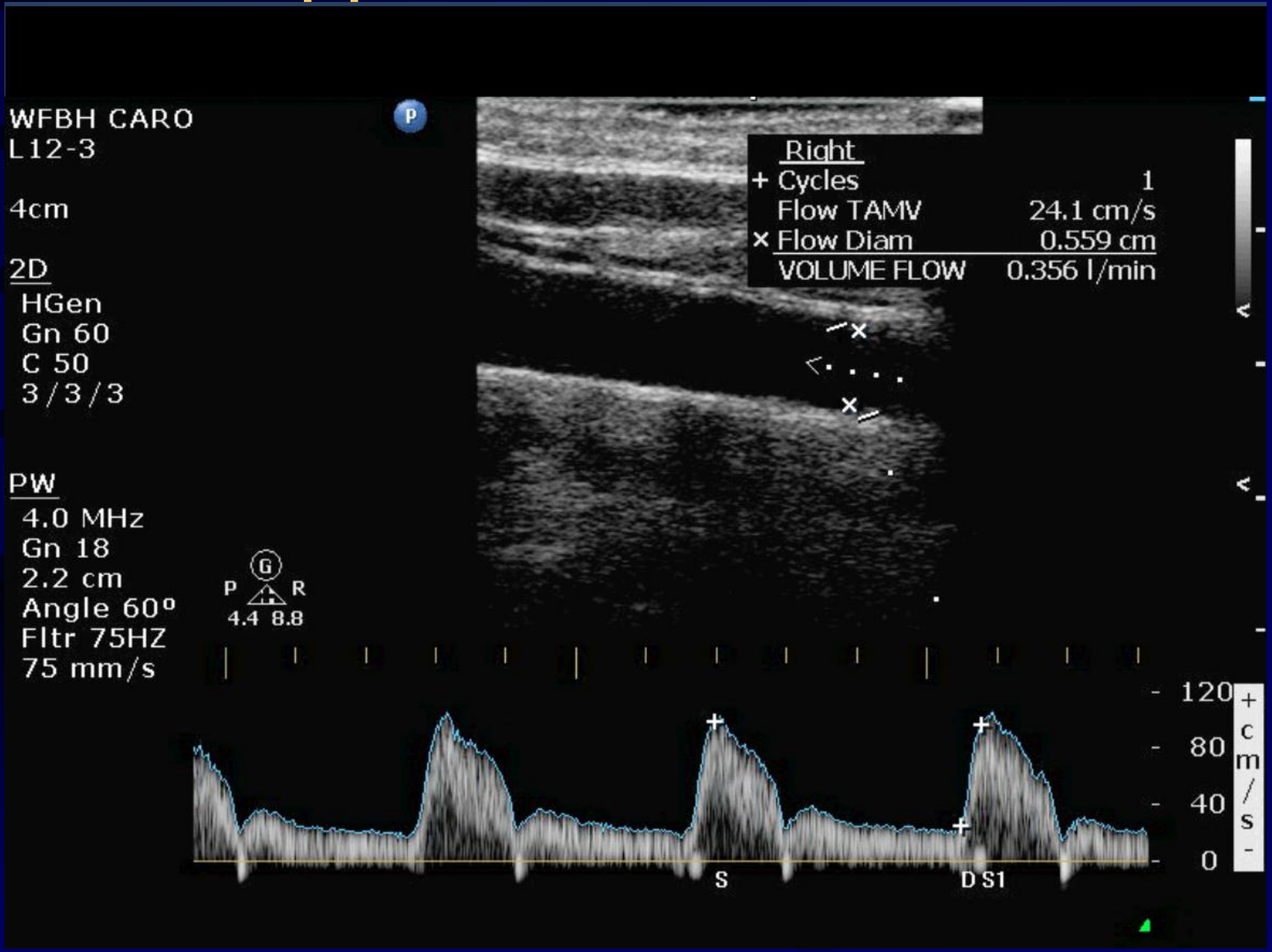


CCA Volume Flow
Distal Occlusion



CCA Volume Flow

Opposite to Occlusion



Volume Flow Measurments

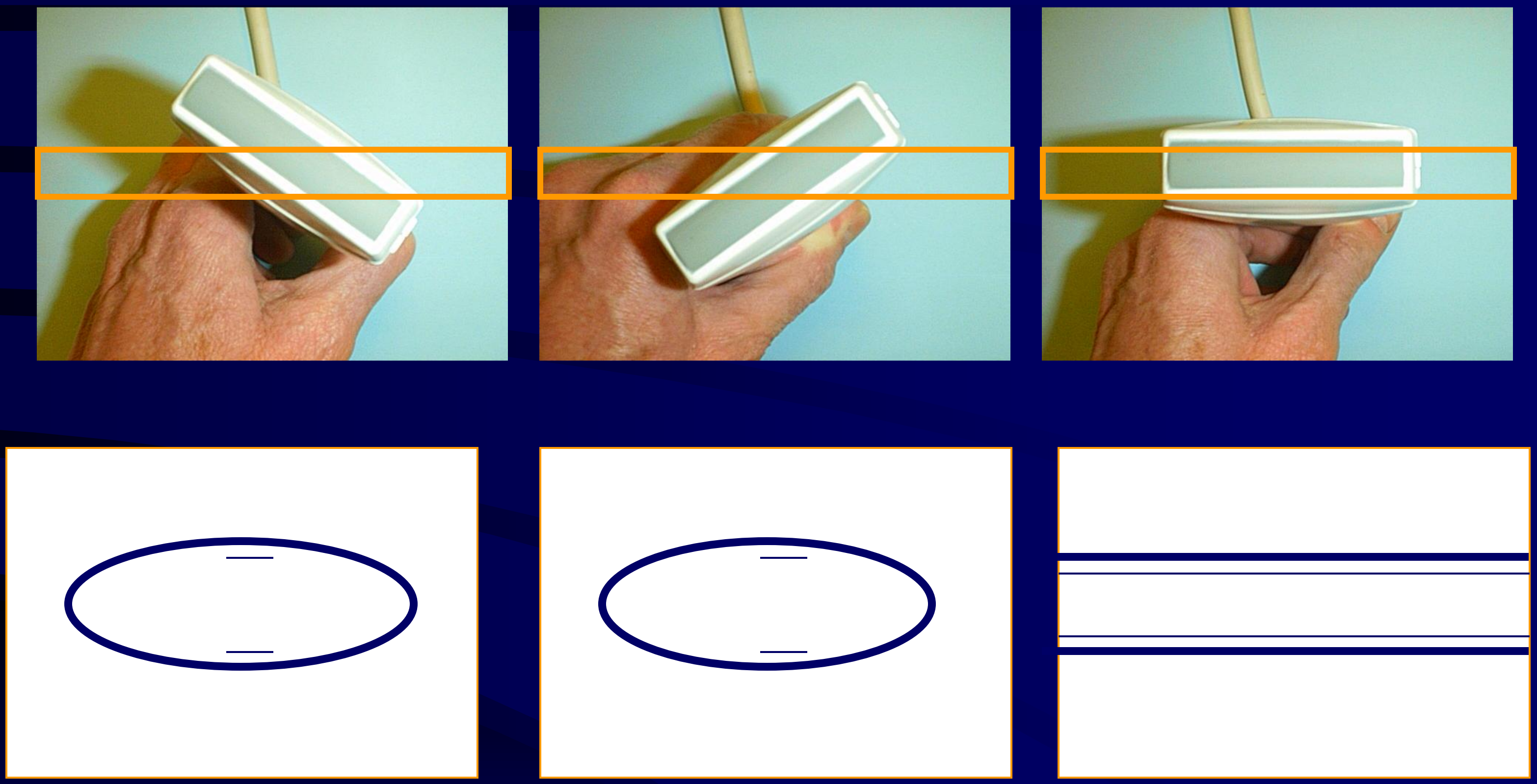
Use at WFSM

- CCA VFR if 70% or greater stenosis
- If spectral changes of distal/prox sten/occl
- Bilateral high or low velocities
- Waveform suggestive of an AVM
- Assess collateral function and avoid error contralateral to stenosis or occlusion
- Follow progression of stenosis

Carotid Interpetation
Suggestions/Biases

- Larger Doppler sample volume helps avoid missing off center high velocity jet, and covers entire width of vessel easier
- Sample with ends of vessel segment open (so vessel appearance is more like a stove pipe) so more confident of flow direction and angle of insonation

Rotating scan head



Doppler Sampling

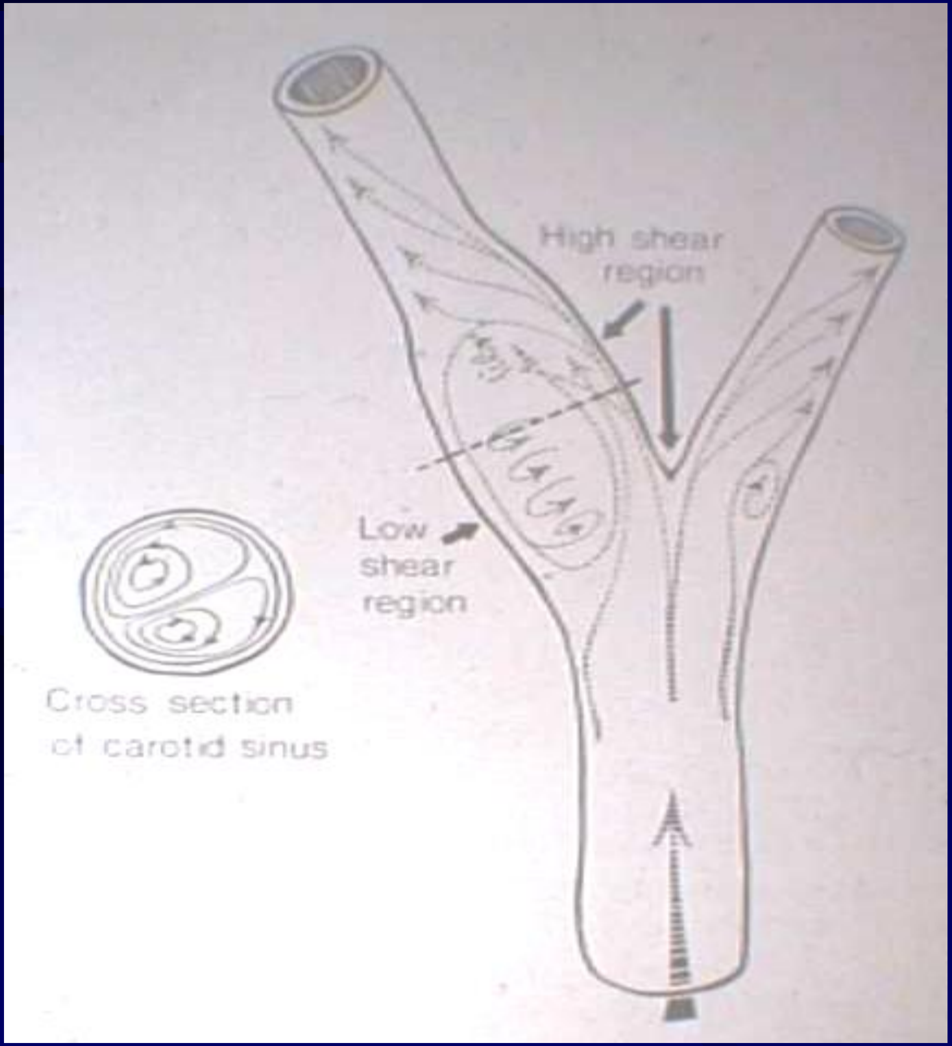
Ends of Vessel "Open"

Doppler Sampling

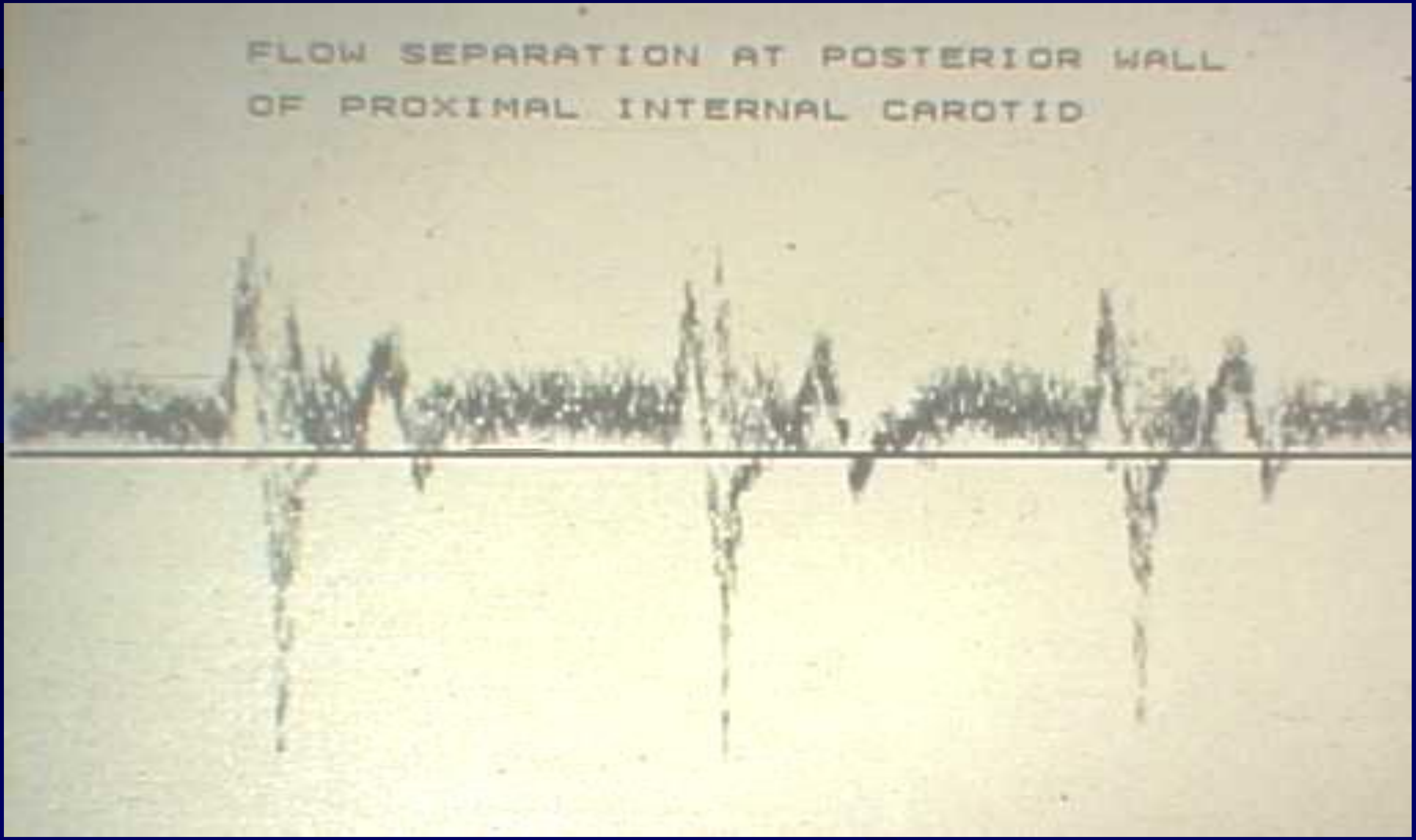
Ends of Vessel "Closed"

Doppler Spectral Analysis

Disturbed Flow at BIF/ICA



Doppler Spectral Analysis
Disturbed Flow at BIF/ICA



Carotid Protocol & Techniques

Suggestions/Biases

- May need to sample from transverse to better identify vessel (but can't tell angle)
- Try transverse image with color/power Doppler imaging to better see string/trickle flow if longitudinal sampling difficult
- If cardiac irregularity, use cardiac cycle with highest velocity, or pick typical cycle

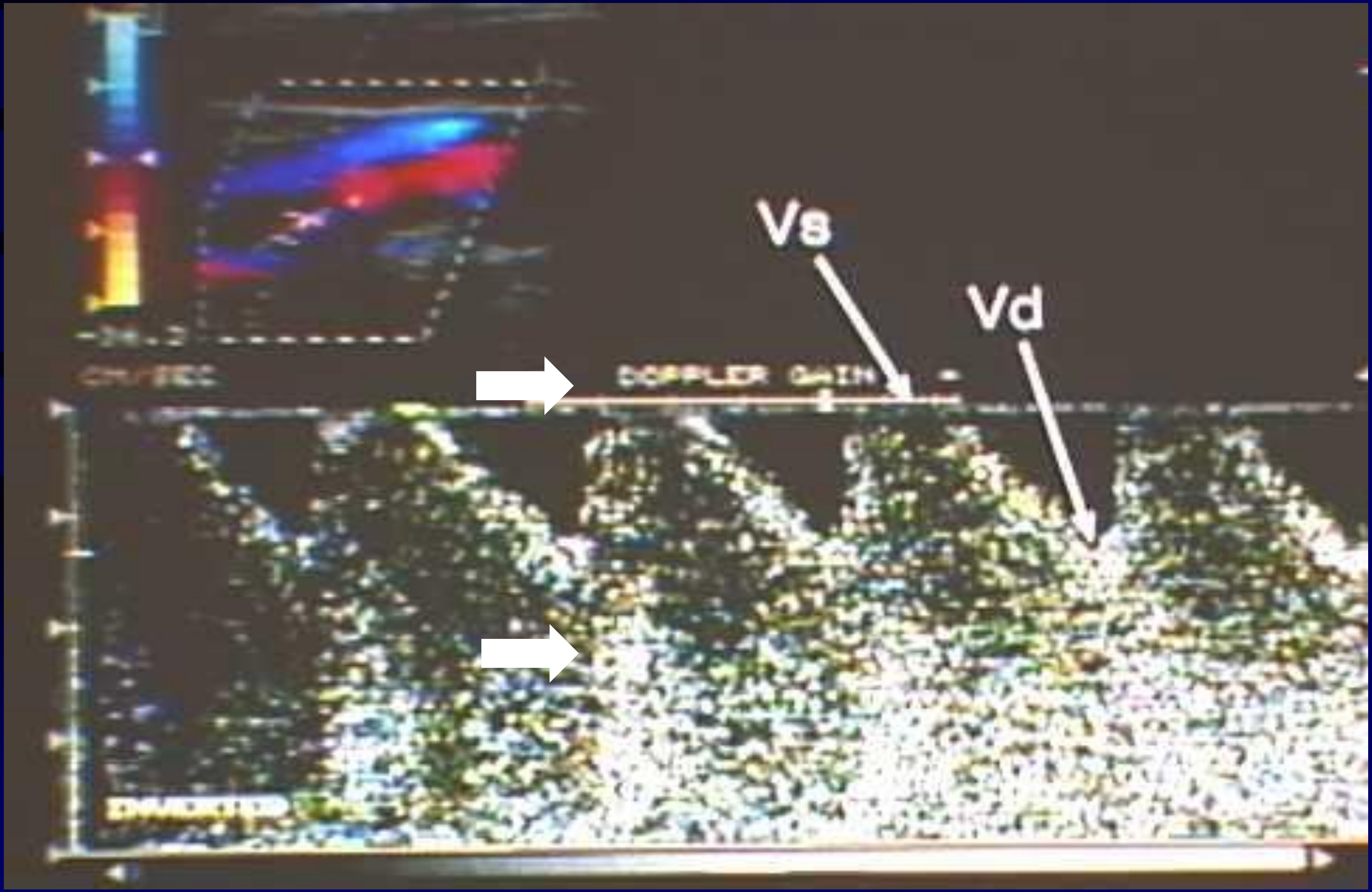
Transverse Duplex Sampling

Transverse Duplex Sampling

Aliasing

- If the Doppler frequency shift (DFS) is high, there may no longer be 2 pulses for each cycle of the DFS (PRF not high enough to accurately sample)
  - Creates erroneous display of the Doppler information (as with wagon wheels appearing to go backwards in the old western movies)
- Aliasing occurs when the DFS > 1/2 PRF
  - Known as the Nyquist limit

Aliasing in a Severe Stenosis/Near Occlusion



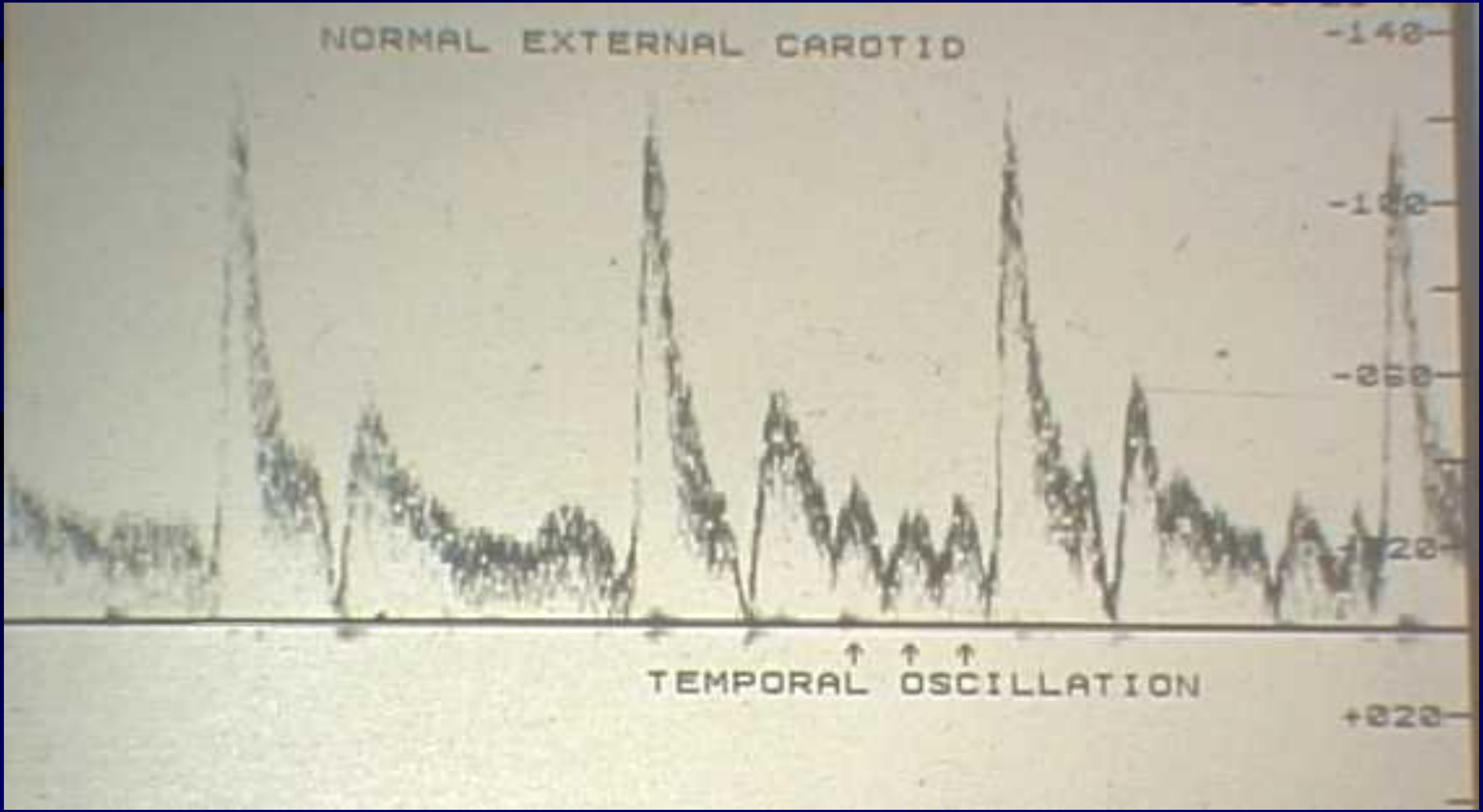
Carotid Protocol & Techniques

Practical Suggestions/Biases

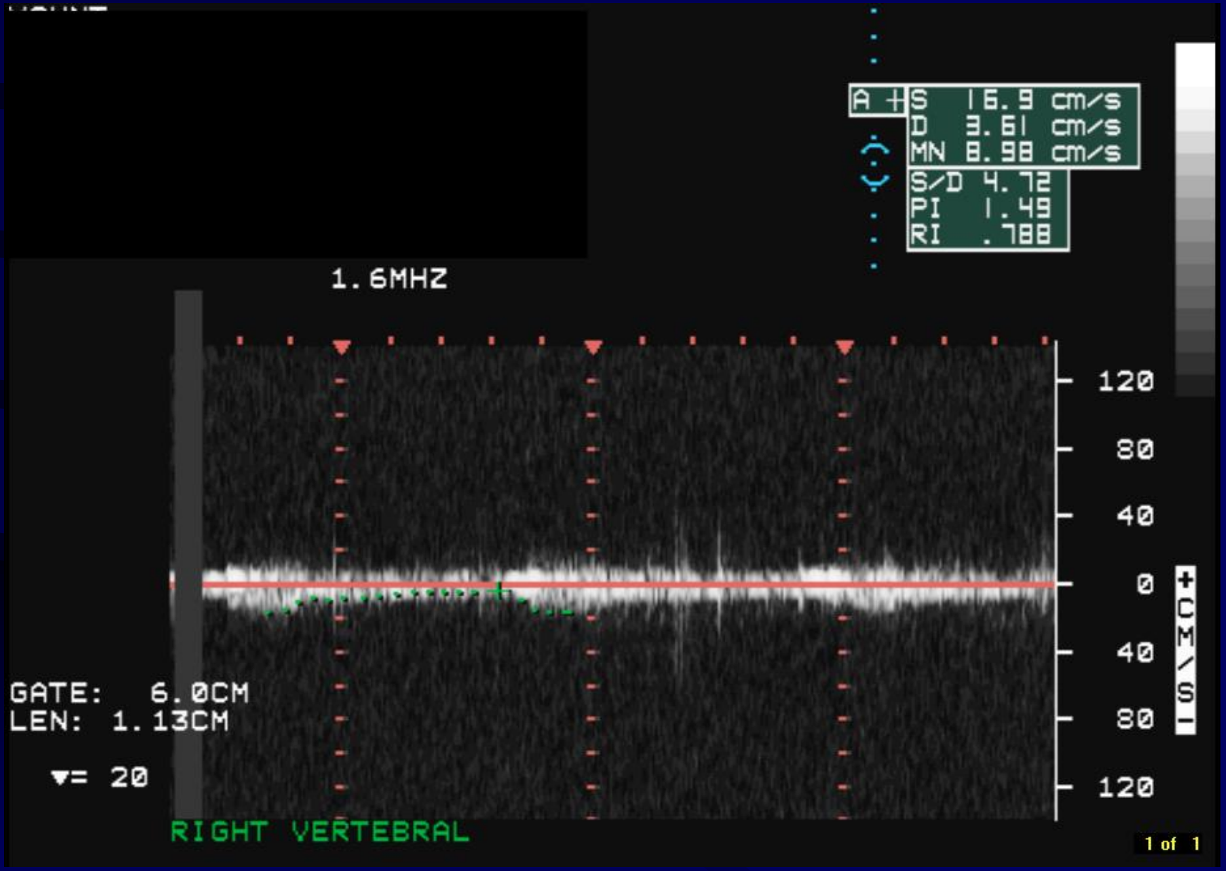
- Tapping of superficial temporal artery can help identify ECA (along with branches, and waveform characteristics)
- Adjust baseline/scale so velocity spectrum fills 2/3-3/4 of screen
- If signal sounds abnormal, but can't capture waveforms, try higher velocity scale

ECA Doppler Identification

Temporal Tap/Oscillation



Doppler Scale Too High



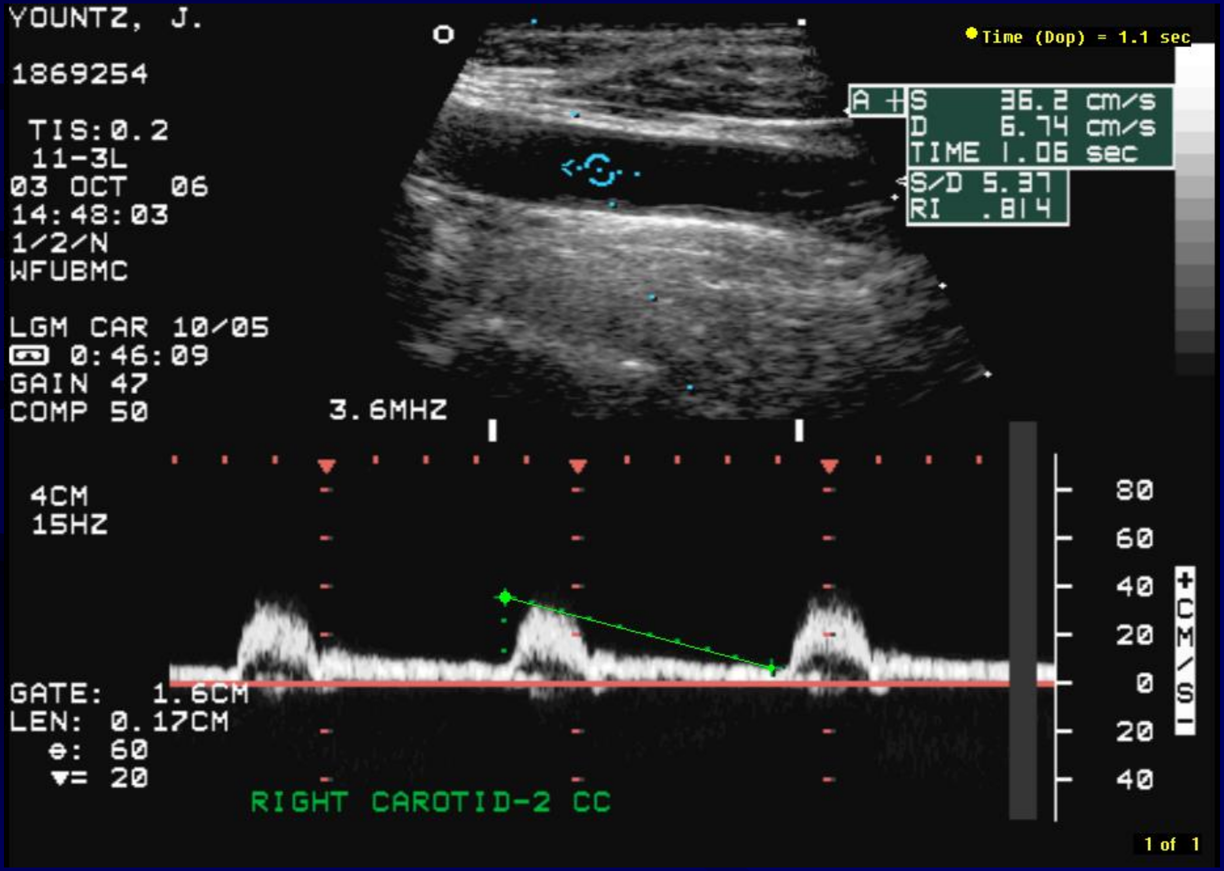
Vascular Doppler
Suggestions/Biases

- Make use of indirect changes from proximal or distal disease
  - High resistance wave form implies distal tight stenosis or occlusion, stiff pipes, heart problem
  - Rule of “10”: < 10 cm/s diastolic in CCA or >10 diastolic in the ECA
  - Post-stenotic wave form (low pulsatility)
  - Watch out for “internalization” of the ECA due to collateral flow

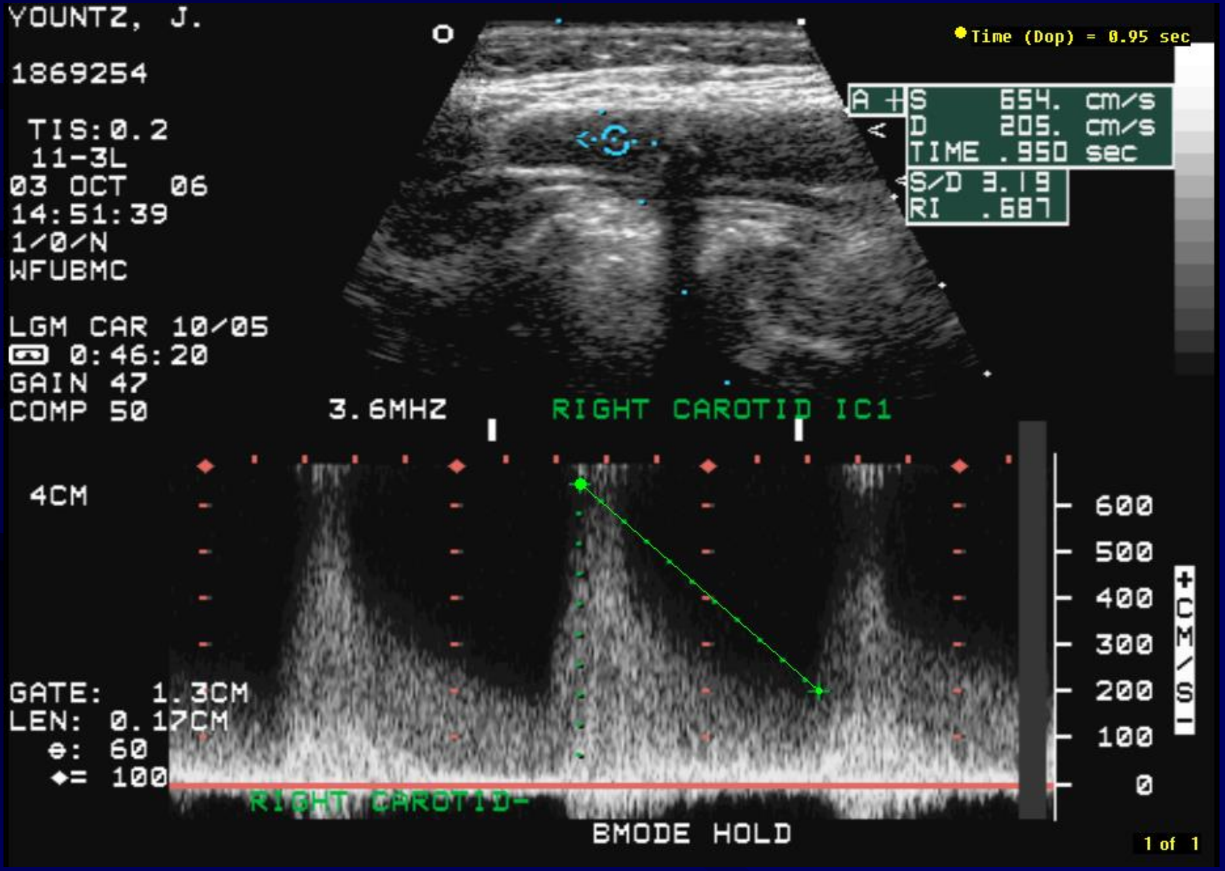
Indirect Changes

Right ICA String Sign

(Diastolic velocity low)

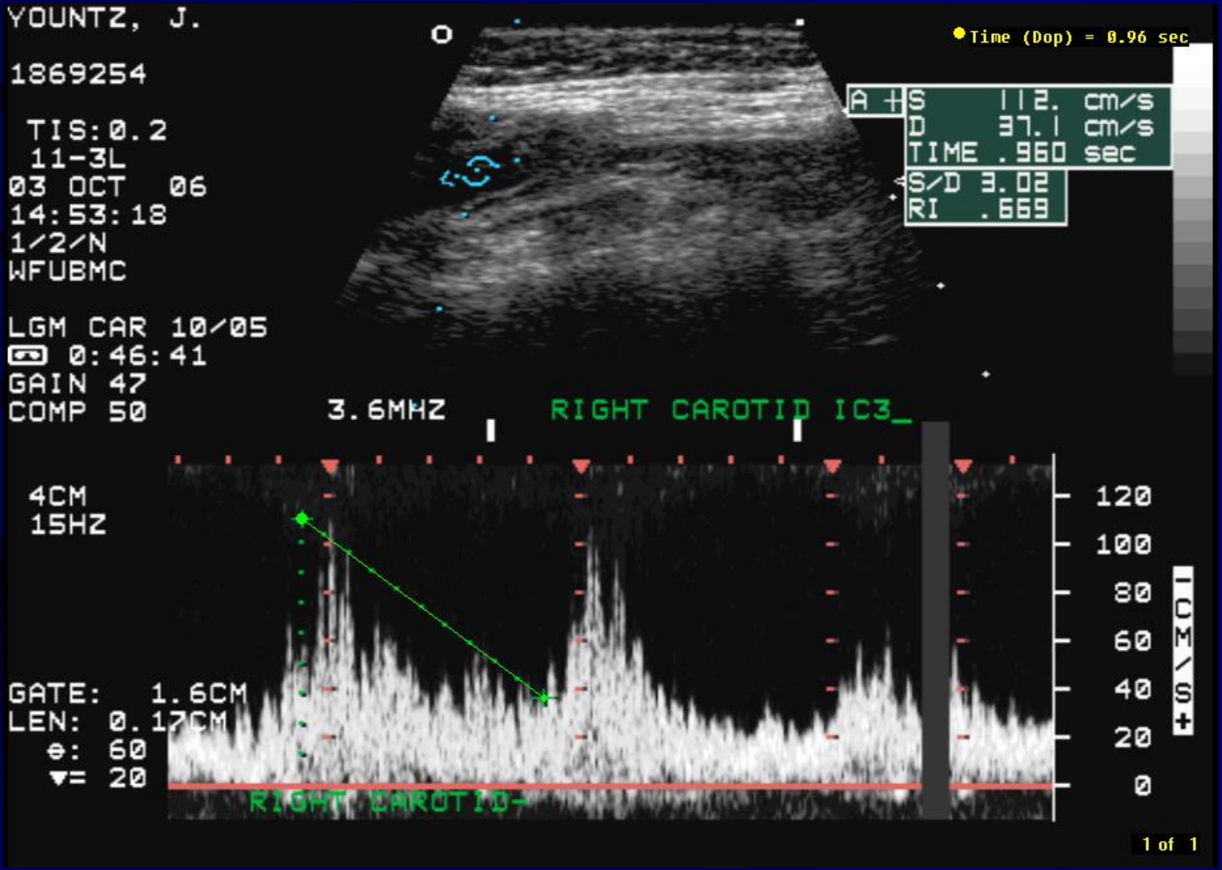


Right ICA String Sign



ICA String Sign

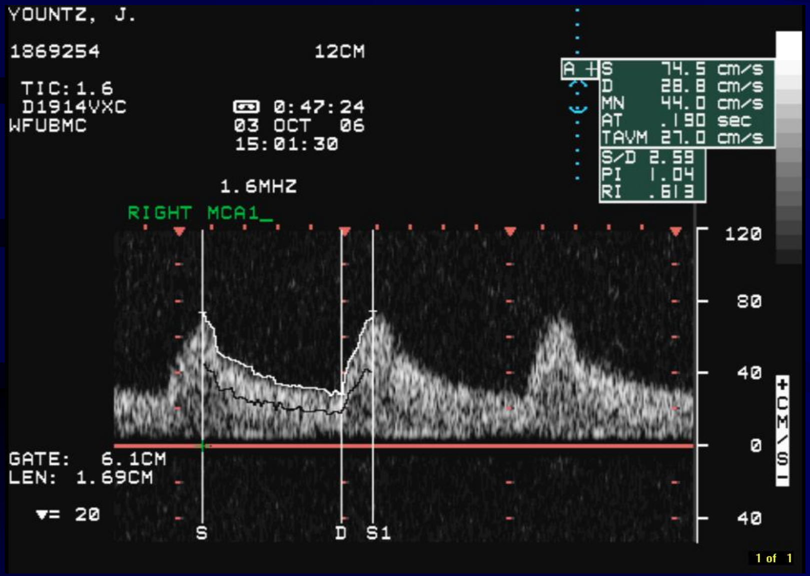
Distal/Post-Stenotic Turbulence



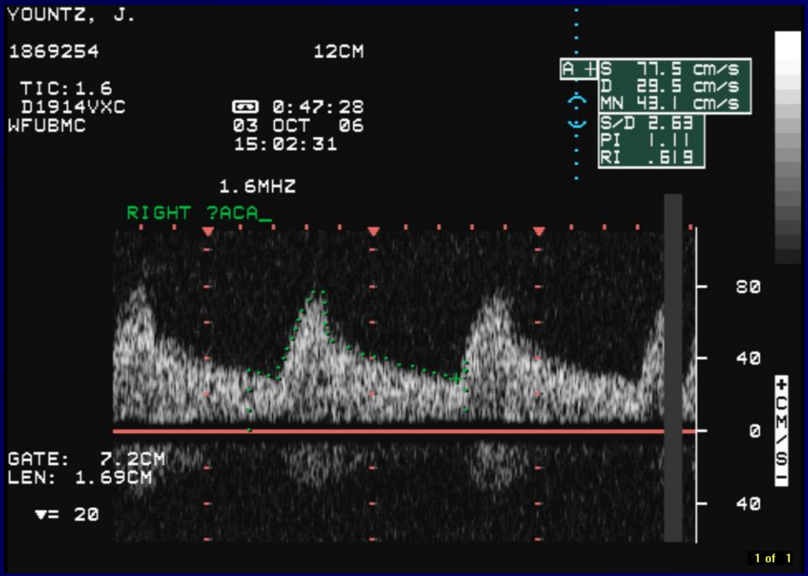
Right ICA String Sign

Intracranial Effects

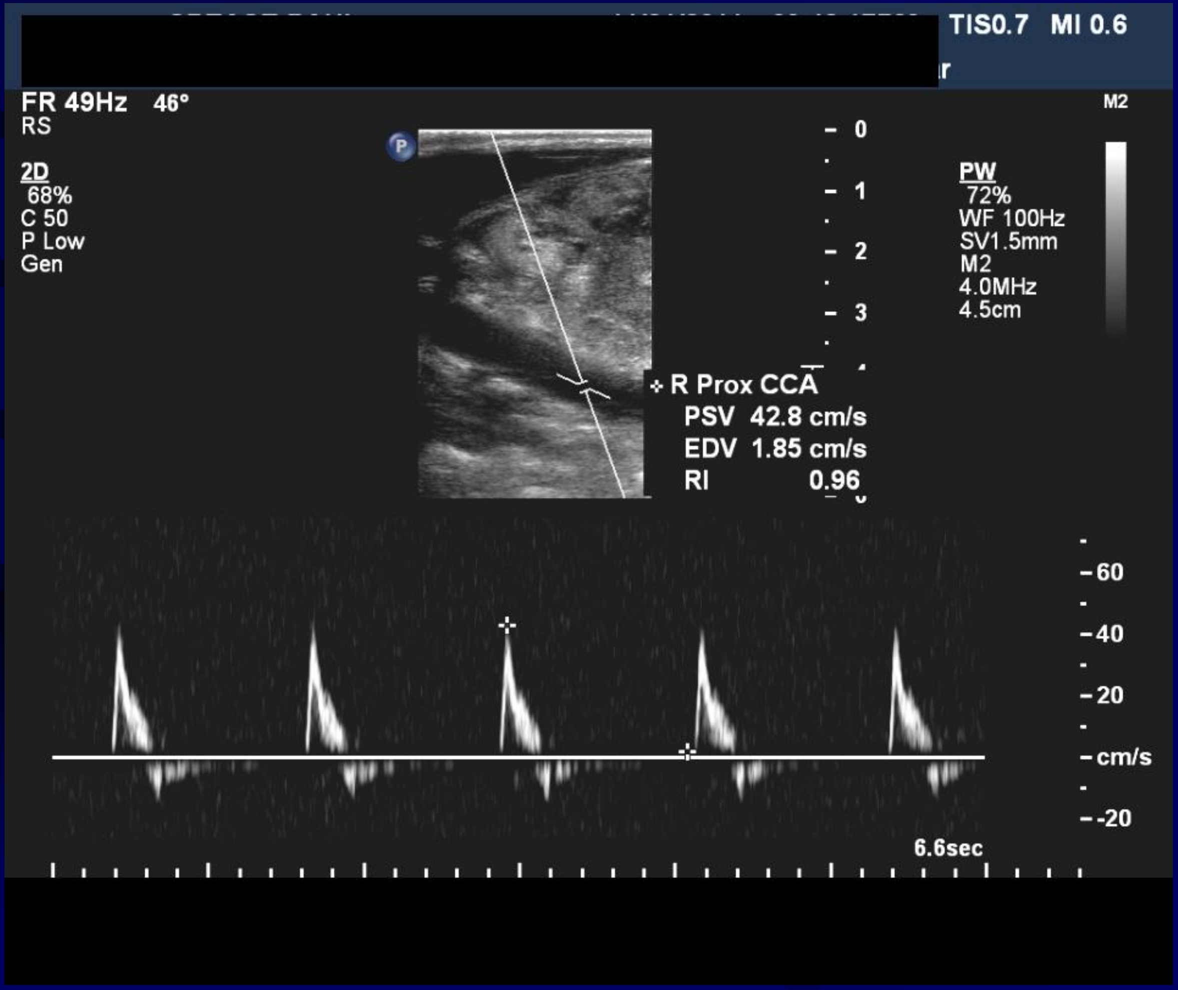
MCA



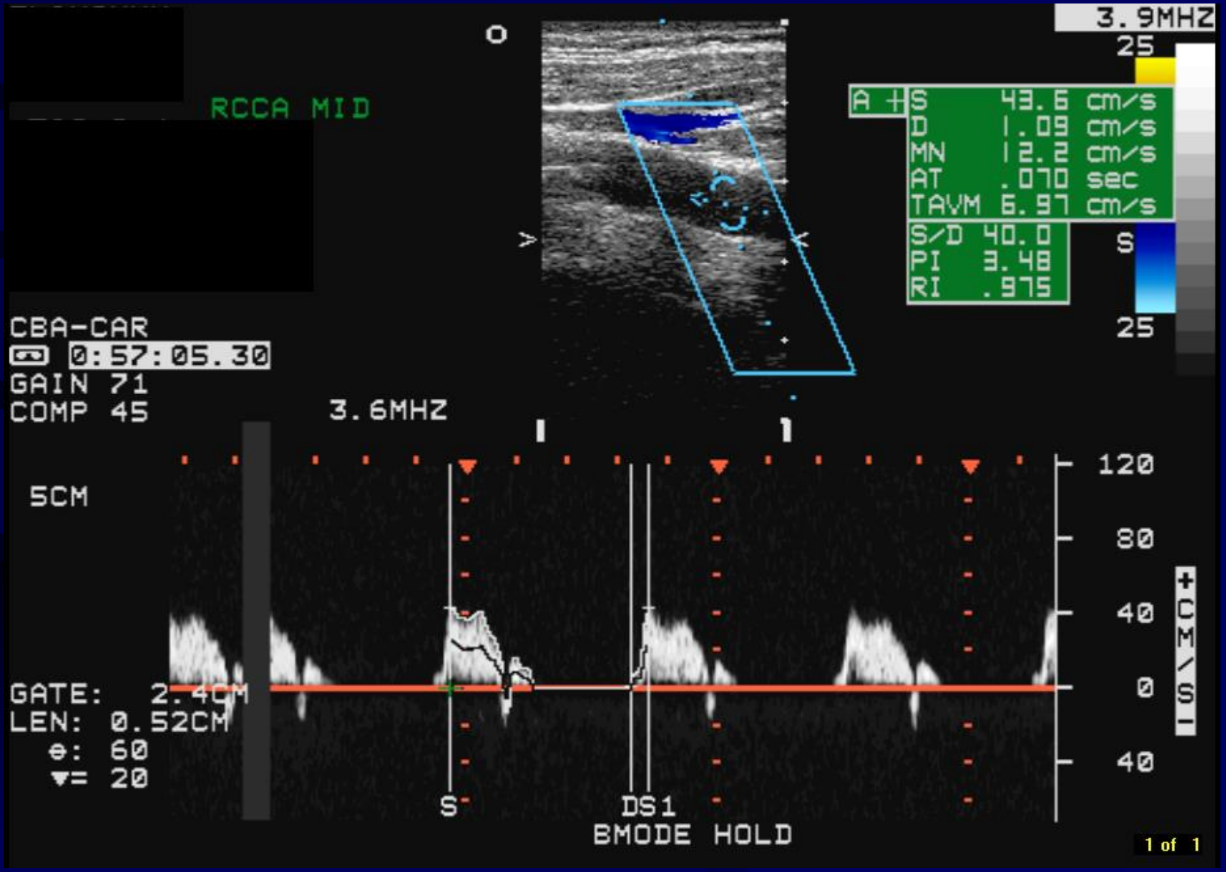
ACA



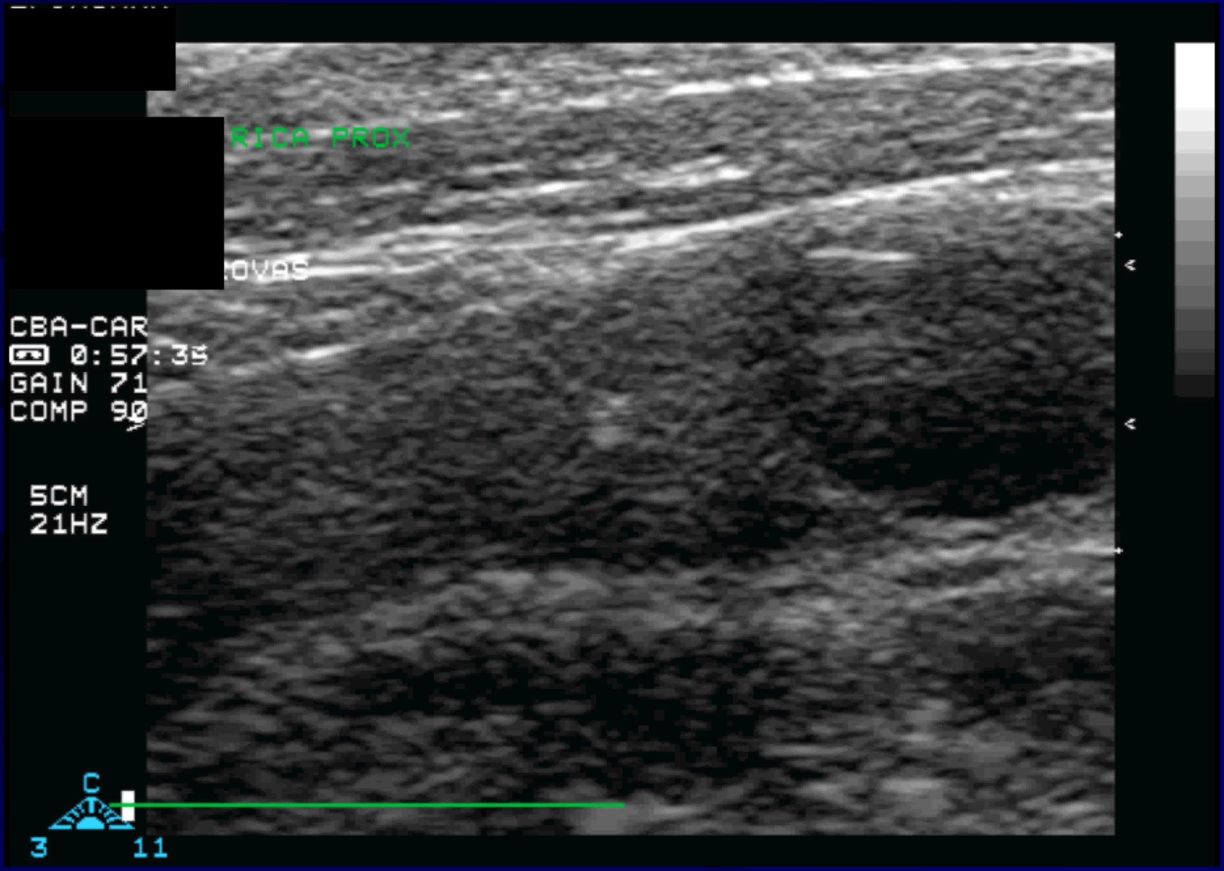
High Resistance CCA Waveform Proximal to Occlusion



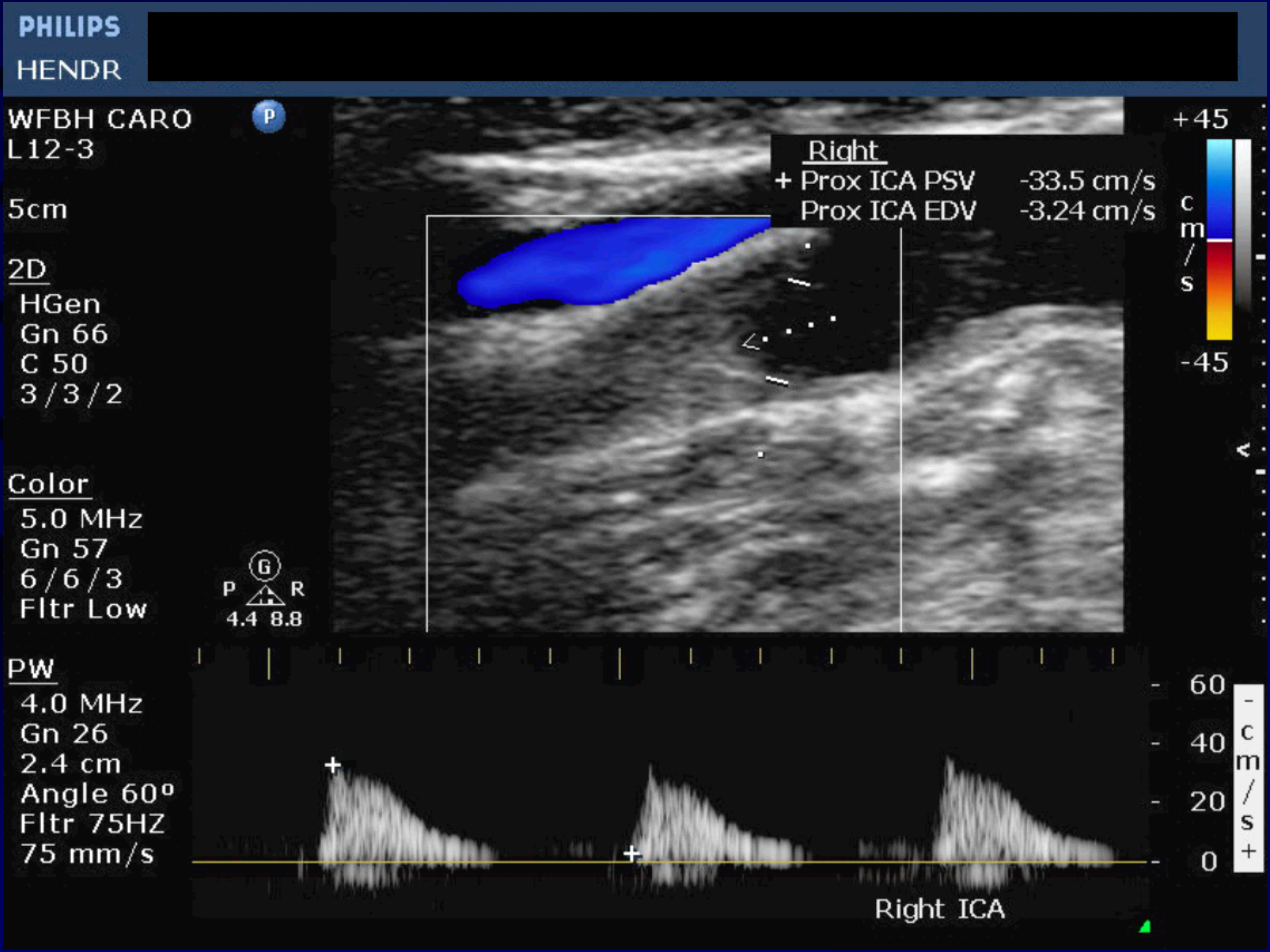
Indirect Changes Distal Occlusion



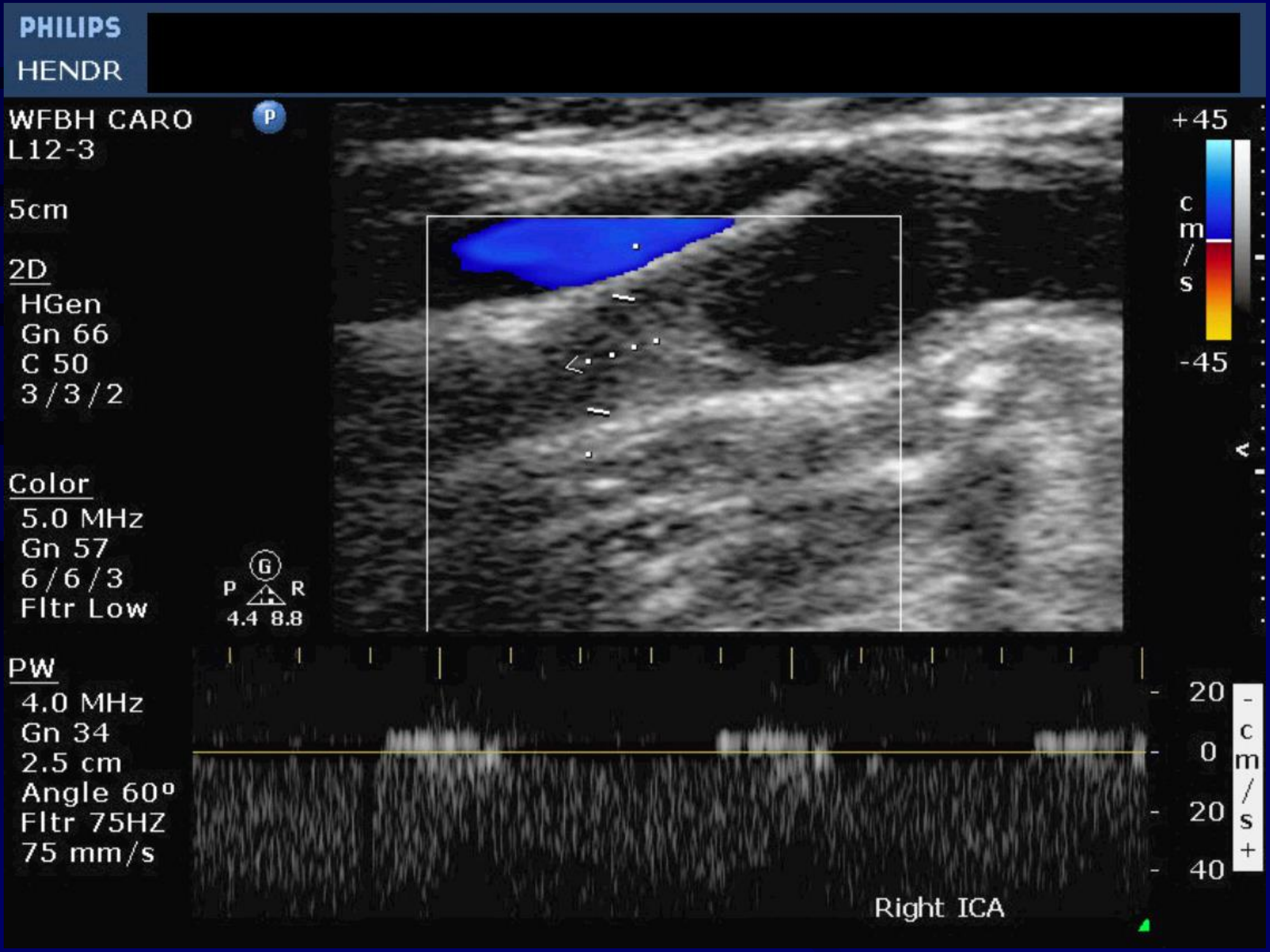
ICA Occlusion



Stump Signal

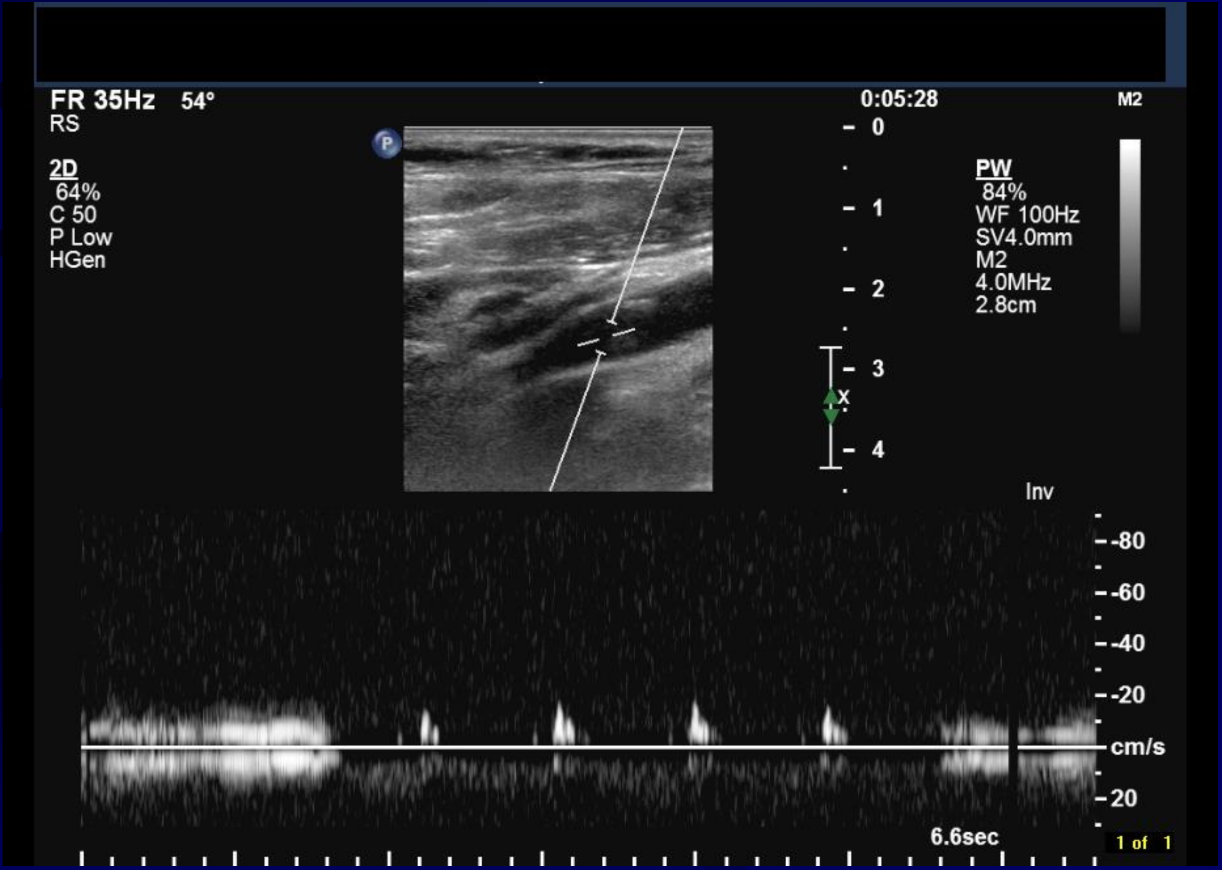


ICA Occlusion



Low Velocity, High Resistance Doppler Signals

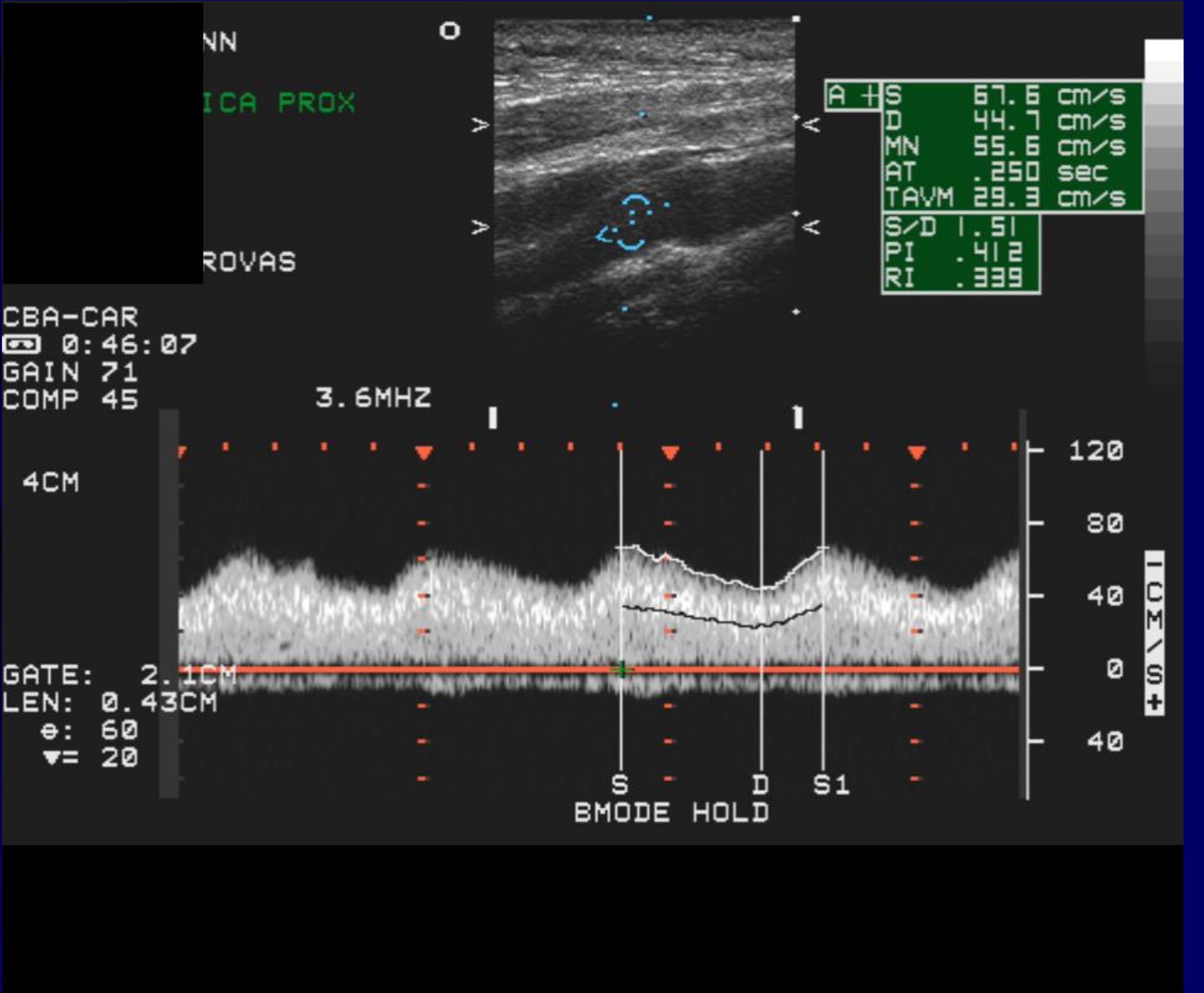
ICA Subtotal Occlusion



Low Velocity, High Resistance Doppler Signals

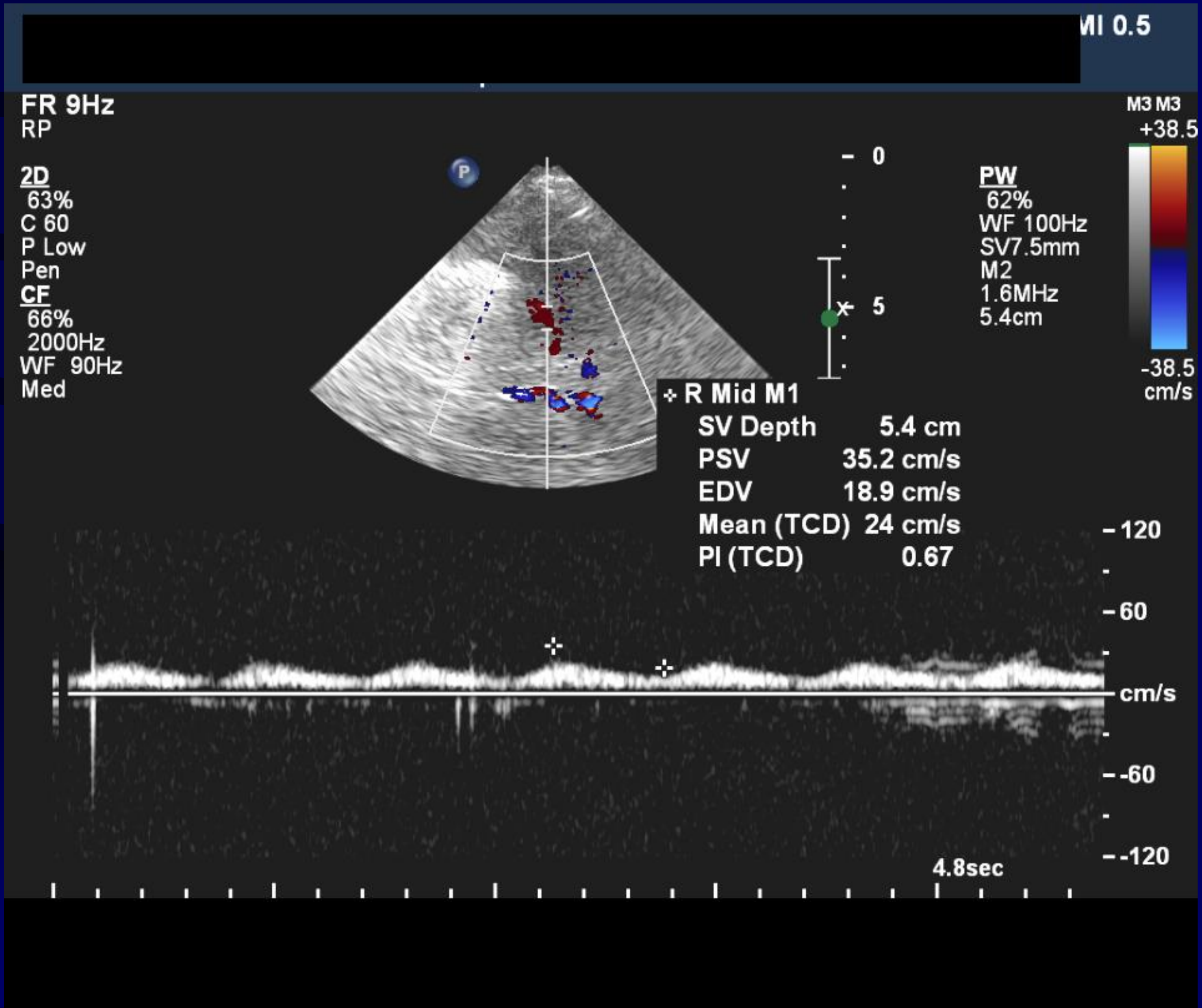
ICA Subtotal Occlusion

Post-stenotic ICA Waveform with Innominate Stenosis



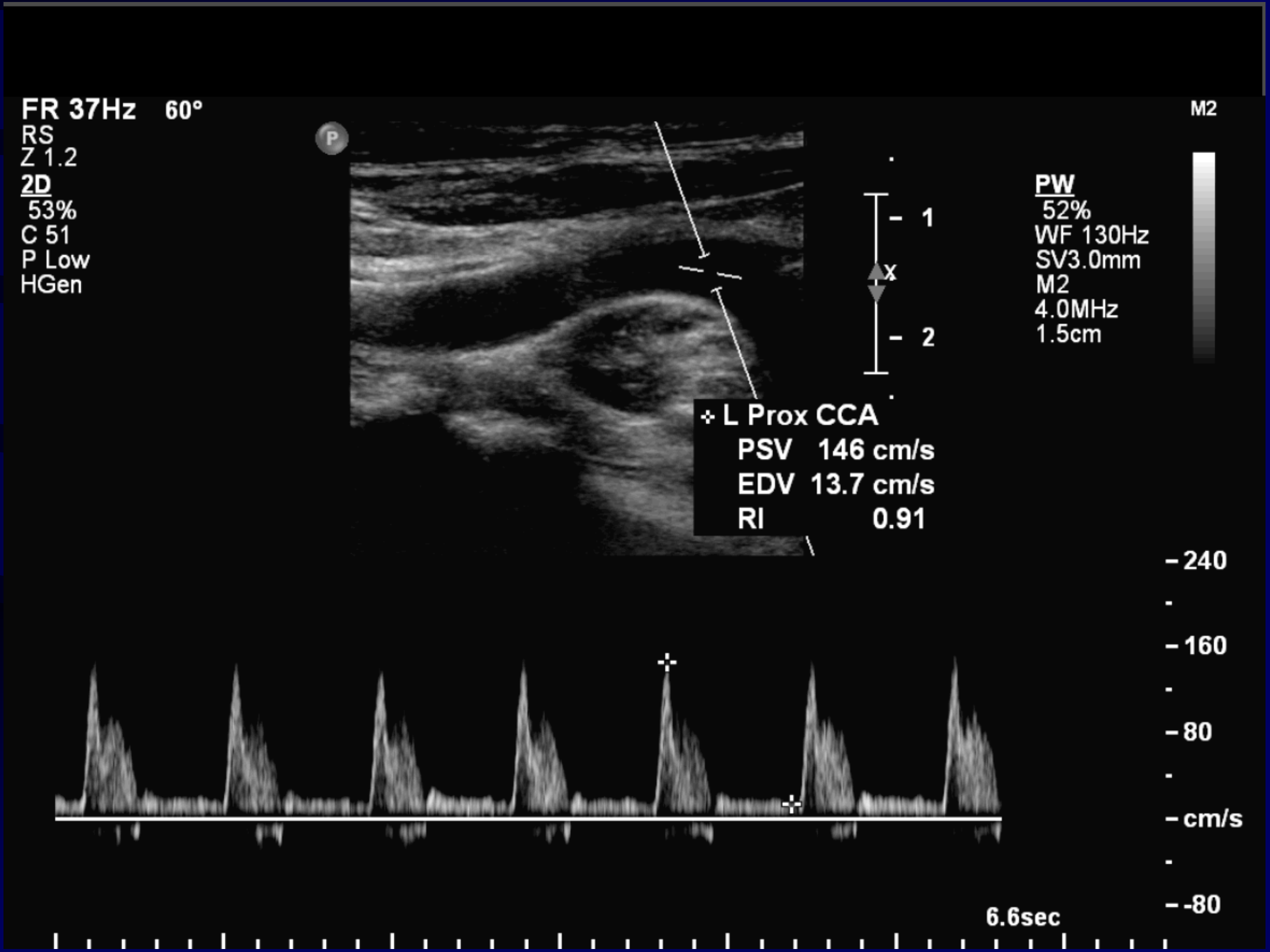
Tardus Parvus
Post-Stenotic Waveform

(R MCA)

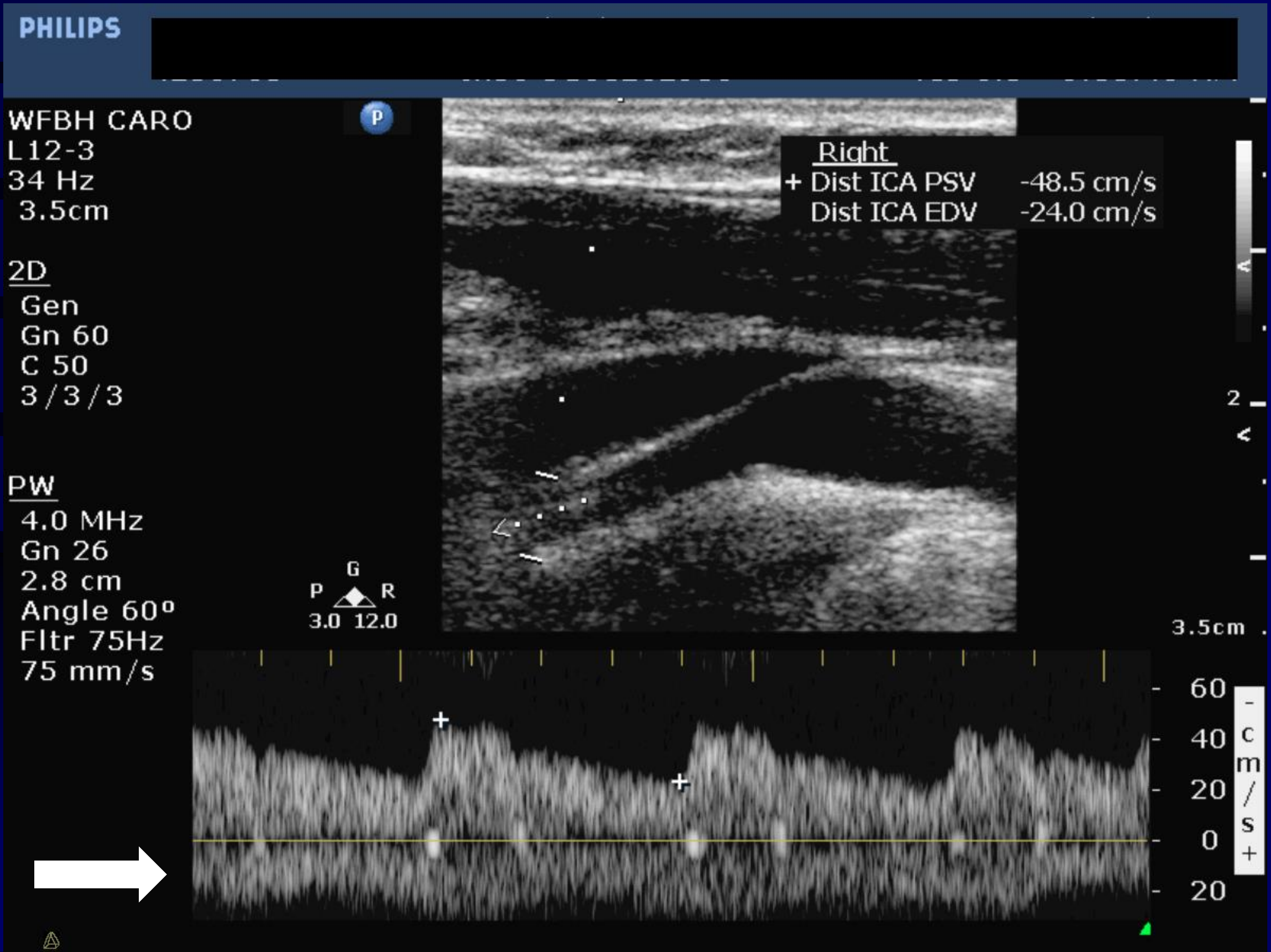


Velocity in Very Proximal CCA

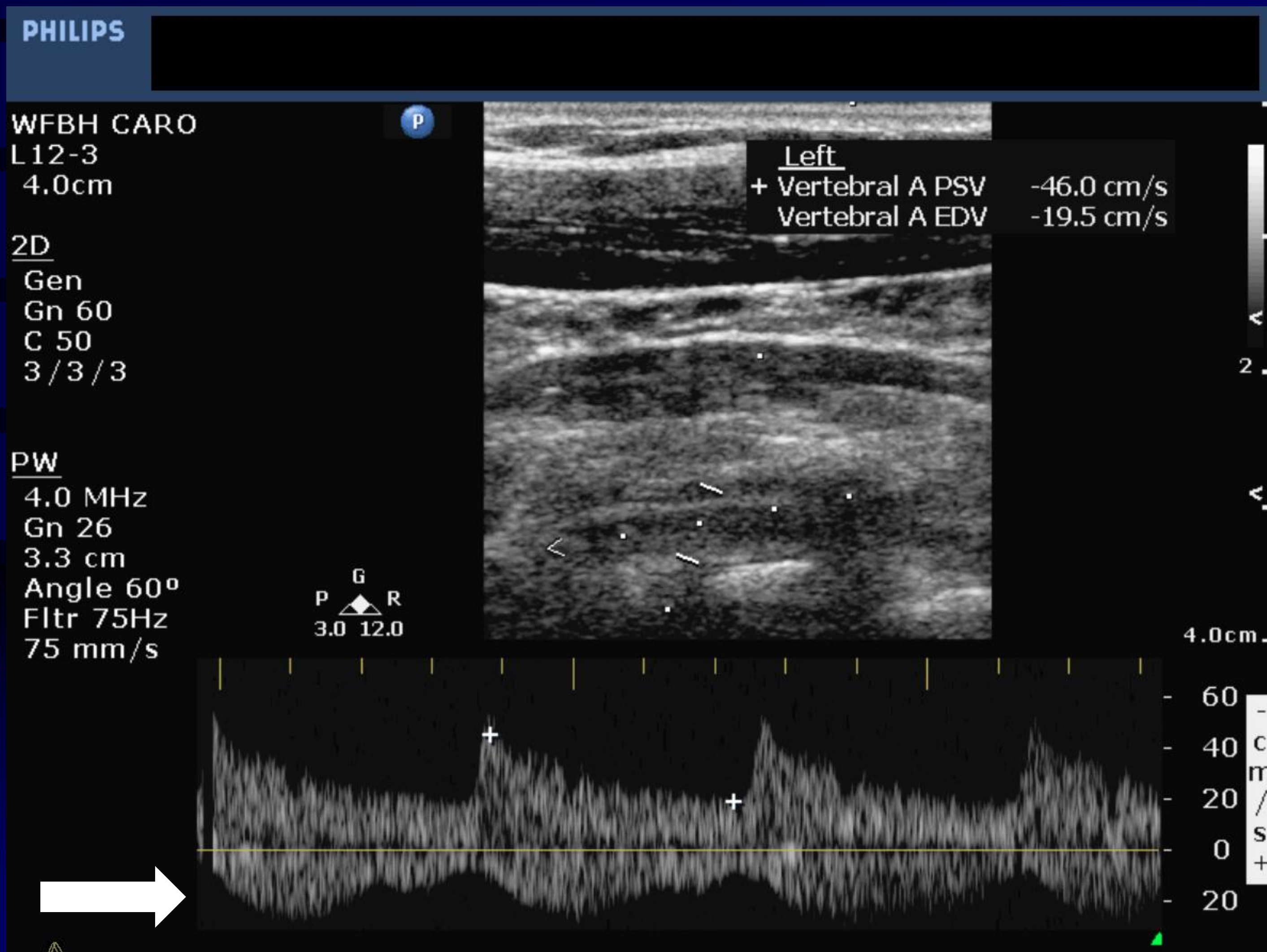
Can be high wihout stenosis



Venous Signal with ICA



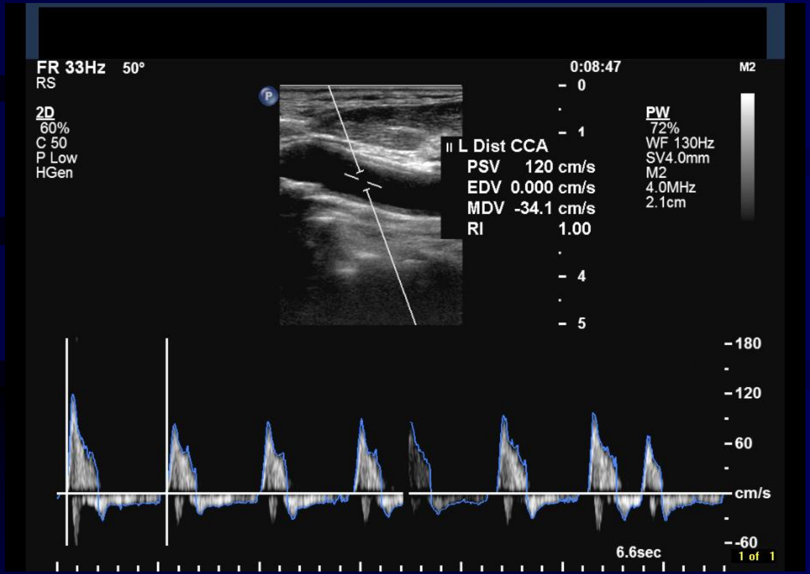
Venous Signal with VA



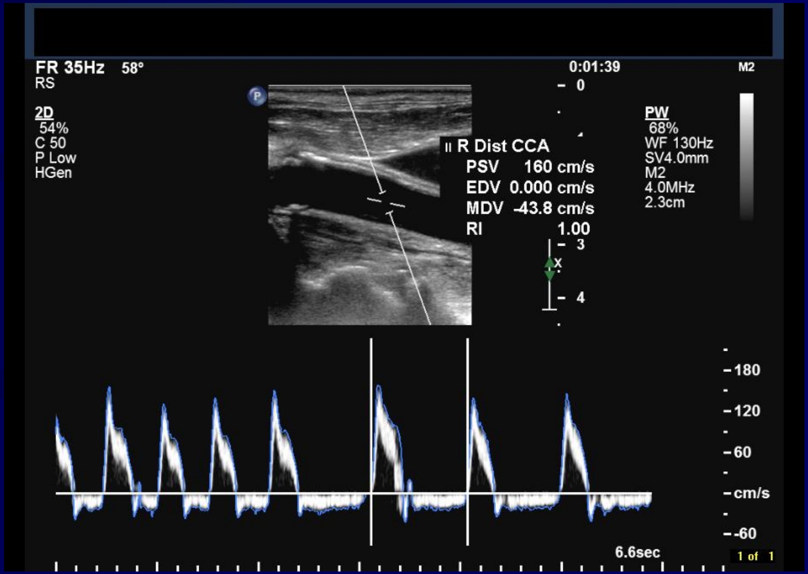
Effect of Cardiac Disease

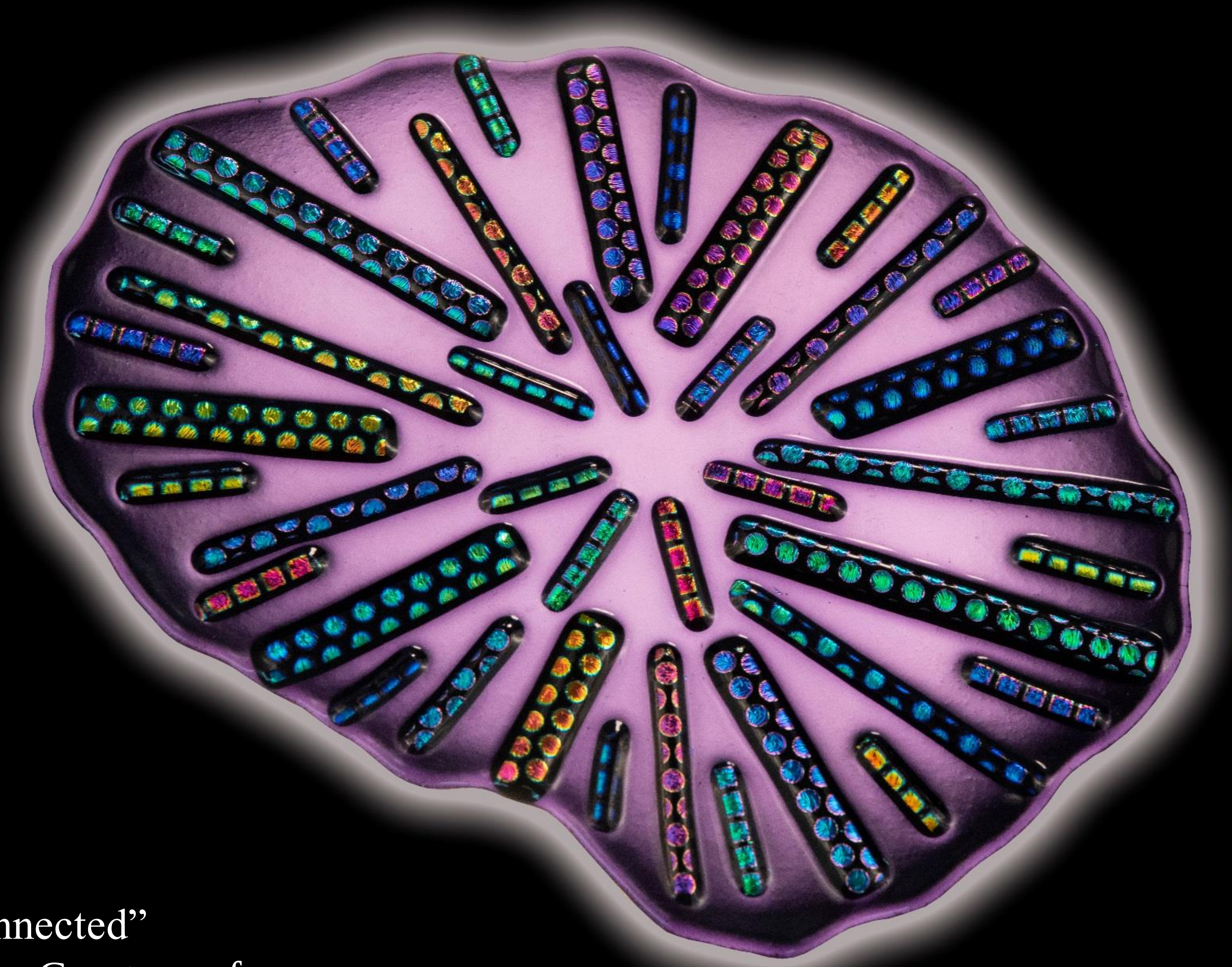
Aortic Insufficiency

Right CCA waveform



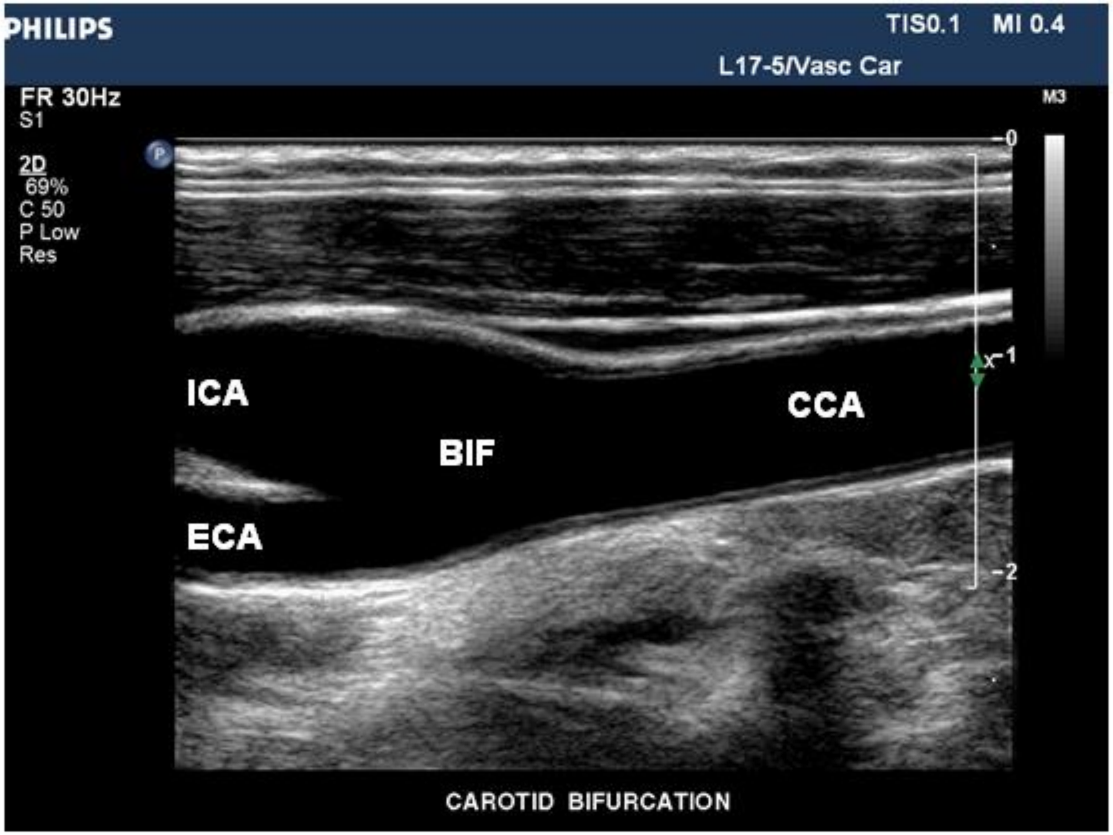
Left CCA waveform





“Connected”
Image Courtesy of
Dr. Renee Healing Art

Carotid B-Mode Imaging



B-Mode Imaging

- “Brightness”-Mode
- Returning, scattered echoes stored in gray scale memory; strong scatterers bright white, weaker ones shades of gray
- Multiple B-Mode scan lines put together across a scan plane create gray-scale, 2-dimensional image
- Update many times/sec (frame rate) for “real-time” imaging as with television (30/sec) the vessel wall, plaque and soft tissues

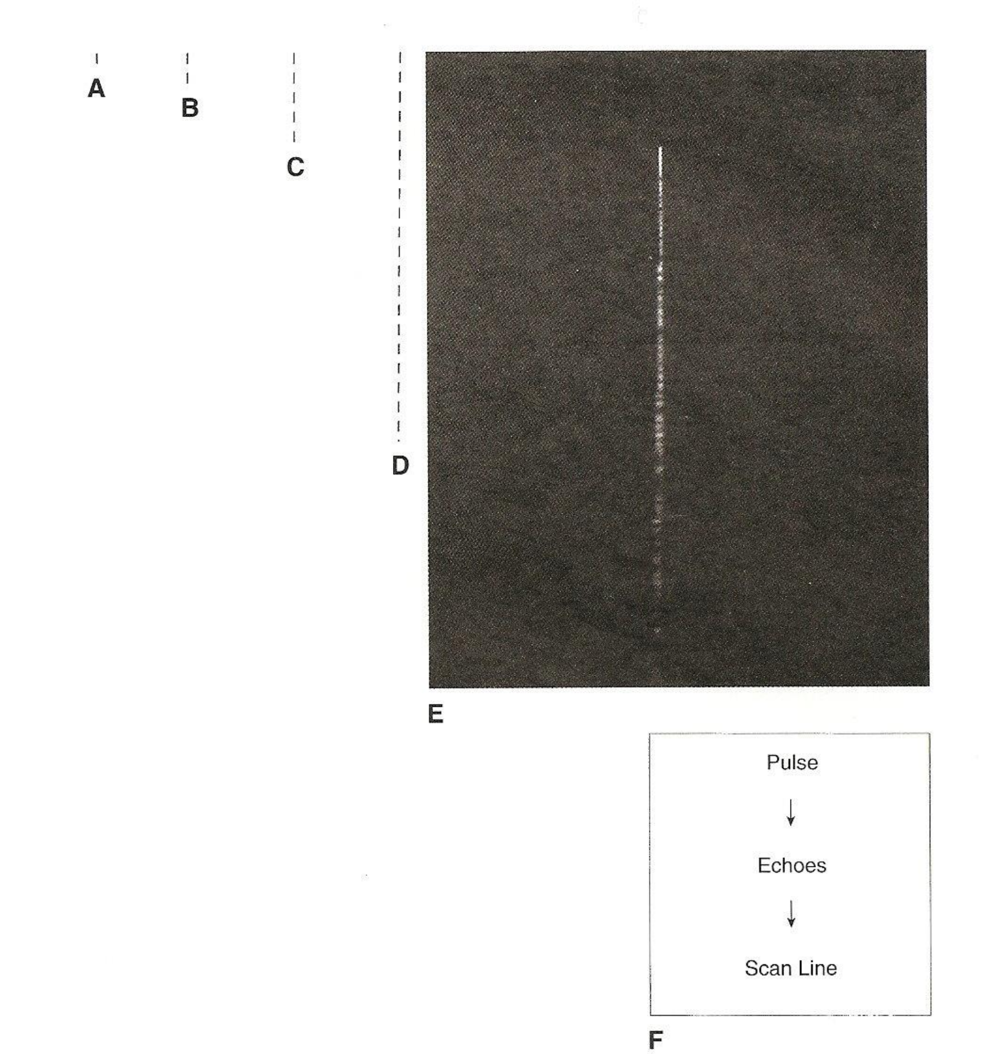
B-Mode Imaging

- Provides ultrasonic picture of tissues, vessels, plaque (not true anatomic image)
- Best to use ultrasonic terms to describe
- Transducer frequency and focusing determine resolution
- Higher frequency, higher resolution
- Higher frequency, greater attenuation, less working depth

B-mode Imaging

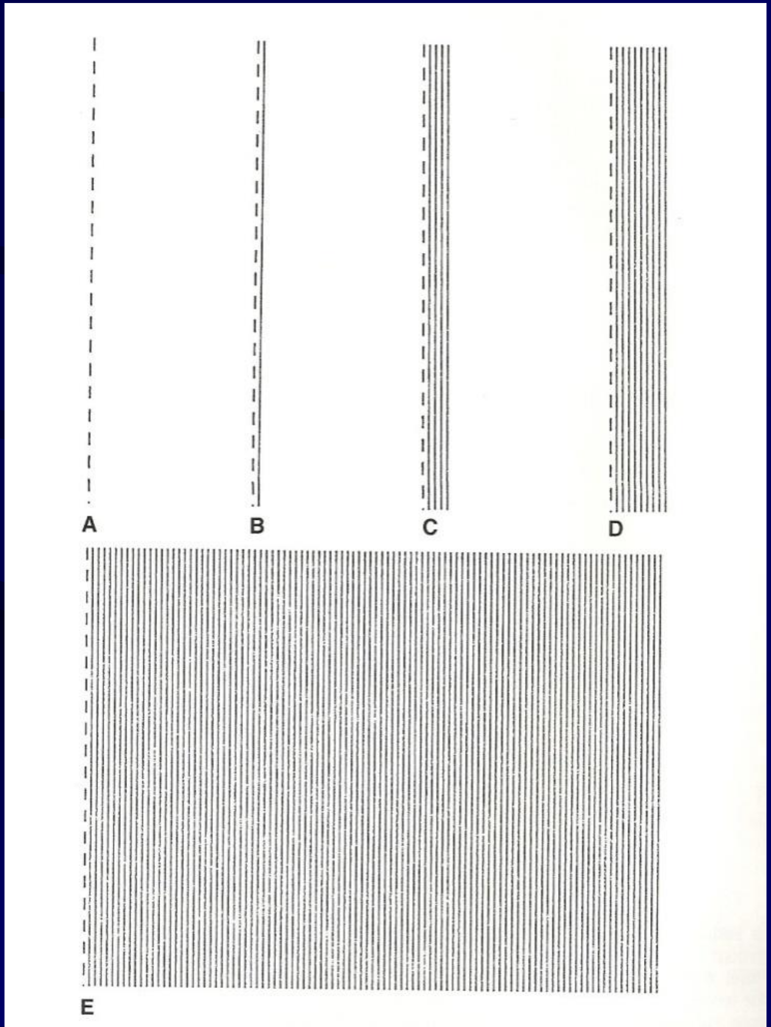
- Scan line swept across plane of tissue to give 2-D image
- Mechanical sector (single transducer moved across plane, fires multiple scan lines)
- Arrays (linear, phased) with multiple transducer elements/channels are electronically steered across the plane to collect multiple scan lines

Single Scan Line of Echo Info



Kremkau,
7th Edition

Building a B-Mode Image
Multiple Scan Lines – Linear Transducer



Kremkau,
7th Edition

B-Mode
Real Time Imaging

- Static 2-D image updated many times per second so appears to be moving in real time
- Rate of updates is Frame Rate
- Television updated 30 times/sec
- Provides ultrasound view of moving targets as with pulsing vessels, moving plaques
- Typical B-Mode movement not quantitative

B-Mode Imaging Resolution

Relationship to Frequency

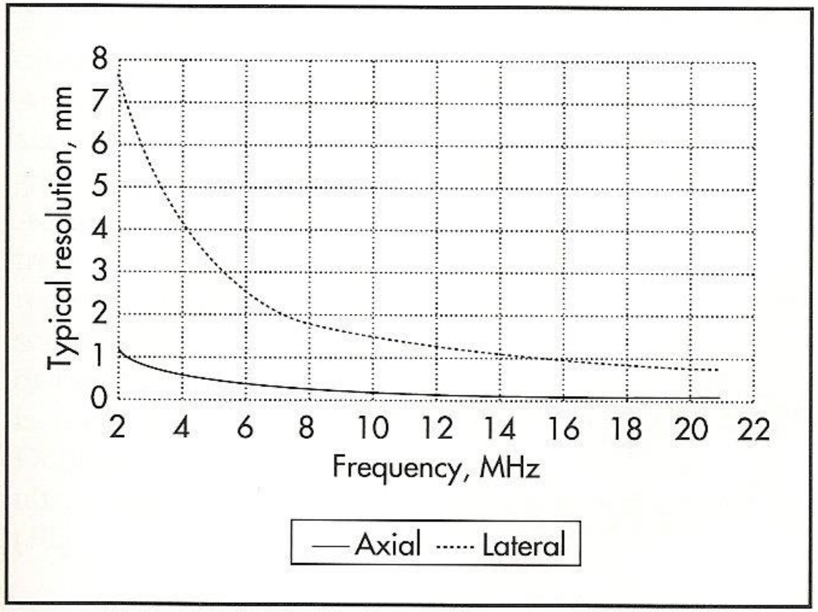


Fig. 1-5. Image resolution depends on many factors but is primarily determined by the frequency and dimensions of the ultrasound transducer. This graph shows the typical axial and lateral resolutions of an unfocused imaging system in the plane located at the depth where the beam diameter is smallest. The pulse duration is assumed to be three cycles long, giving a spatial pulse length of 3 wavelengths. The lateral resolution is assumed to be the diameter of the beam at the depth where it is minimum. Lateral resolution is larger outside this plane.

Riley WA, Neurosonology

Time/Depth Gain Compensation

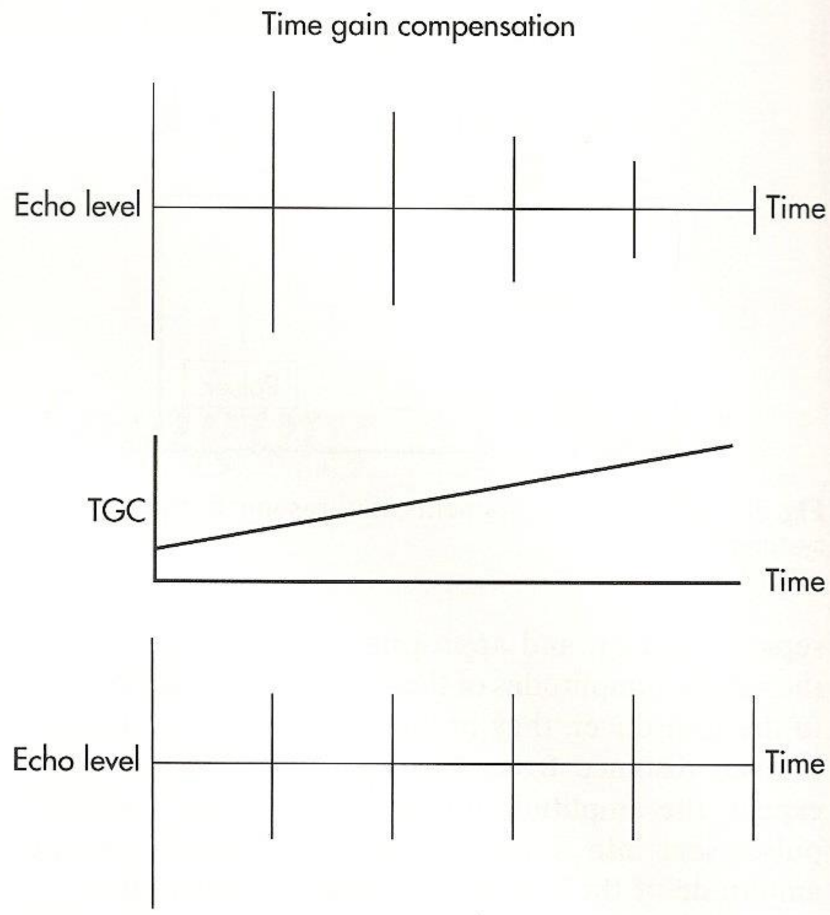


Fig. 3-5. Diagram showing the effect of time gain compensation on echoes arriving at various times from identical targets located at different depths.

Riley WA, Neurosonology

Principle of Shadowing

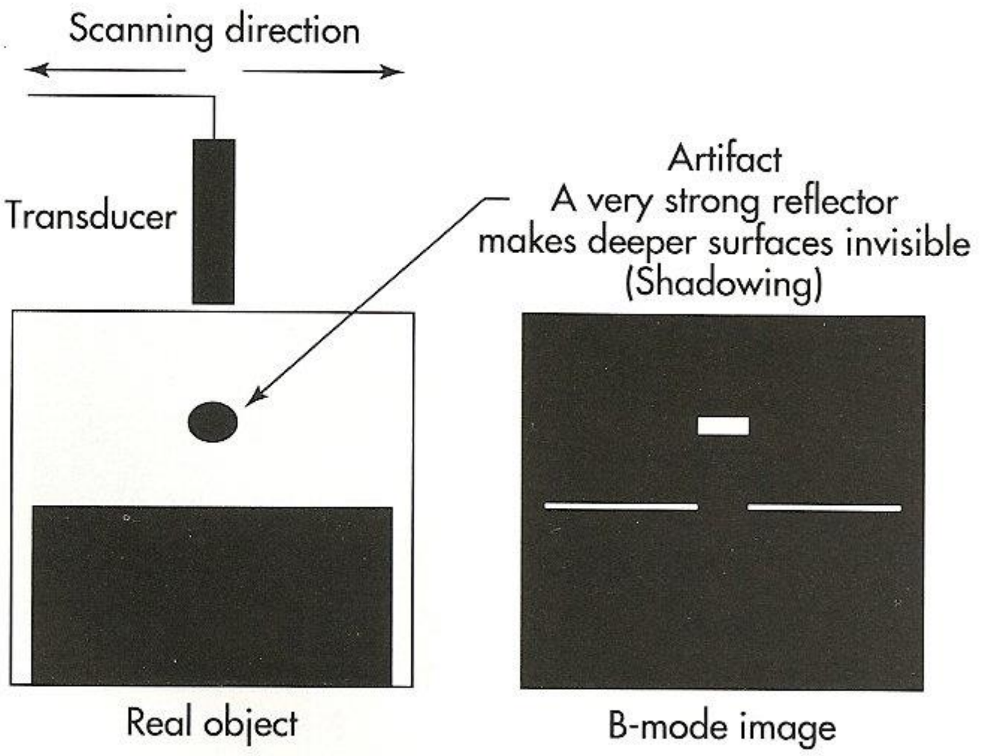


Fig. 5-6. Simplified diagram illustrating the shadowing artifact. A very strong reflector causes deeper surfaces to be invisible on the B-mode image.

Riley WA, Neurosonology

Detection Depends on Acoustic Impedance Difference and Angle

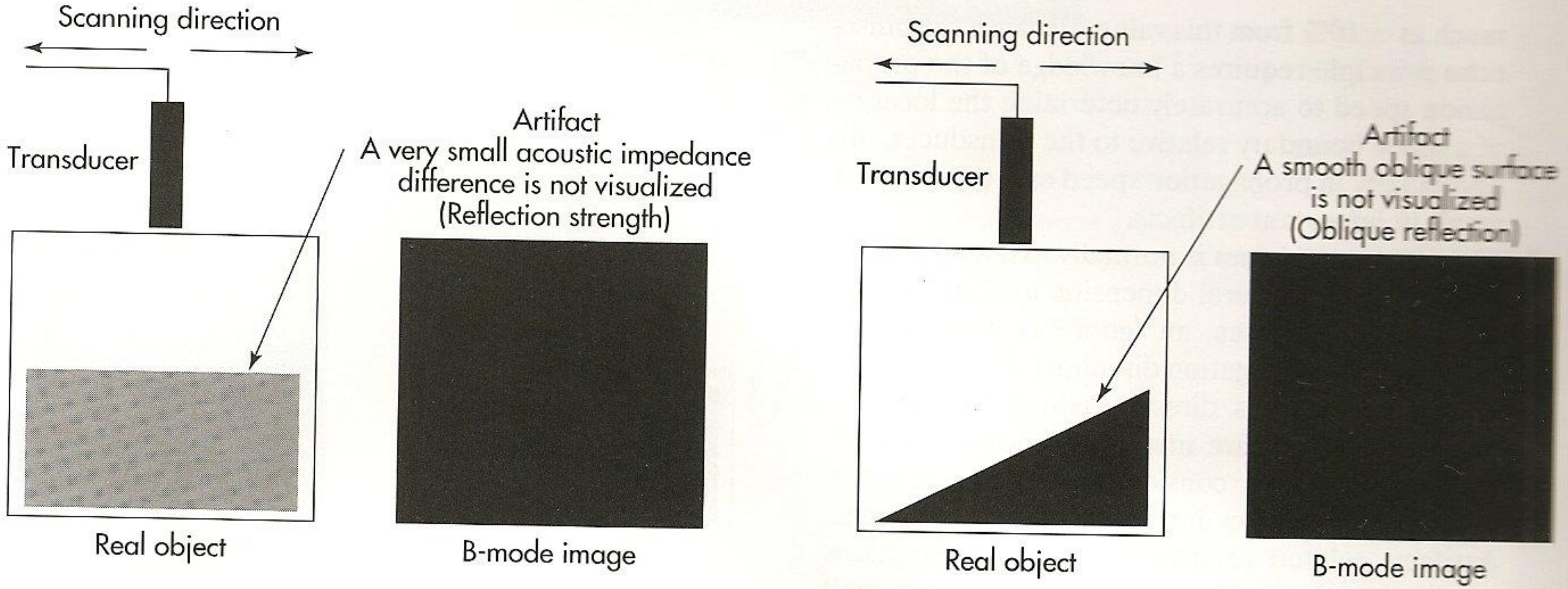


Fig. 5-2. Simplified diagram illustrating the reflection strength artifact. A boundary associated with a very small acoustic impedance difference may not be visualized on the B-mode image.

Fig. 5-3. Simplified diagram illustrating the oblique reflection artifact. A smooth surface that is not perpendicular to the ultrasound beam propagation direction may not be visualized on the B-mode image.

Riley WA, Neurosonology

Reverberation and Mirror Imaging

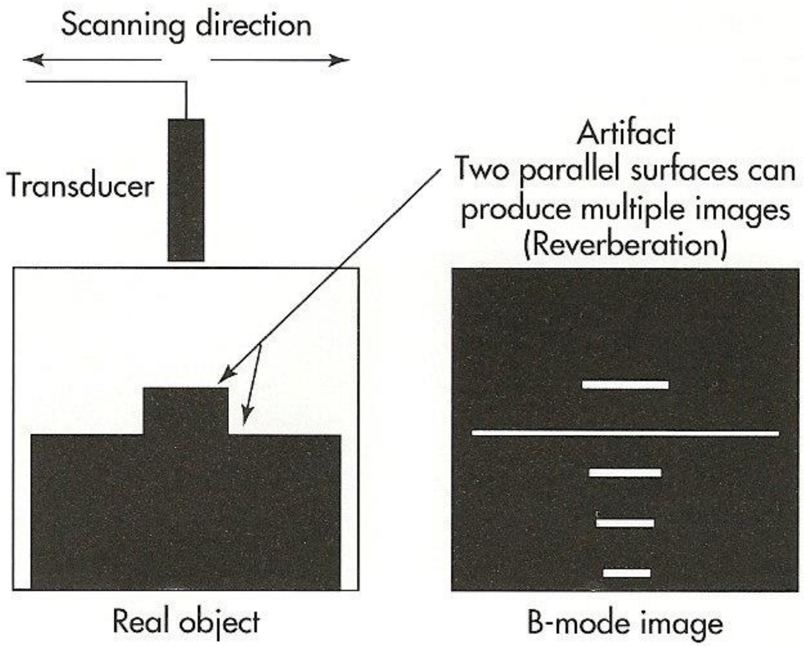


Fig. 5-7. Simplified diagram illustrating the reverberation artifact. Two parallel surfaces with the correct acoustic impedance difference can produce multiple images of the boundaries on the B-mode image.

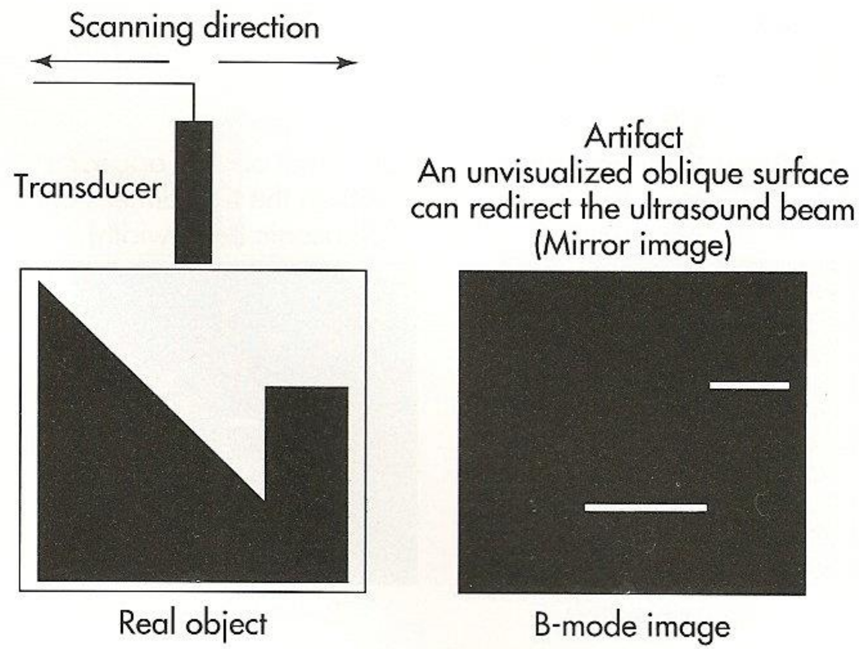


Fig. 5-8. Simplified diagram illustrating the mirror image artifact. A nonvisualized oblique surface can redirect the ultrasound beam to other boundaries and cause them to be visualized in an incorrect location on the B-mode image.

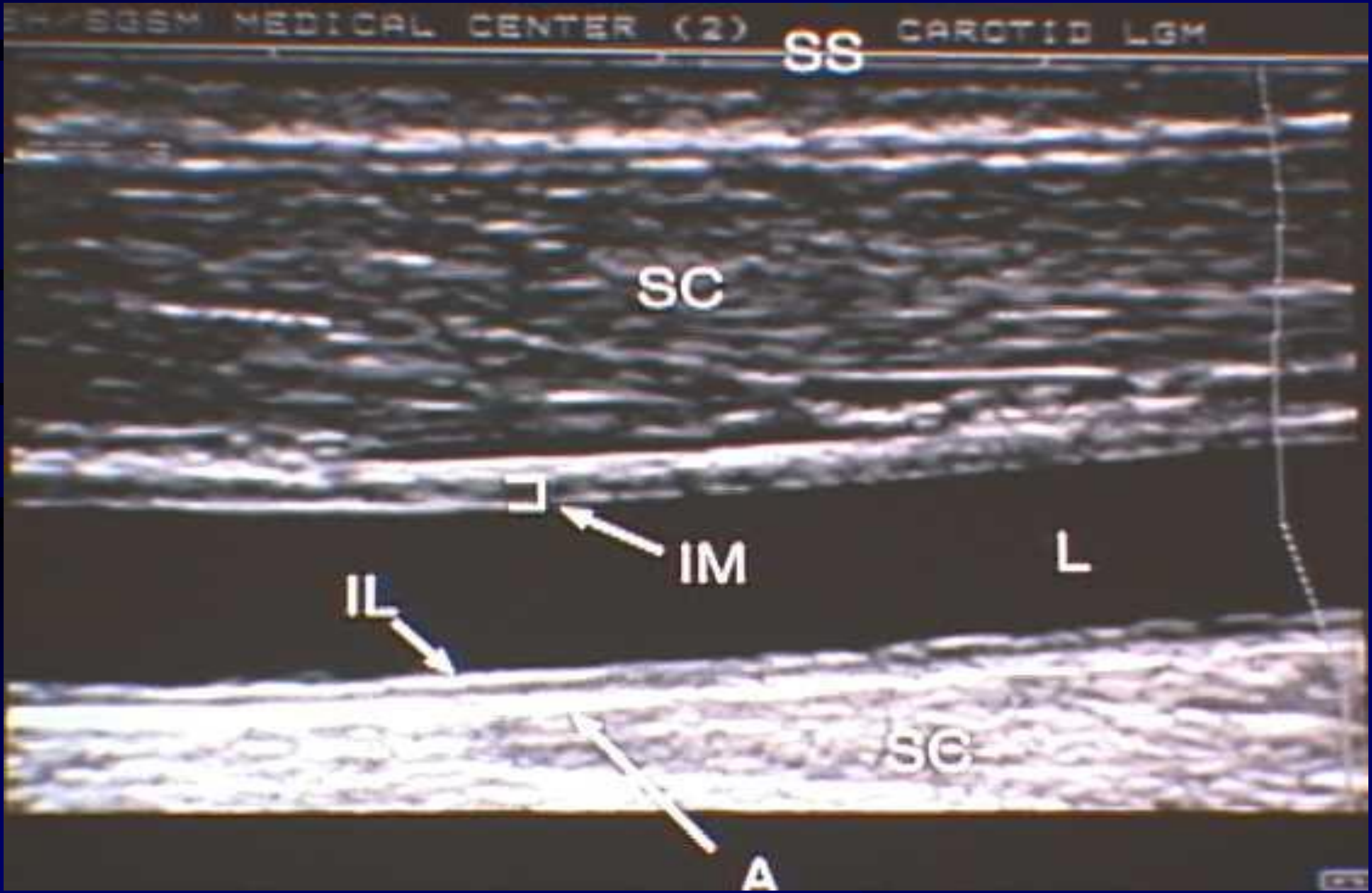
Riley WA, Neurosonology

Carotid Protocol & Techniques

Key Elements of Protocol – B-mode

- B-mode imaging gives 2-D gray scale image of vessel, wall, plaque, & soft tissue
- Location, size, course of vessels
- Information on plaque features including surface (smooth, irregular, ulcer), texture (homogeneous/heterogeneous), echodensity, and movements (pulsation pattern)

B-Mode Landmarks

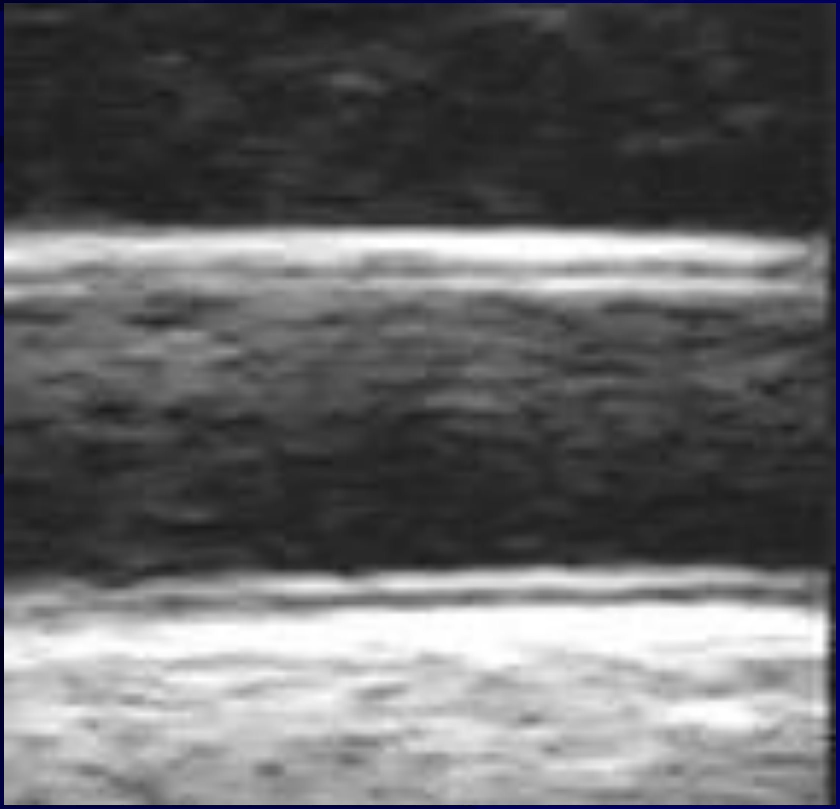


B-Mode Image – CCA Longitudinal

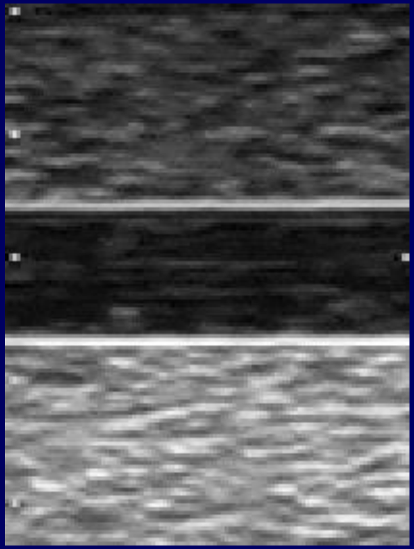
near

lumen

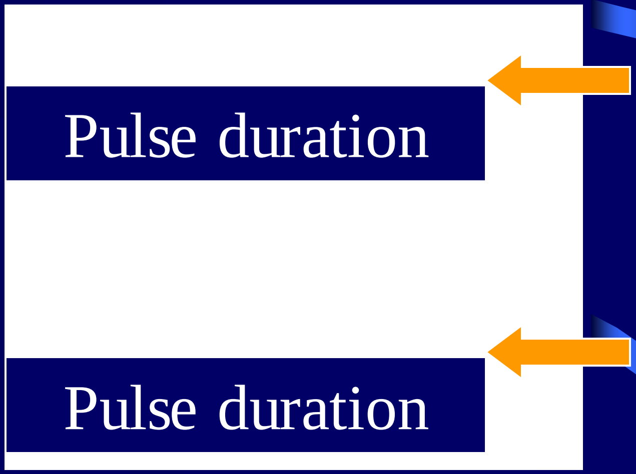
far



cylinder

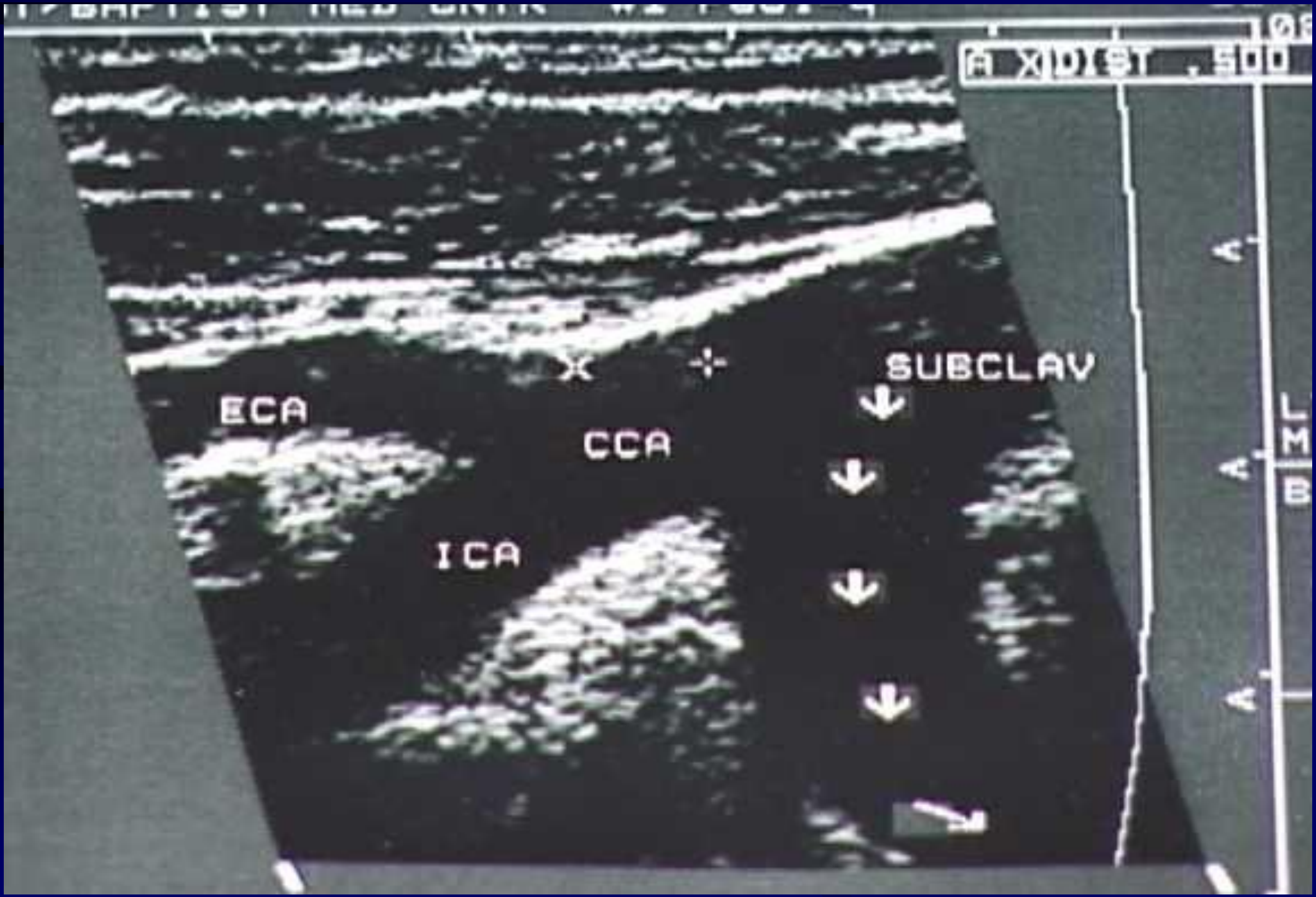


Measurement of CIMT



CCA Tortuosity

Short/Absent CCA



B-Mode Imaging

Plaque Characteristics Assessed

- Location / Distribution
- Plaque thickness
- Surface features
- Texture / Heterogeneity
- Echodensity / Calcification
- Real-time pulsation pattern

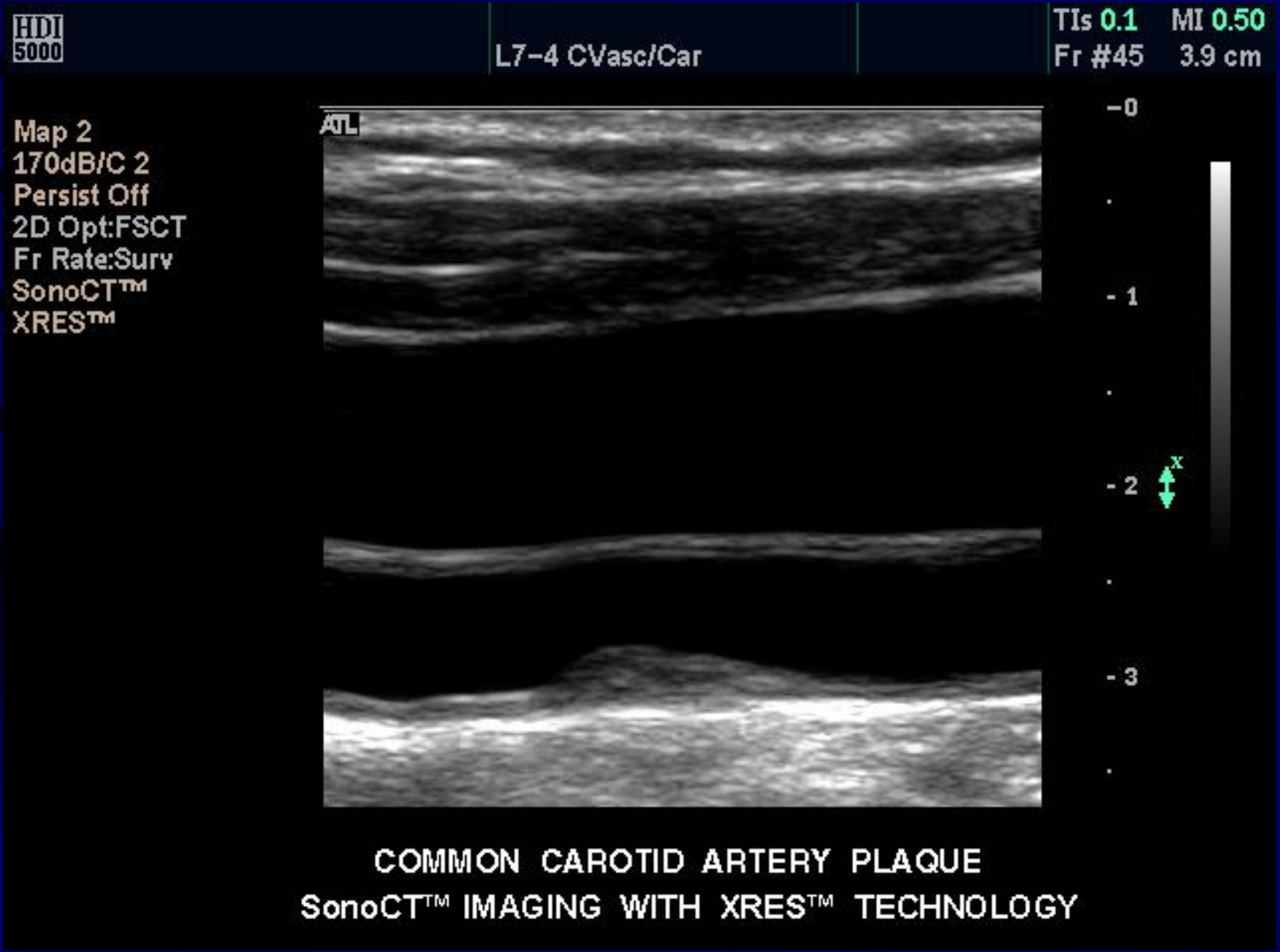
Carotid Plaque Criteria
WFUBMC

Plaque Category	Measurement
Normal	< 1.1 mm
Minimal / Mild	1.1 – 2.0 mm
Moderate	2.1 – 4.0 mm
Large / Severe	> 4.0 mm

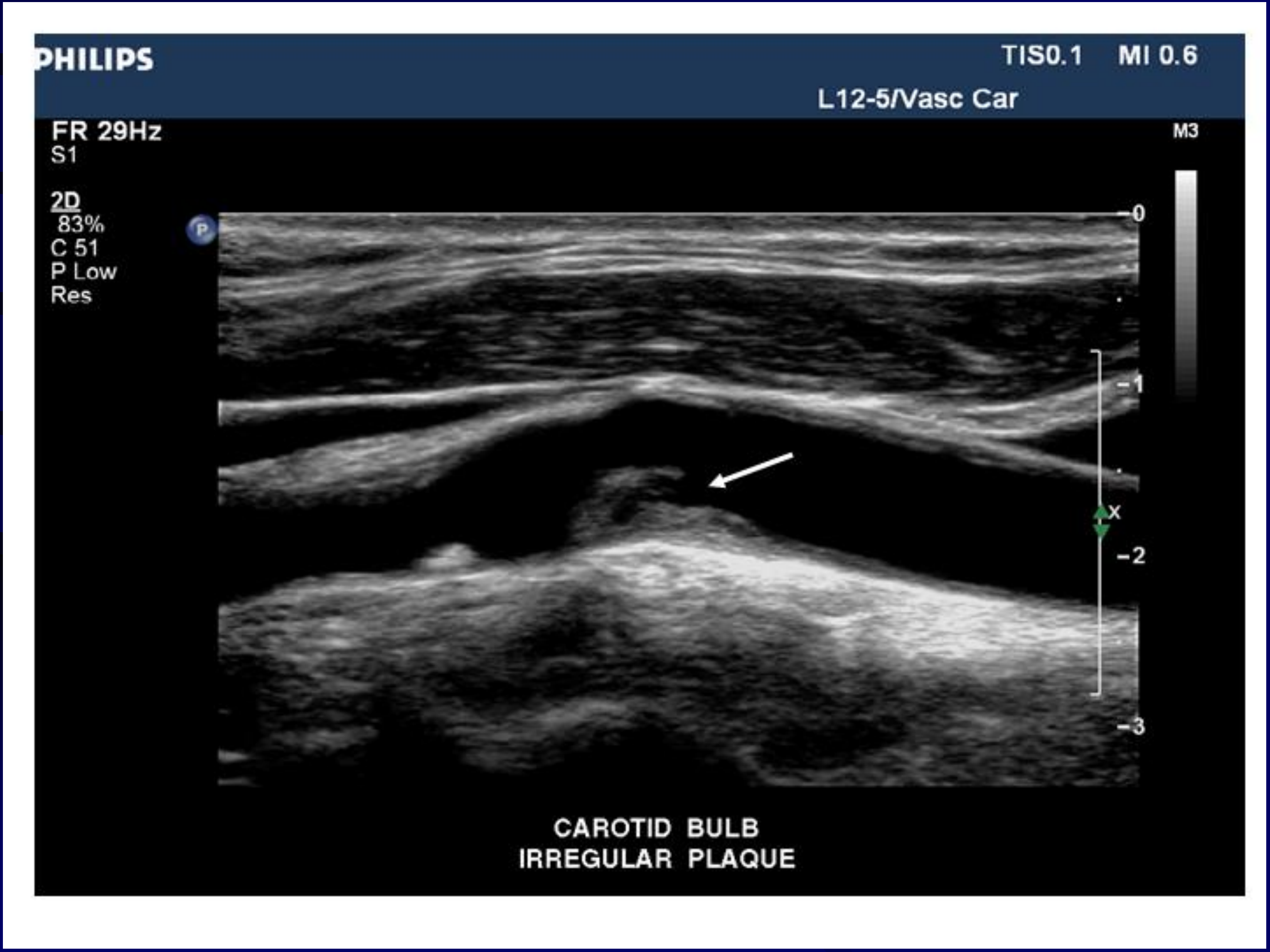
Plaque Features
WFUBMC

Plaque Features	Descriptors / Parameters
Location	Specific vessel segment
Surface Features	Smooth, Irregular, Crater/Ulcer/Niche
Texture / Composition	Homogeneous, Heterogeneous /mixed, Possible intraplaque hemorrhage
Echodensity	Hypechoic, Echogenic, Hyperechoic/dense, +/- shadowing
Plaque Motion	Radial (normal), longitudinal

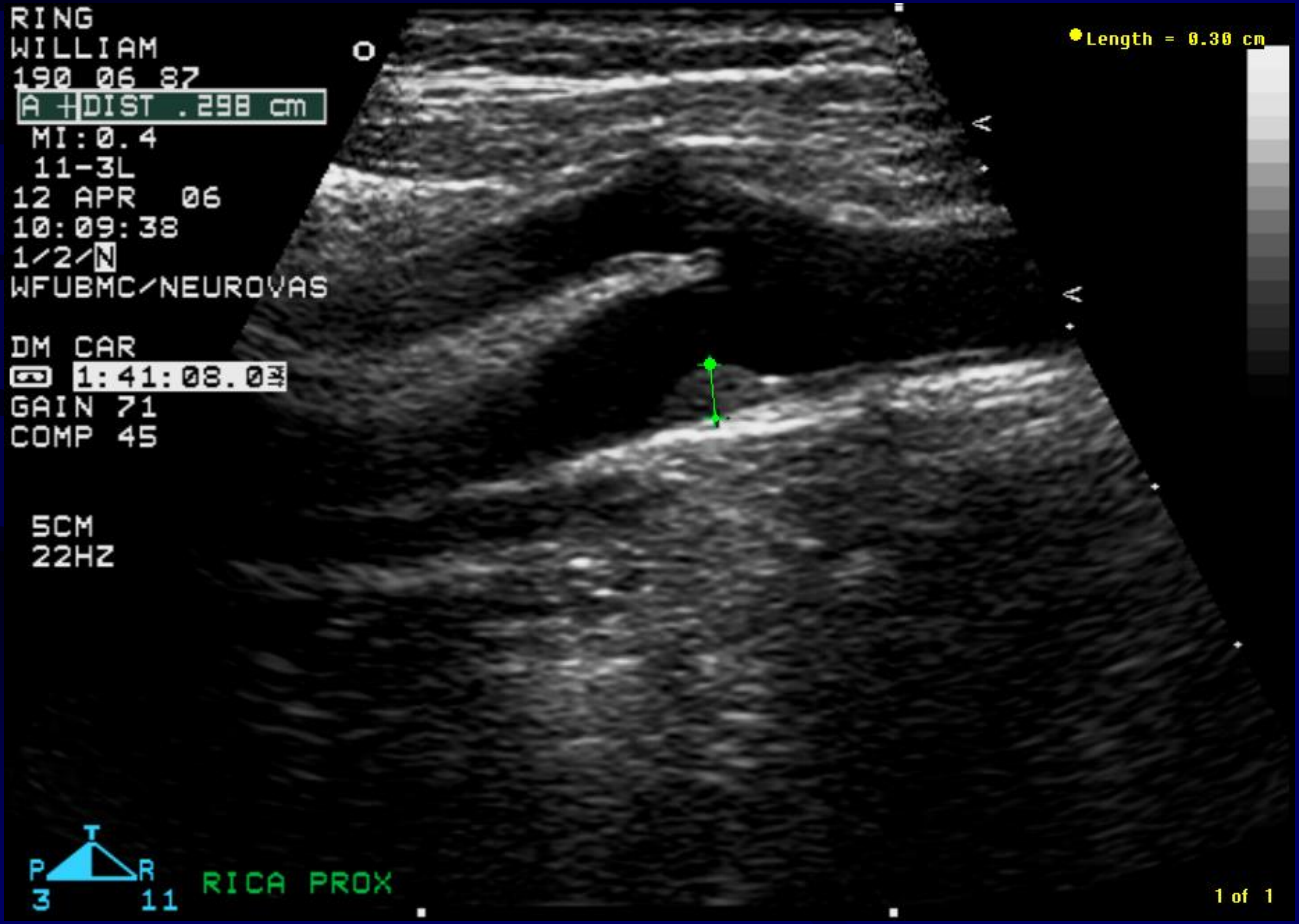
Smooth Carotid Plaque



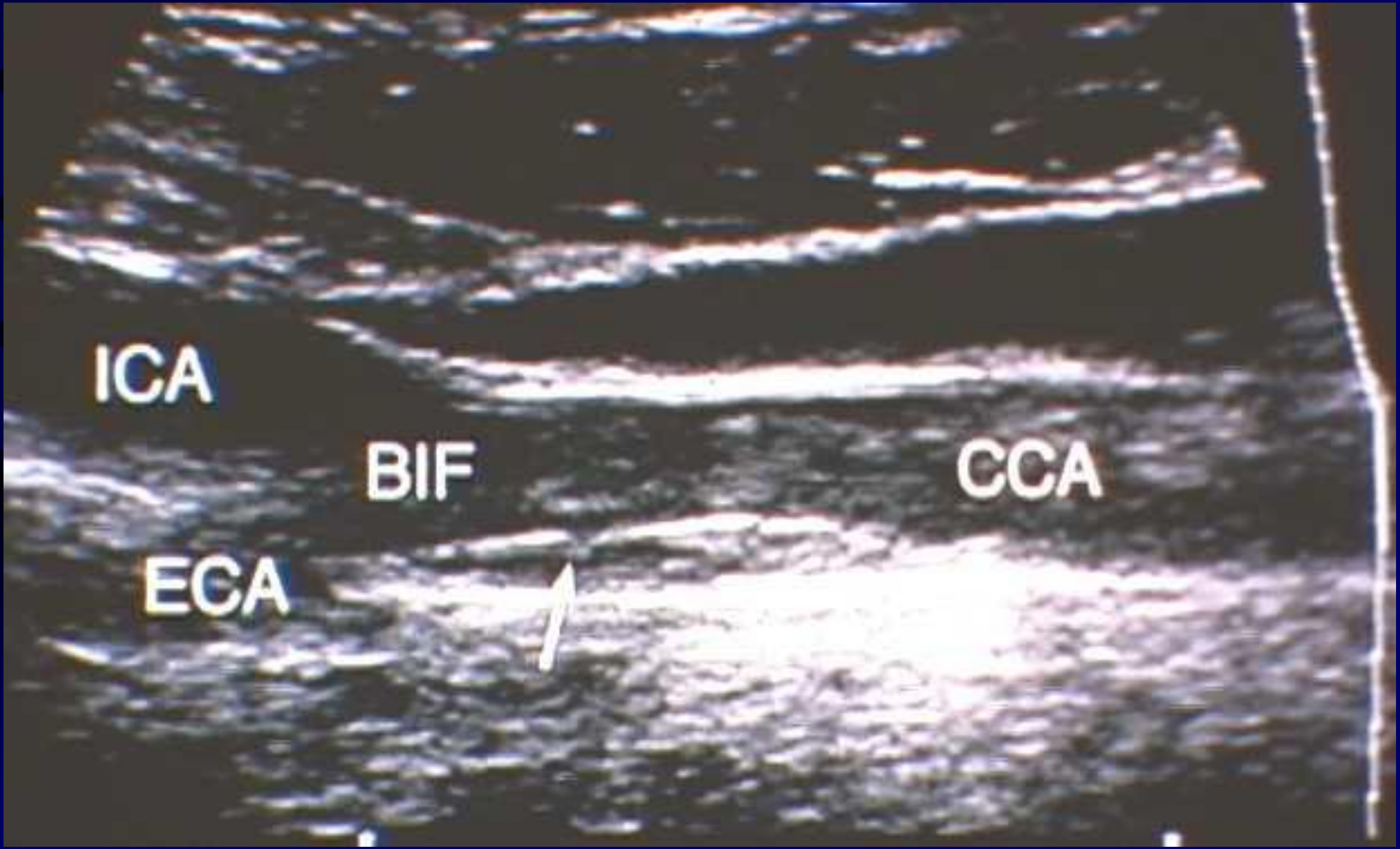
Irregular Plaque



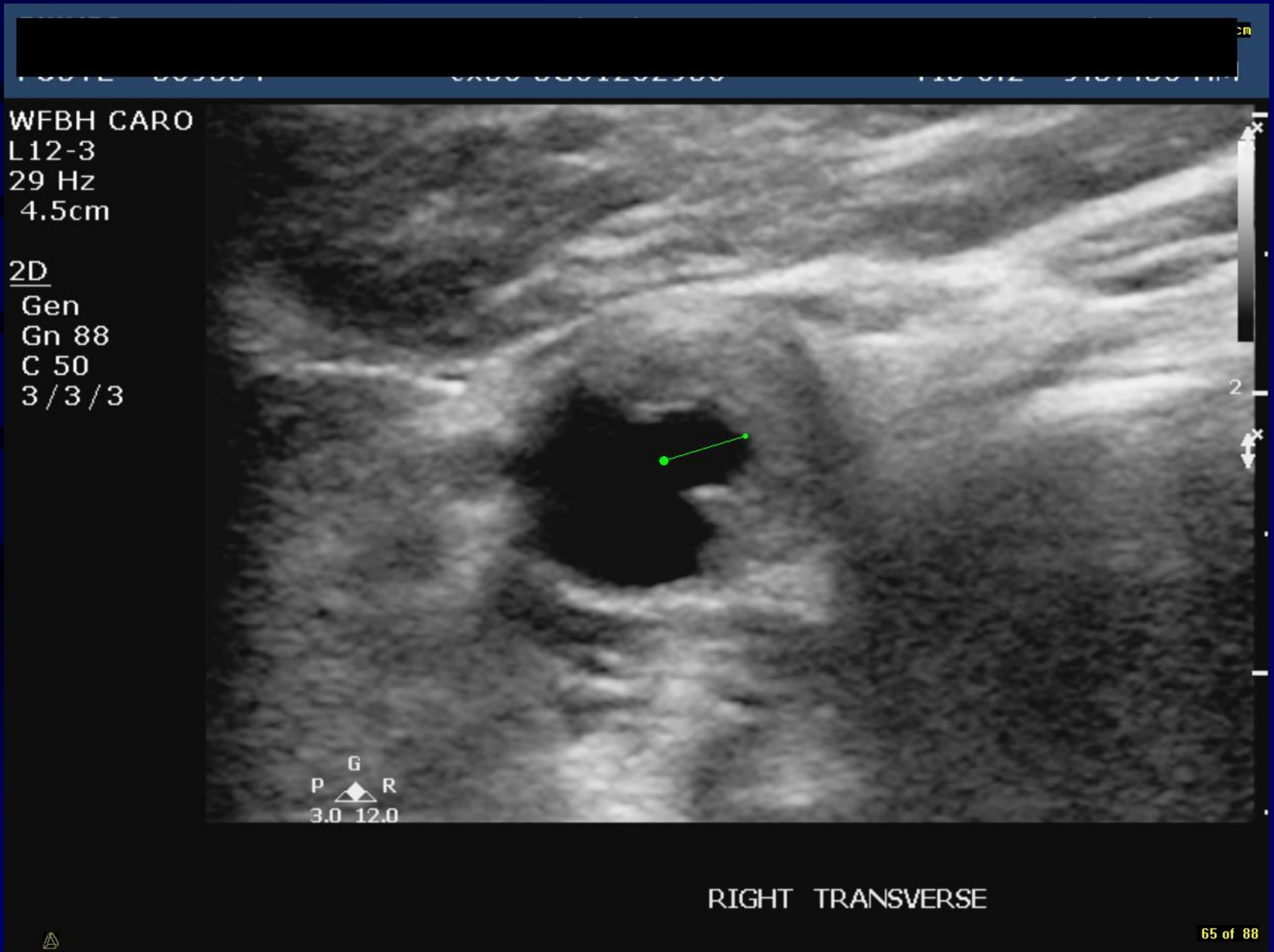
Homgeneous Plaque



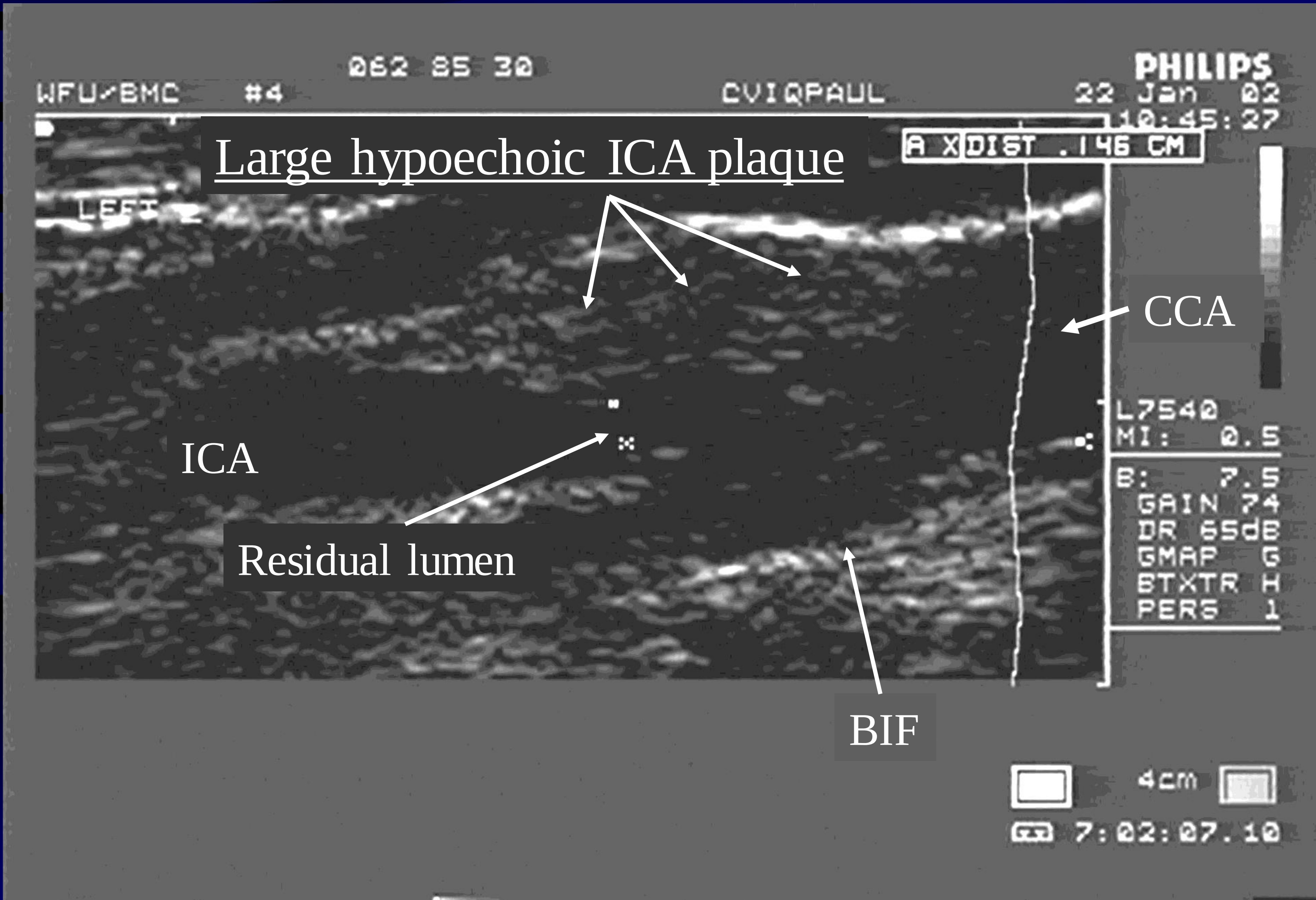
Plaque Features:
Smooth; Heterogeneous



Crater in CCA Plaque

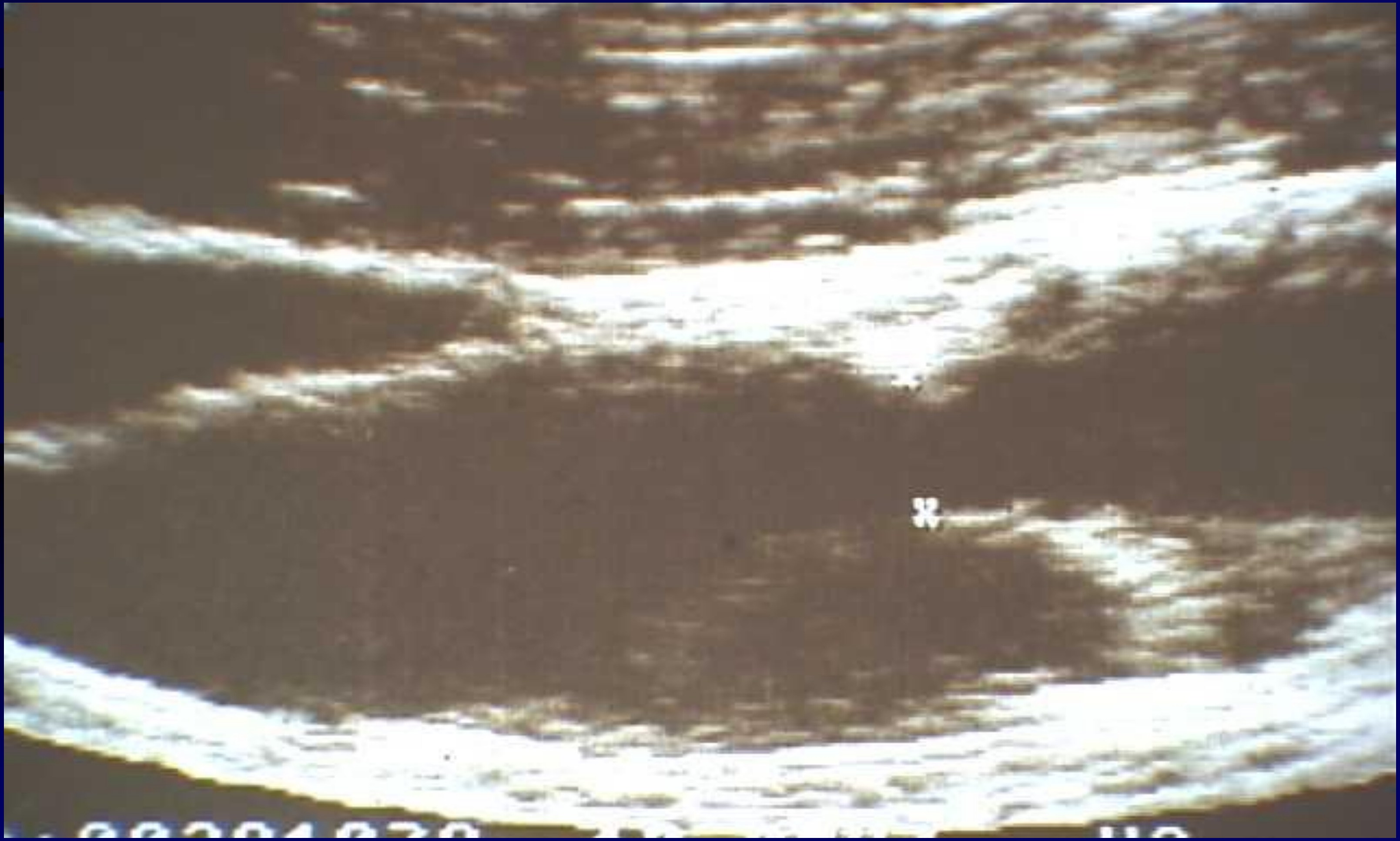


Plaque Features:
Crater filled with thrombus

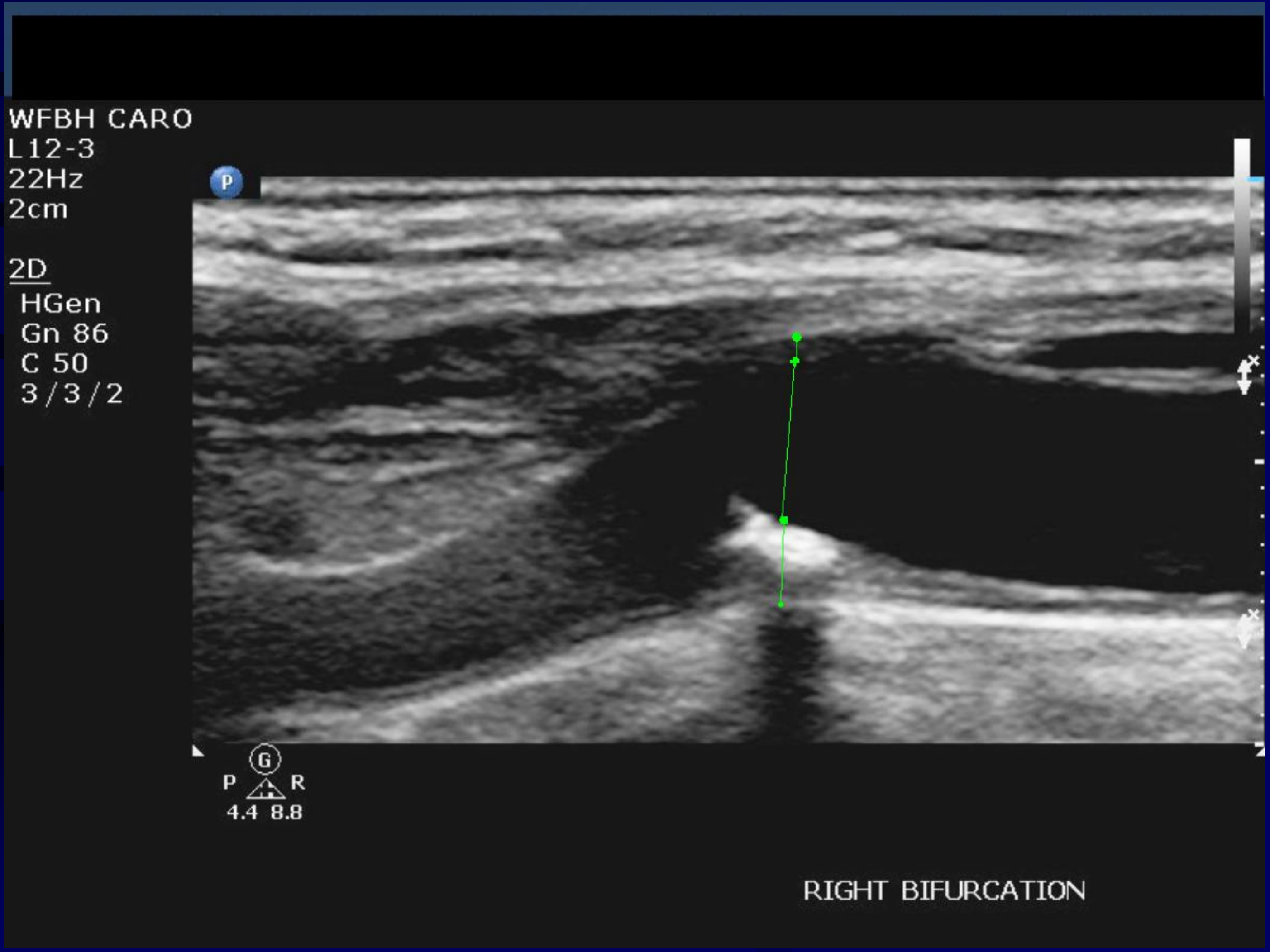


062 85 30
WFU/BMC
#4
CVIQPAUL
PHILIPS
22 Jan 02
10:45:27
Large hypoechoic ICA plaque
A X DIST .146 CM
LEFT
CCA
L7540
MI: 0.5
ICA
B: 7.5
GAIN 74
DR 65dB
GMAP G
BTXTR H
PERS 1
Residual lumen
BIF
4cm
7:02:07.10

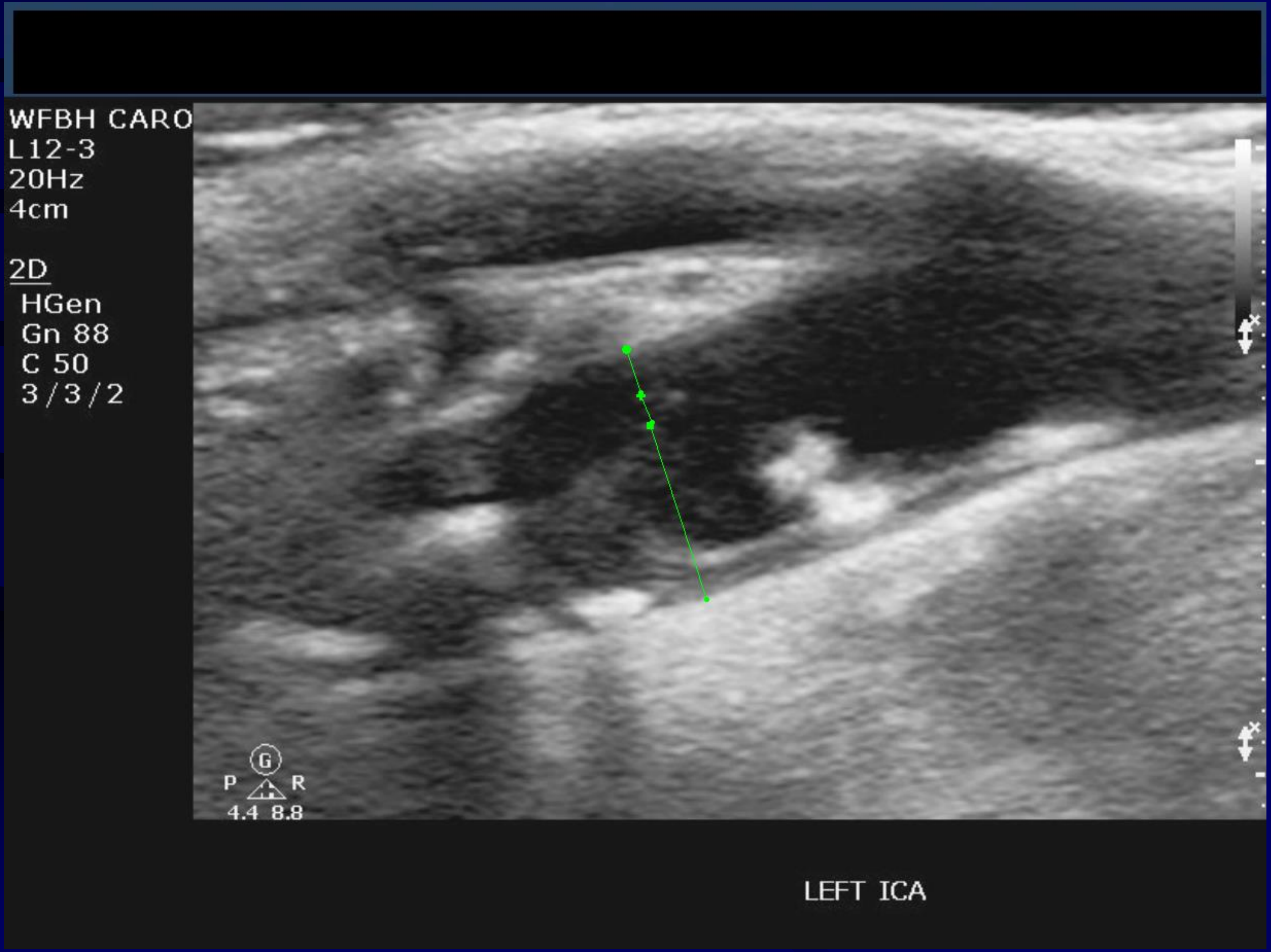
Plaque Features:
Hypoechoic region/? IPH



Calcification with Acoustic Shadowing



Complex ICA Plaque



Carotid Protocol & Techniques

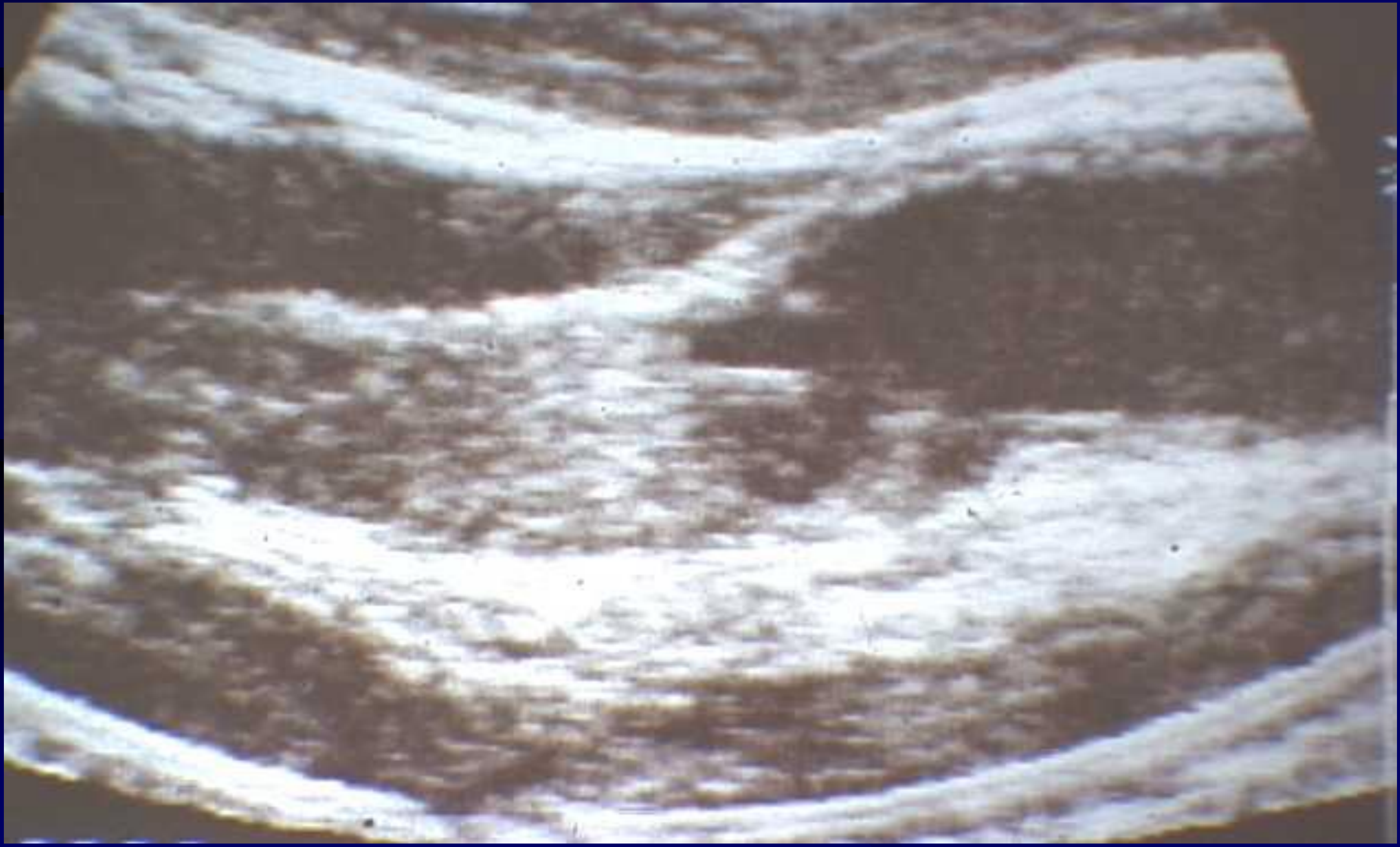
Key Elements of Protocol – B-mode

- Measurements made on B-mode image of plaque thickness and residual lumen
- Measurements from view with optimal or best image of lesion
- When possible document location relative to internal landmark (flow divider)

Plaque Characteristics

- Suffered from lack of standardized nomenclature and scheme
- Many suggested systems, but pathologic correlations mixed
- More emphasis on hemodynamics, color flow, technical challenges, and time

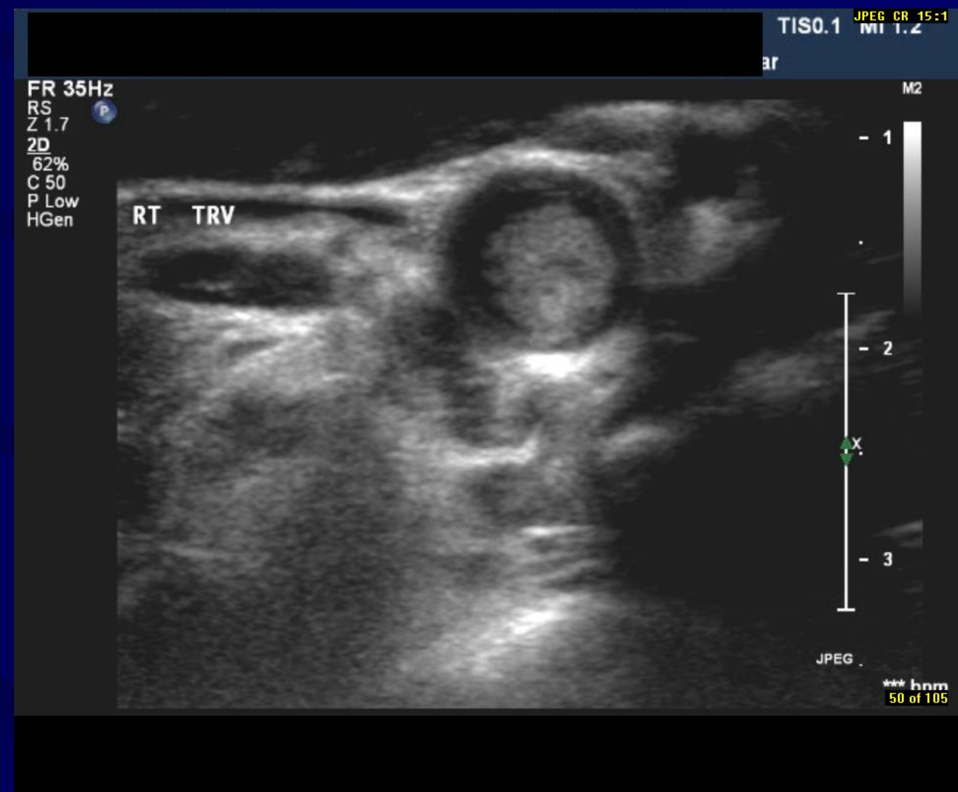
Thrombosis/Occlusion of ICA



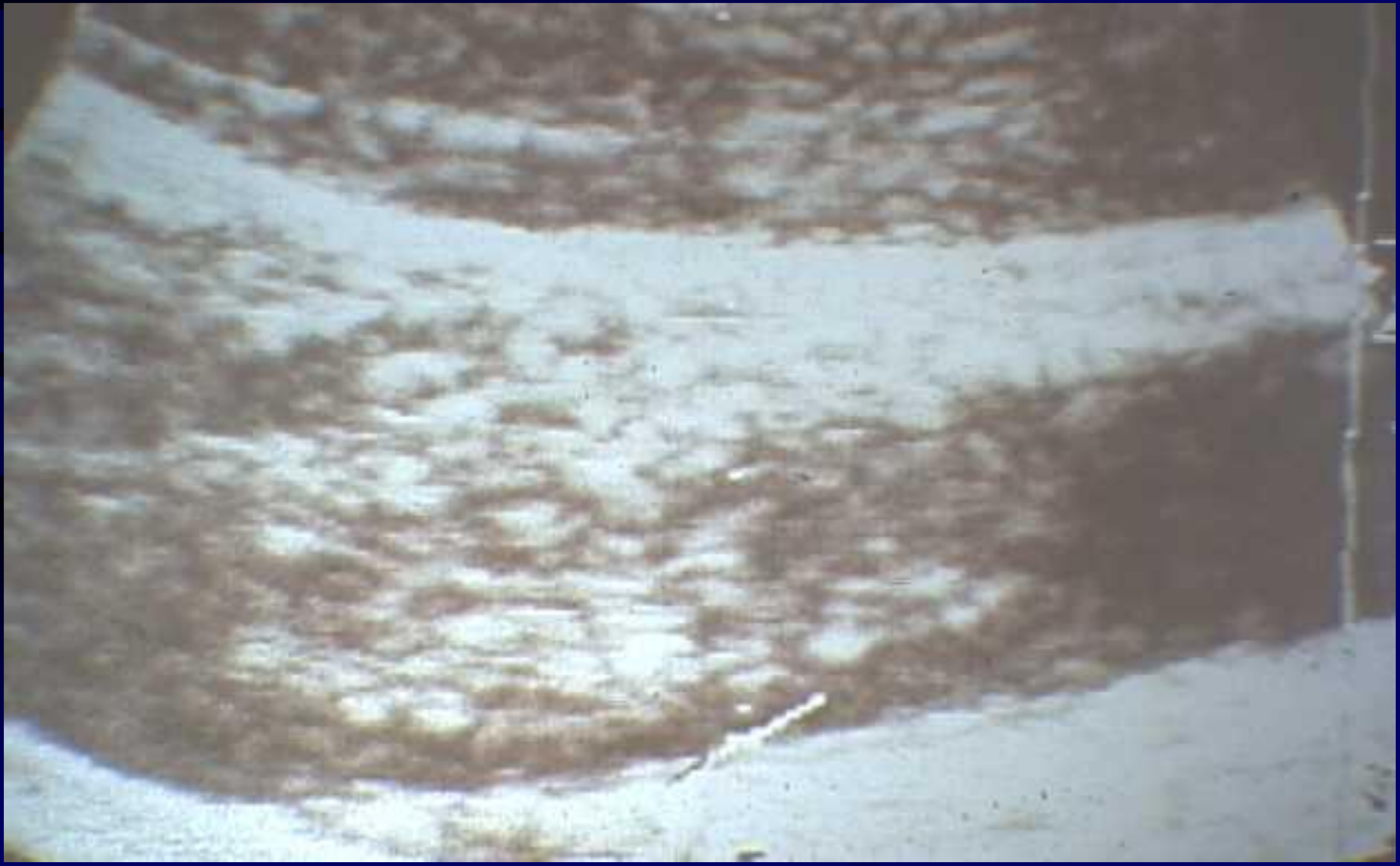
CCA Thrombus in Acute Stroke

Longitudinal

Transverse



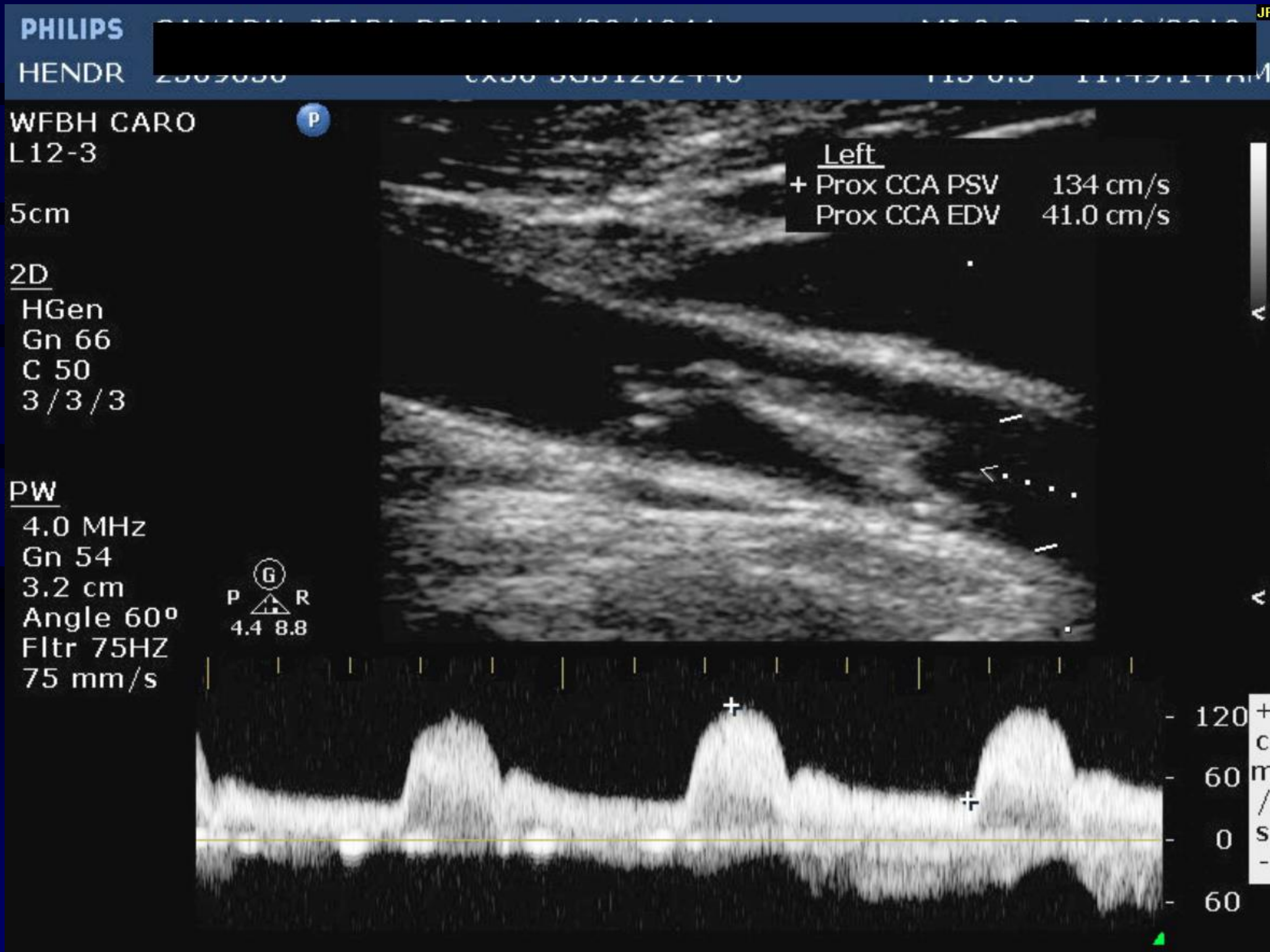
Thrombus in Wall (Dissection)



ICA Dissection

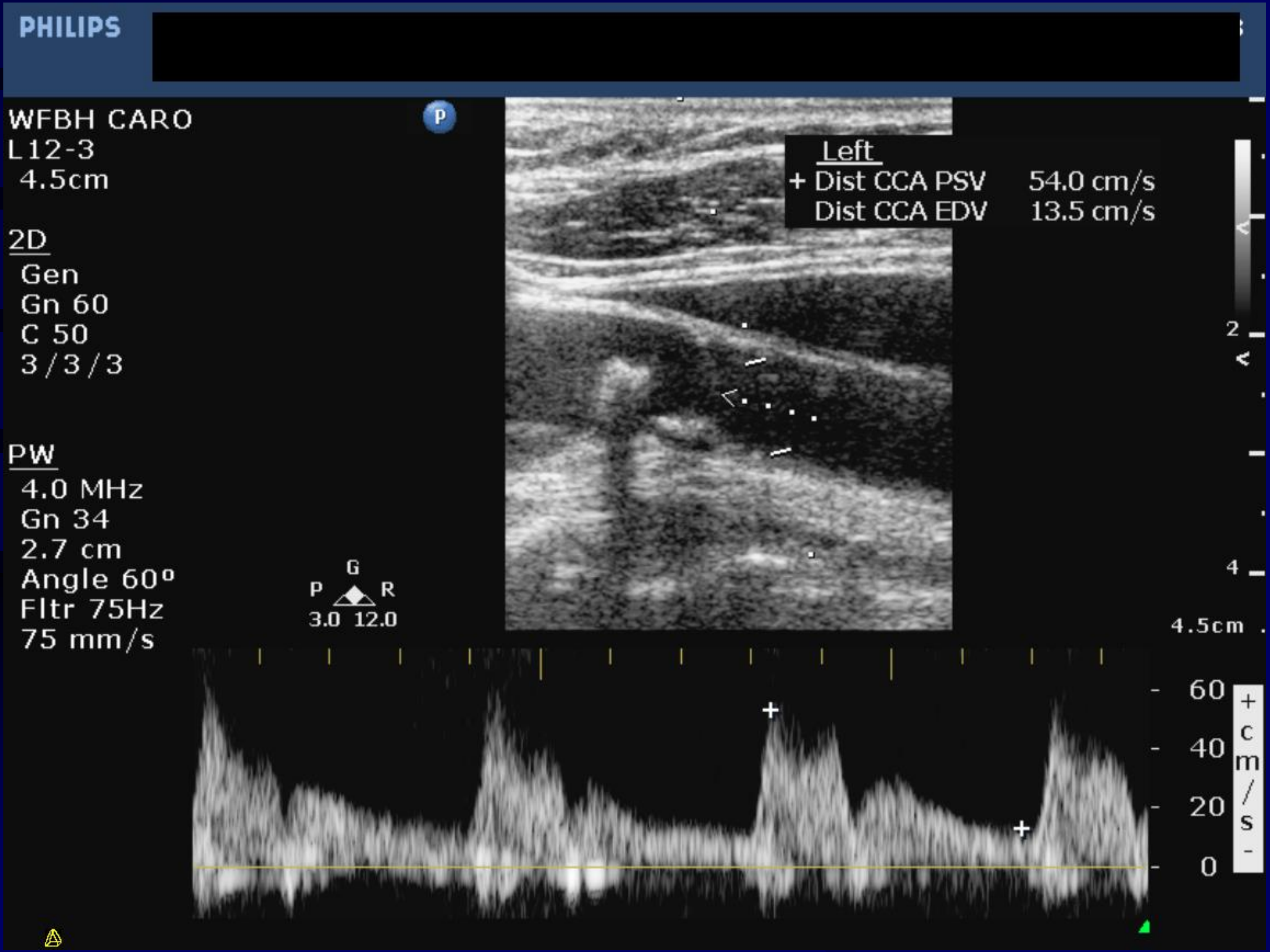
Transverse View

Thrombus in CCA (Tiger)

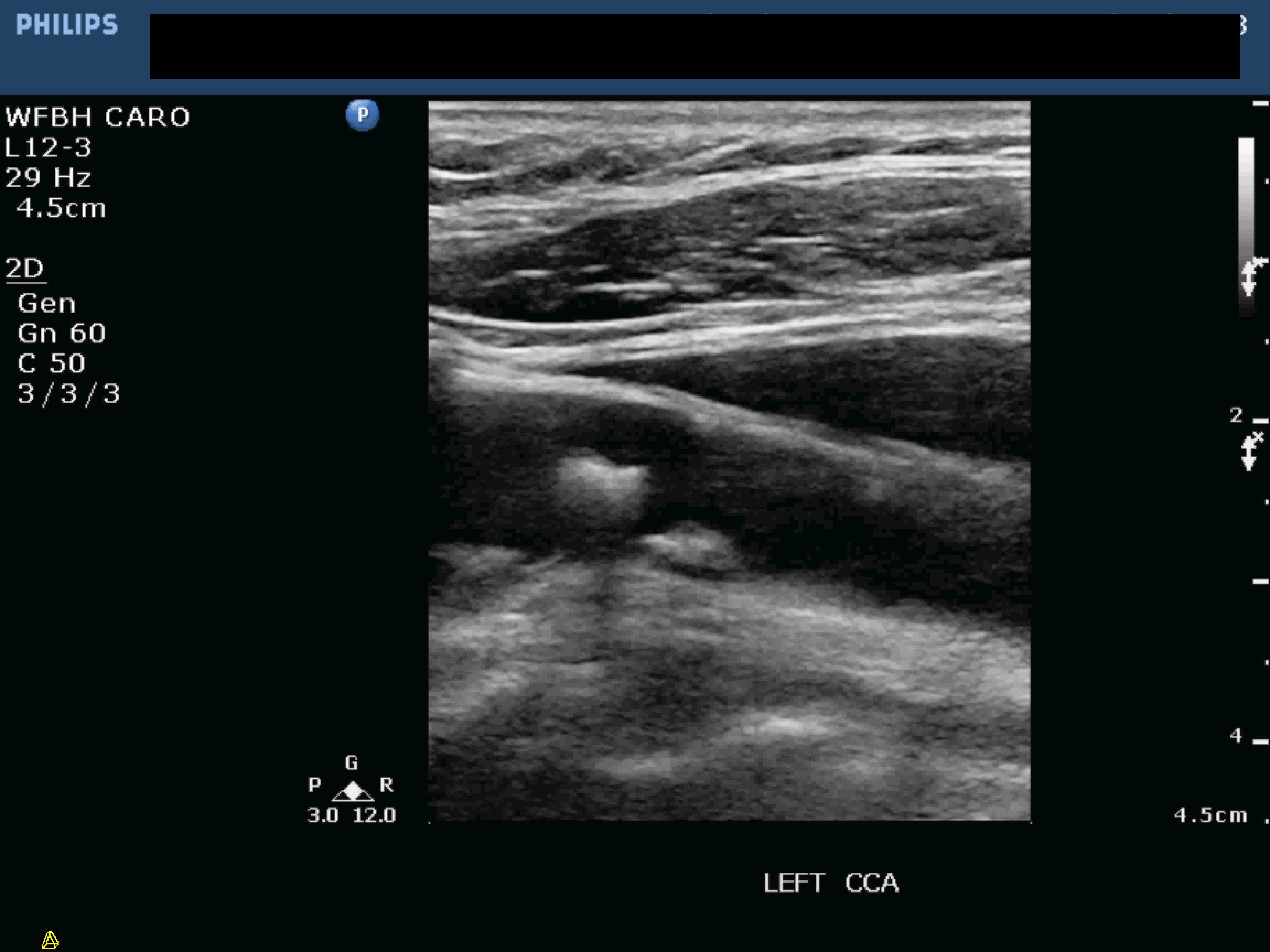


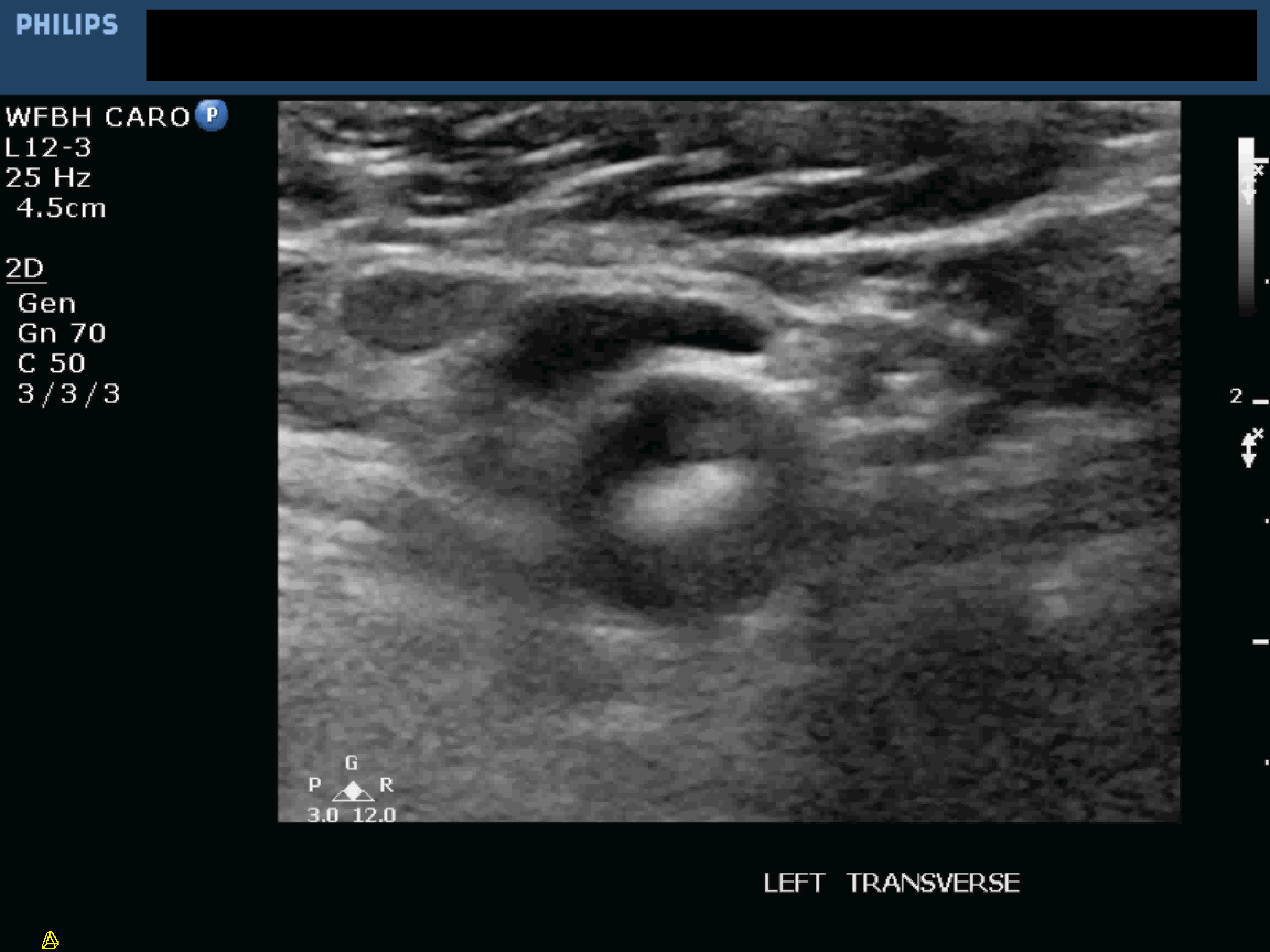

WFBH CARO
L12-3
20Hz
4cm
2D
HGen
Gn 86
C 50
3/3/2
RIGHT ICA

Mobile Lesion Distal CCA

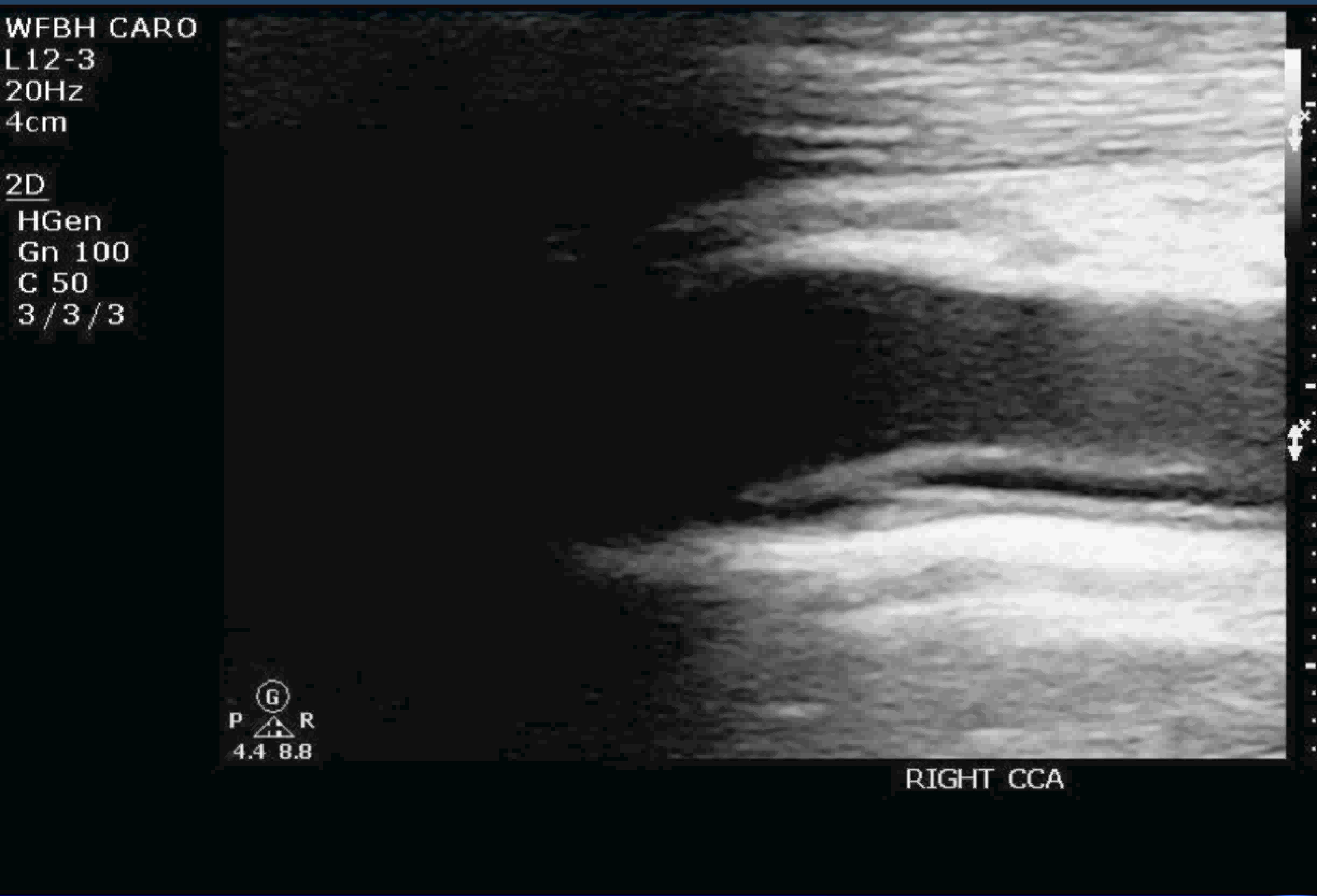



0:34 AM
PHILIPS
BARGO
[redacted]
M
WFBH CARO
L12-3
18Hz
5cm
2D
HGen
Gn 72
C 50
3 / 3 / 2
P
G
P R
4.4 8.8
LEFT ICA


PHILIPS
[redacted]
WFBH CARO
L12-3
29 Hz
4.5cm
2D
Gen
Gn 60
C 50
3 / 3 / 3
G
P
R
3.0 12.0
2
4
4.5cm
LEFT CCA

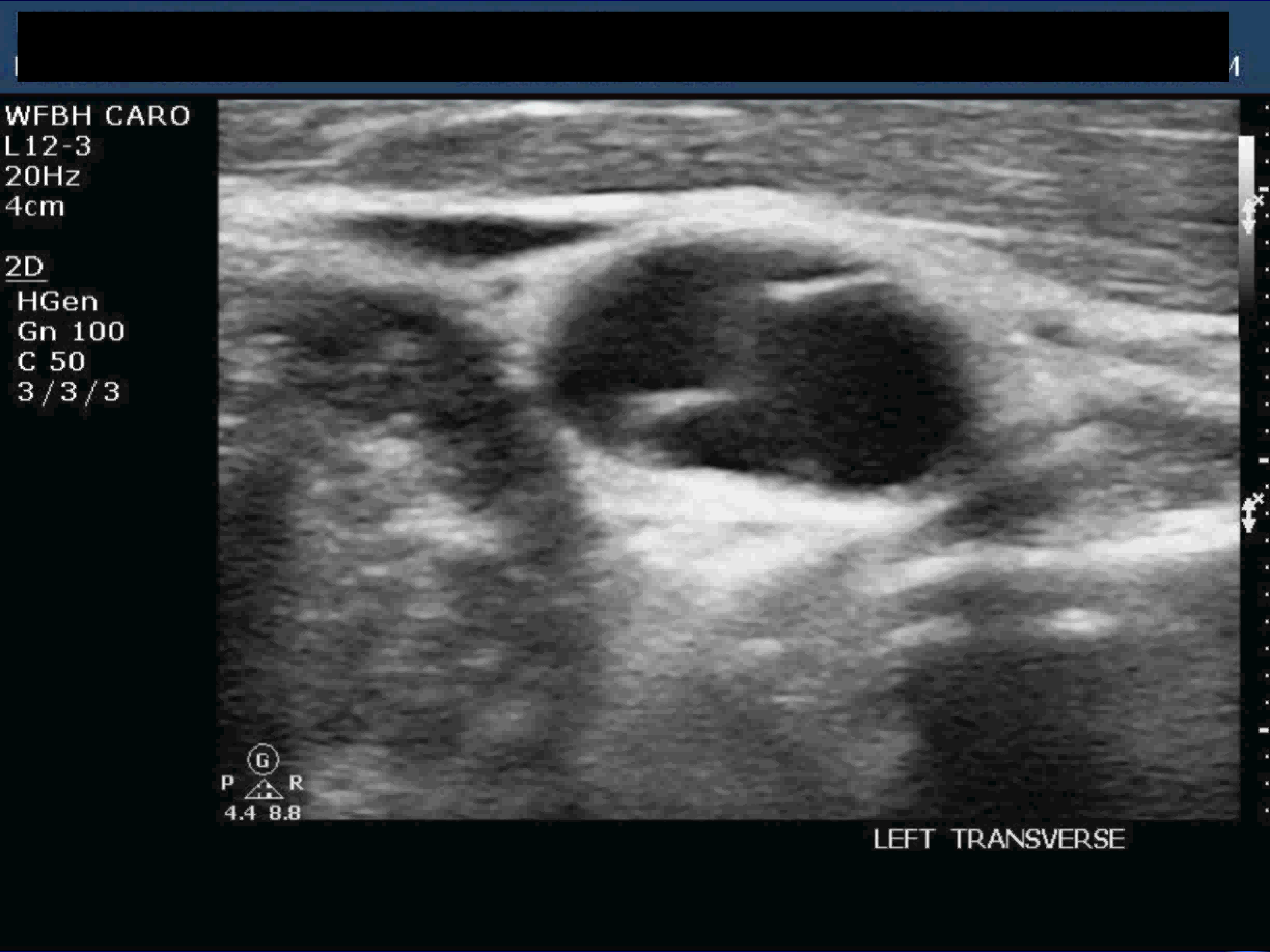

PHILIPS
WFBH CARO
L12-3
25 Hz
4.5cm
2D
Gen
Gn 70
C 50
3 / 3 / 3
G
P
R
3.0 12.0
2
LEFT TRANSVERSE

[redacted]


WFBH CARO
L12-3
20Hz
4cm
2D
HGen
Gn 100
C 50
3 / 3 / 3
G
P
R
4.4 8.8
RIGHT CCA

[redacted]

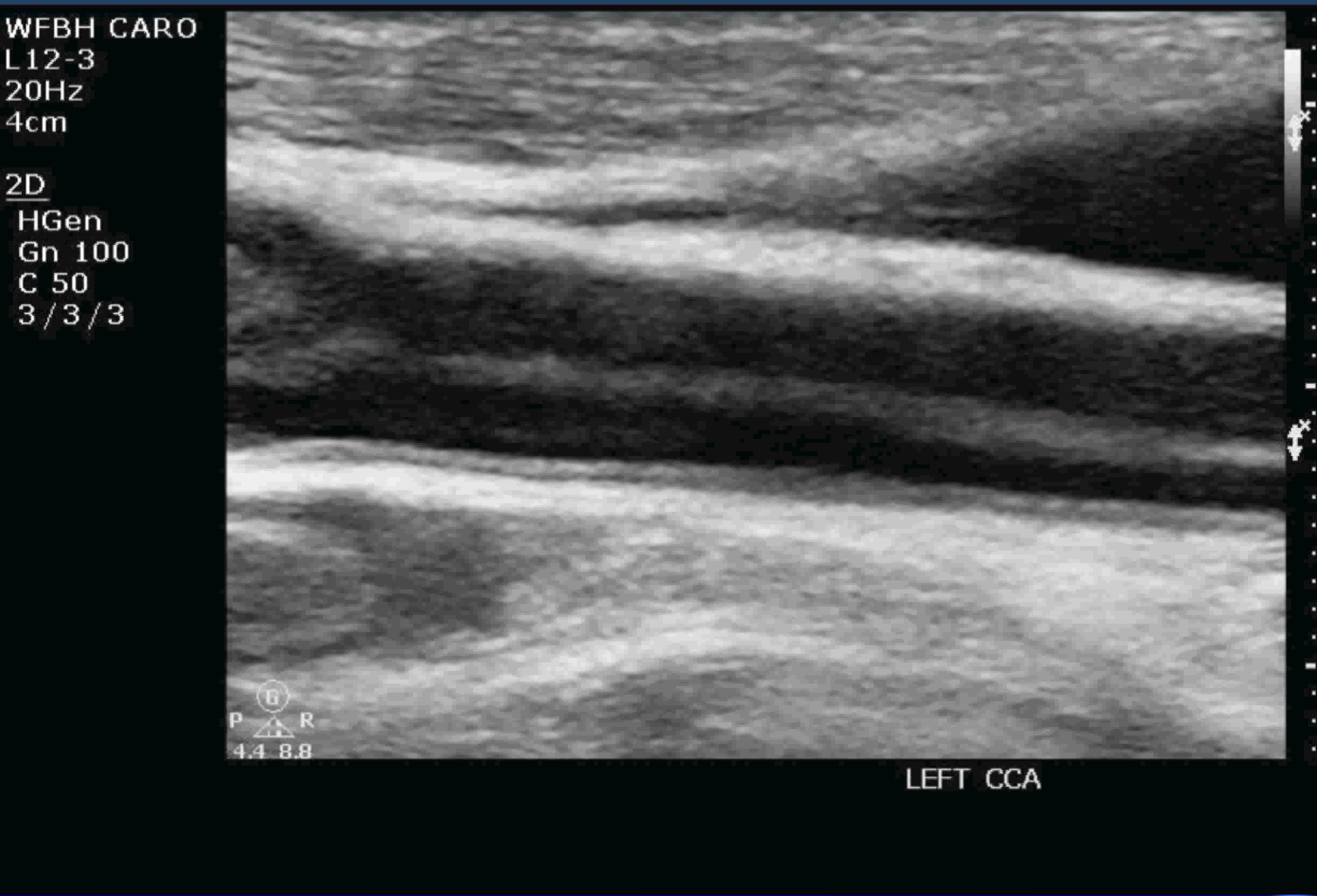

WFBH CARO
L12-3
20Hz
4cm
2D
HGen
Gn 100
C 50
3 / 3 / 3
G
P R
4.4 8.8
LEFT ICA


[redacted]
WFBH CARO
L12-3
20Hz
4cm
2D
HGen
Gn 100
C 50
3 / 3 / 3
G
P
R
4.4 8.8
LEFT TRANSVERSE

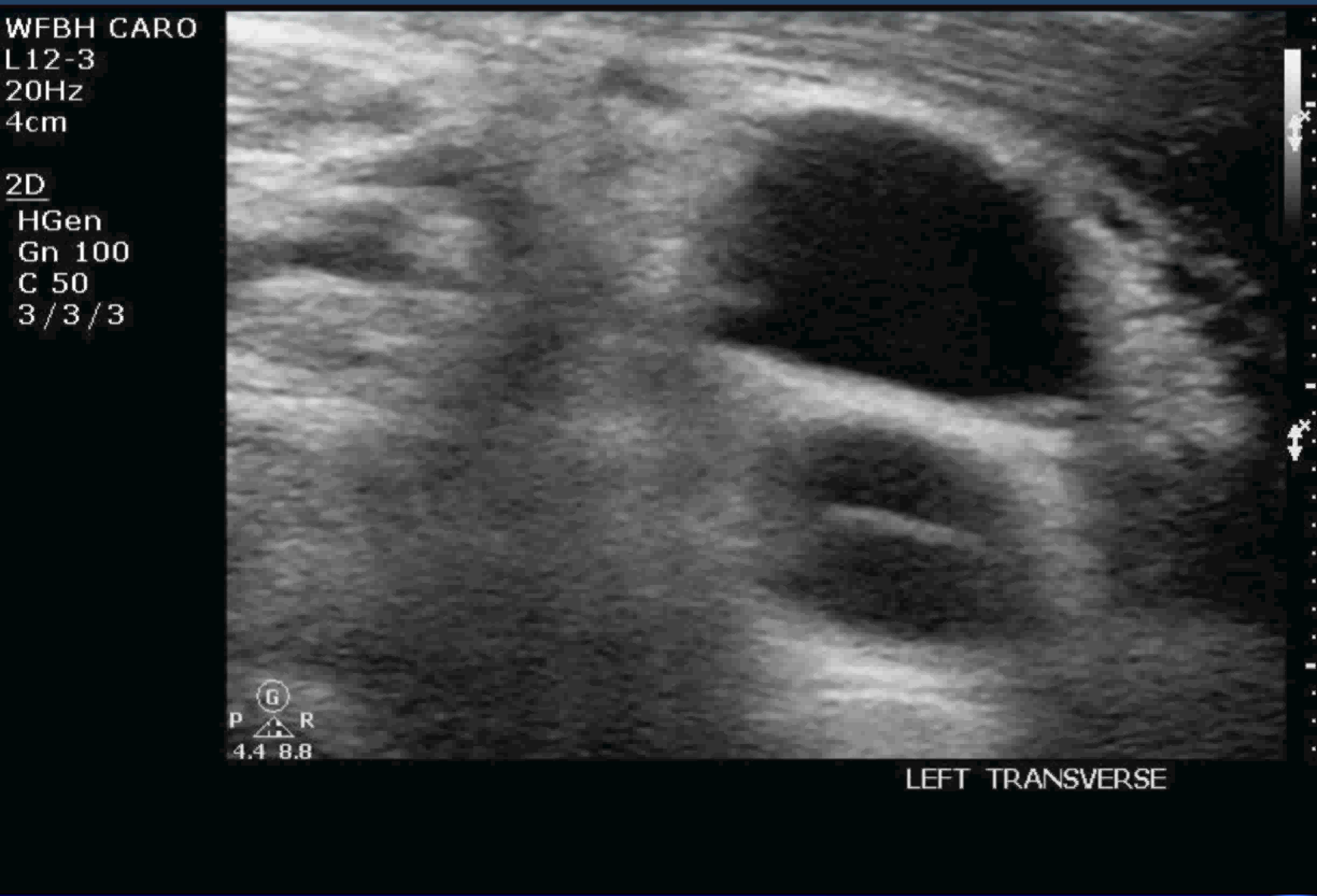
[redacted]

WFBH CARO
L12-3
20Hz
4cm
2D
HGen
Gn 100
C 50
3 / 3 / 3
G
P
R
4.4 8.8
LEFT BIFURCATION

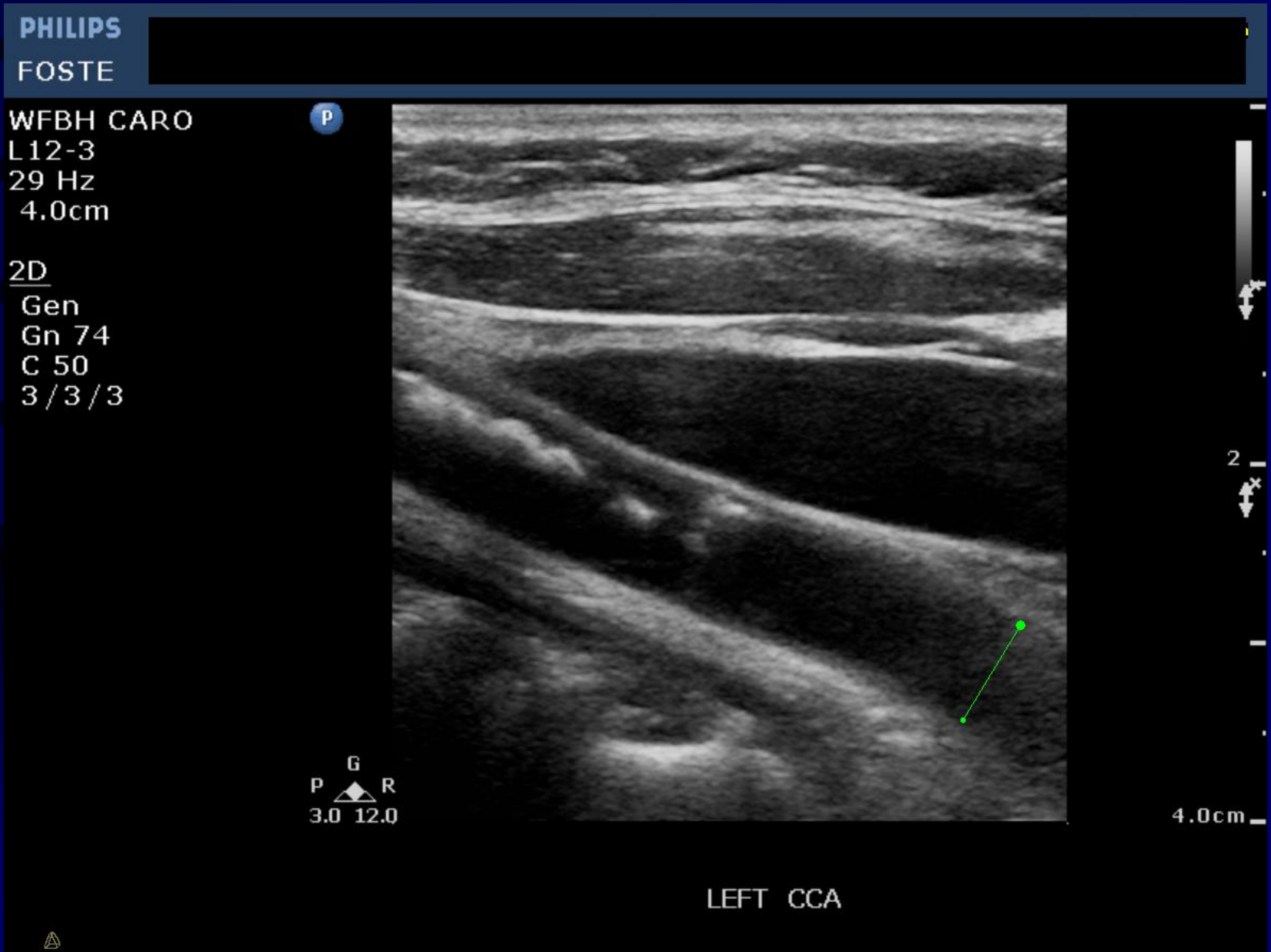
[redacted]



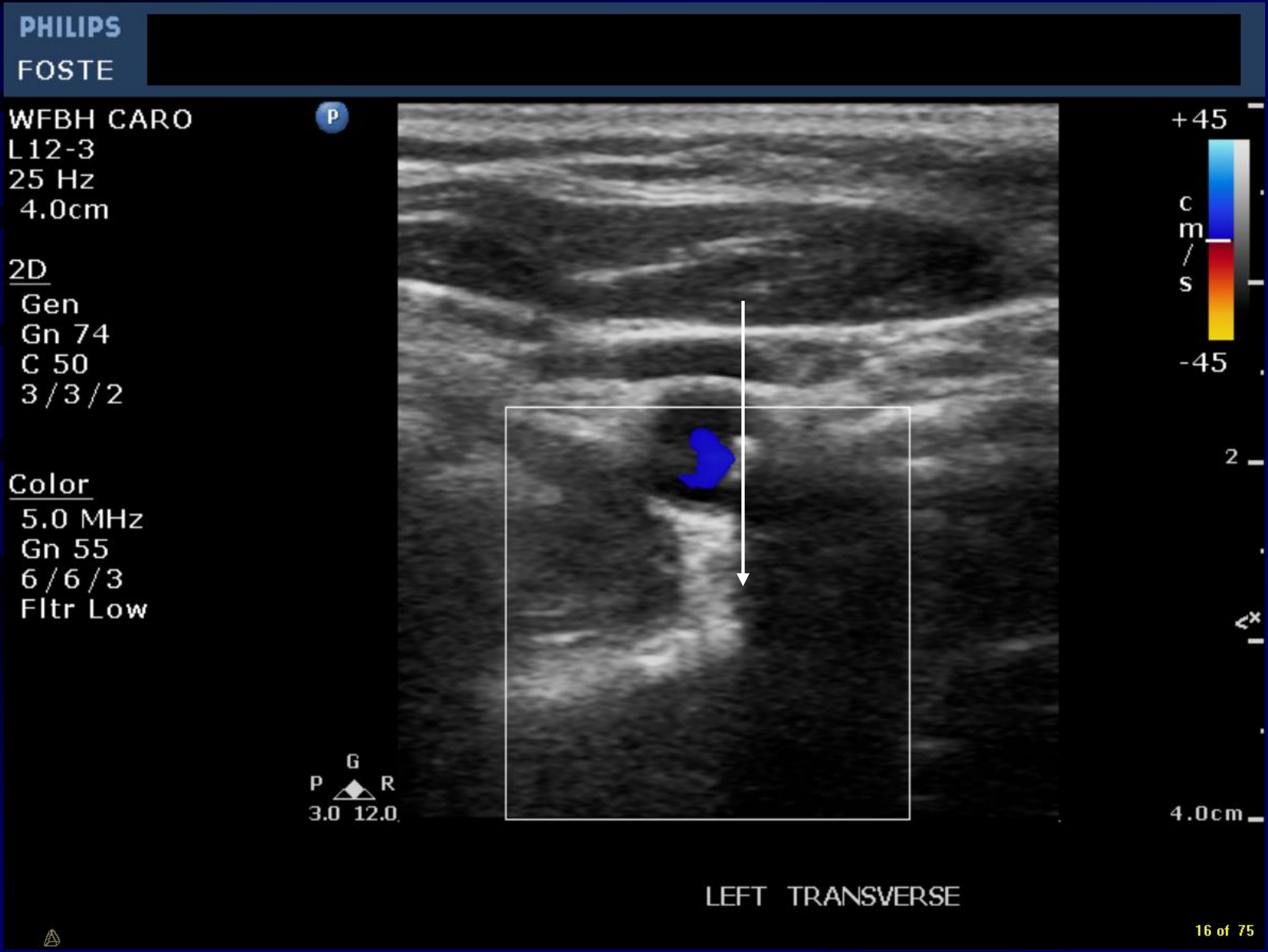
[redacted]


WFBH CARO
L12-3
20Hz
4cm
2D
HGen
Gn 100
C 50
3 / 3 / 3
P
R
4.4 8.8
LEFT TRANSVERSE

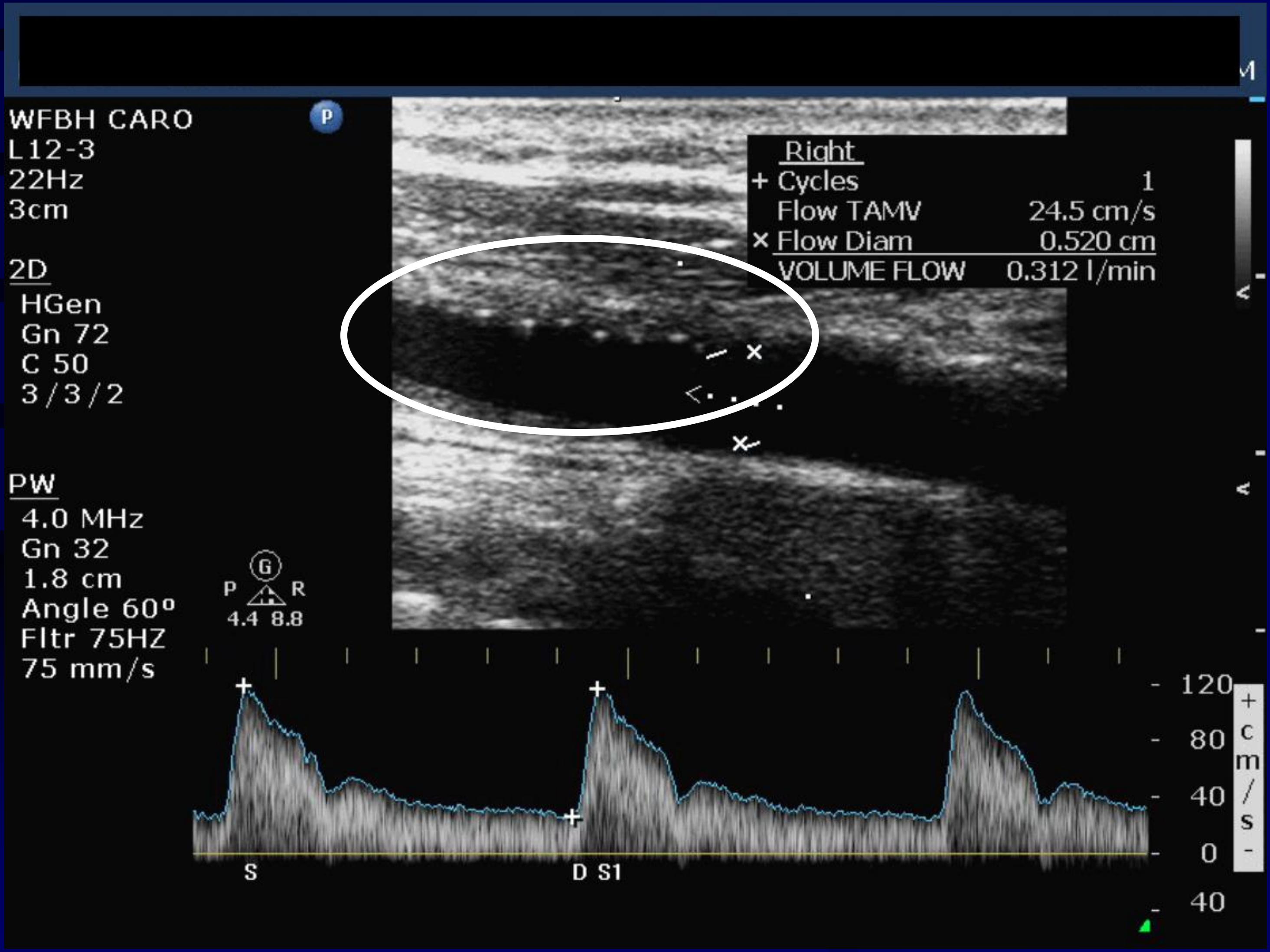
Side Wall Plaque



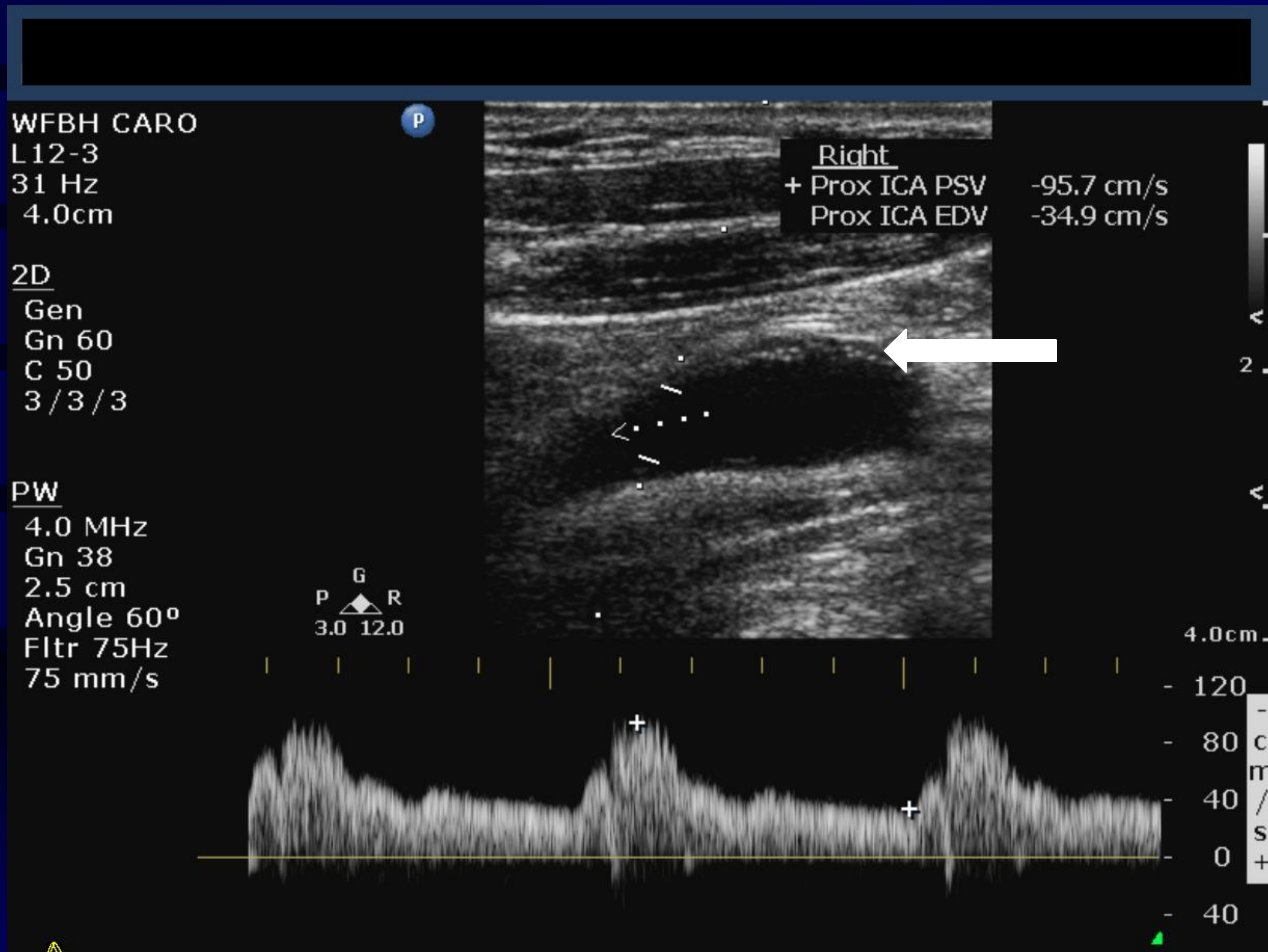
Side Wall Plaque



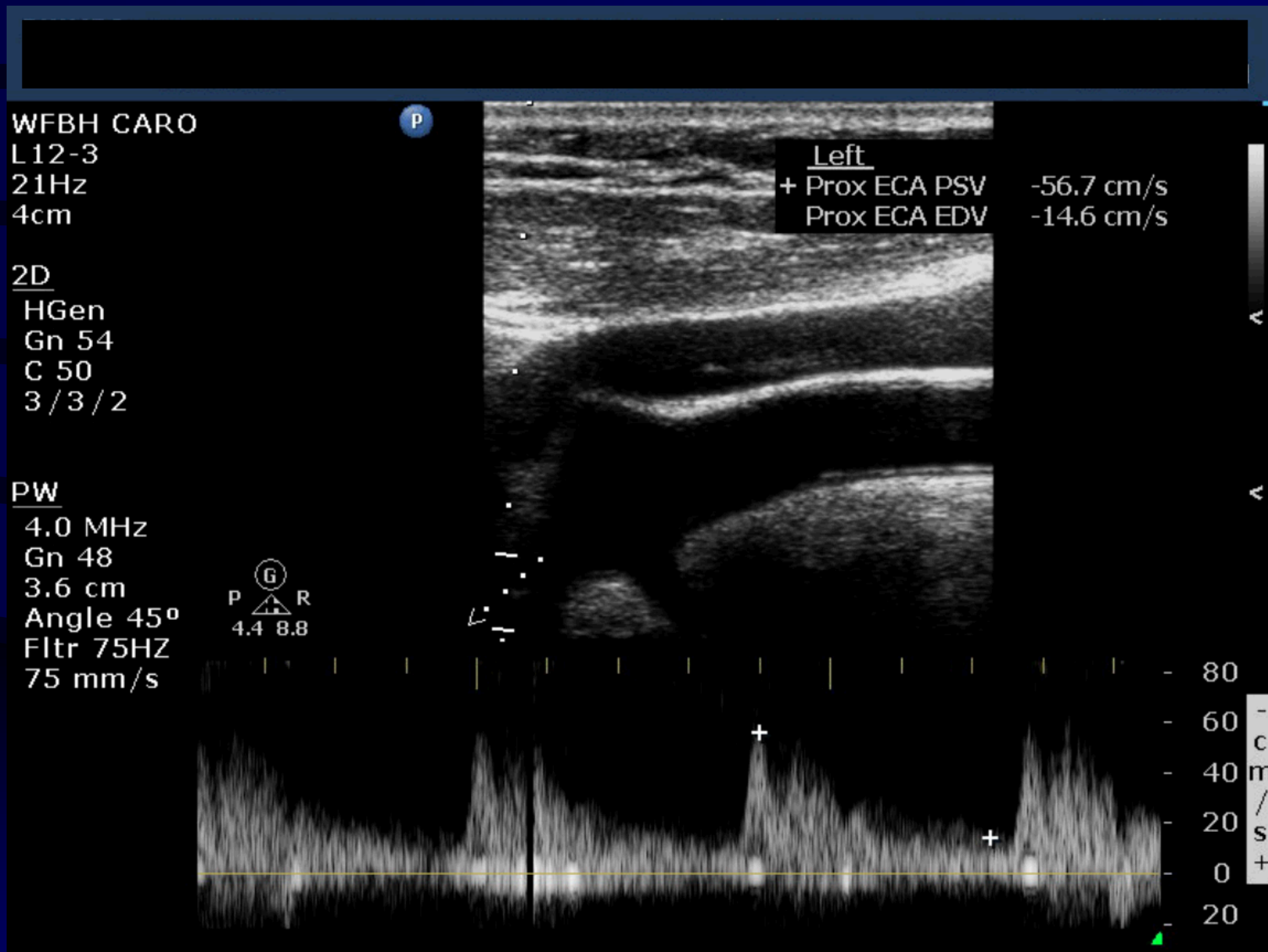
Prior CEA Suture Line



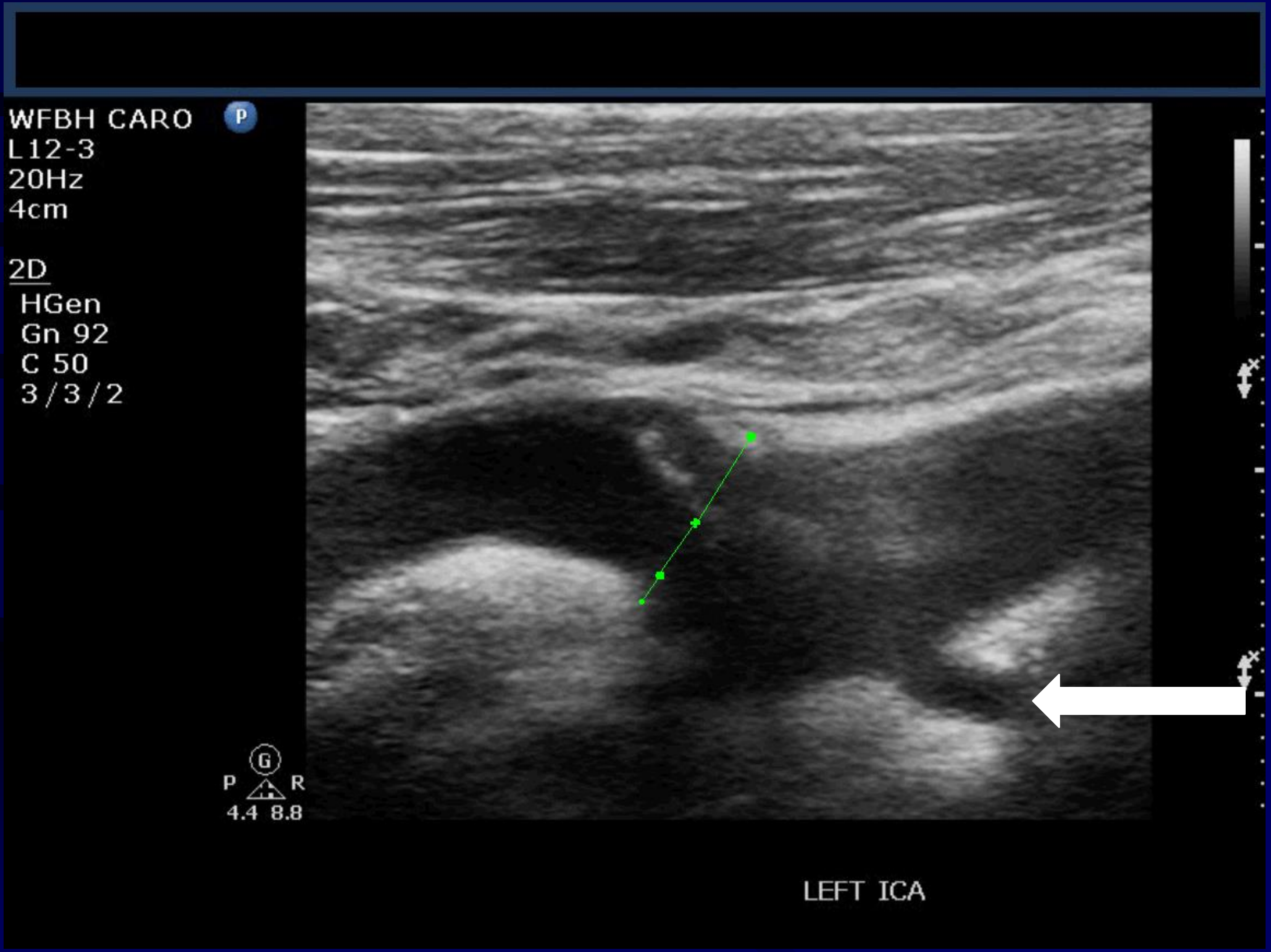
Suture Artifact Post-CEA



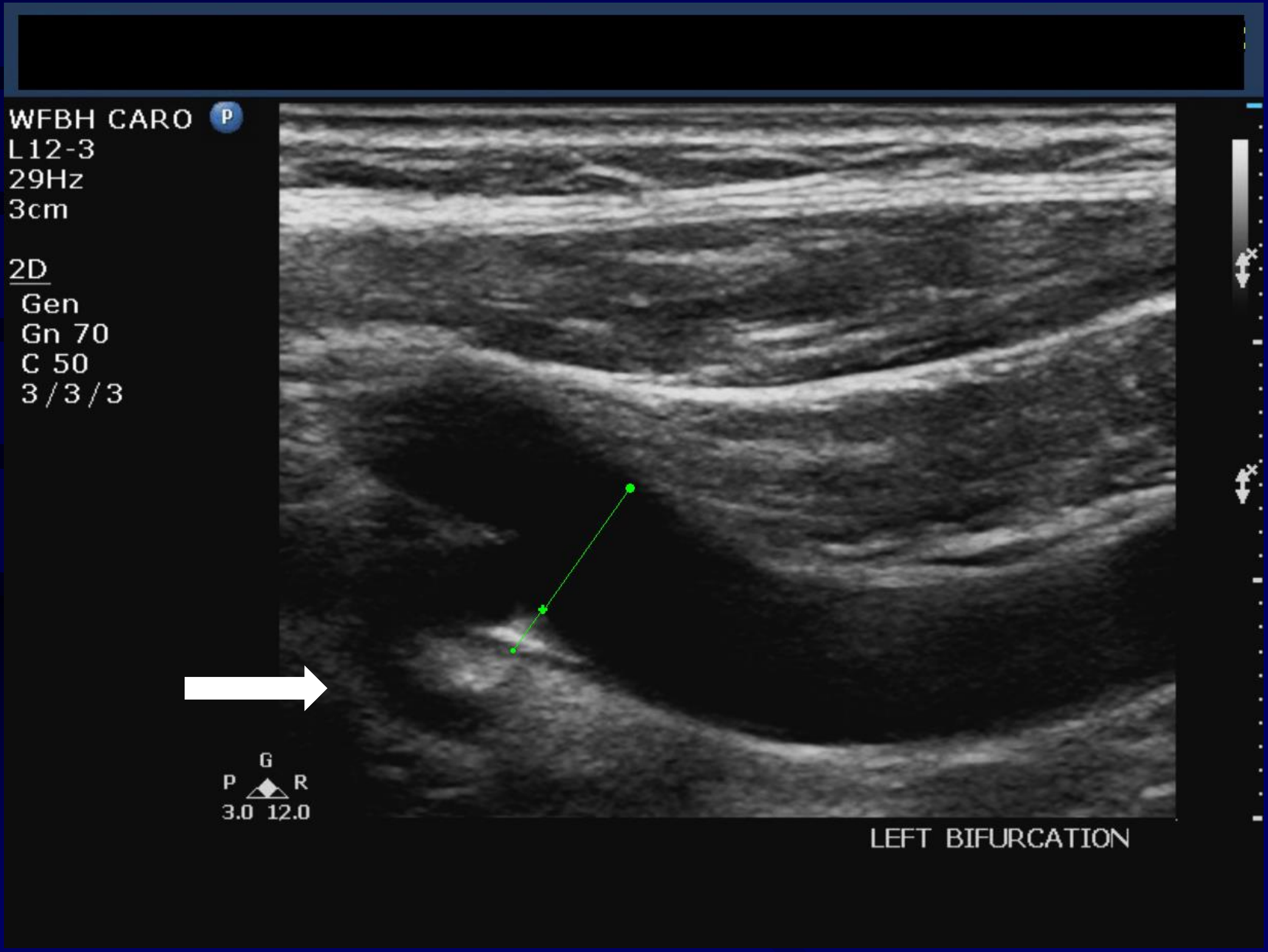
Typical Take-off of Superior Thyroidal



Low Take-Off of Superior Thyroidal Artery

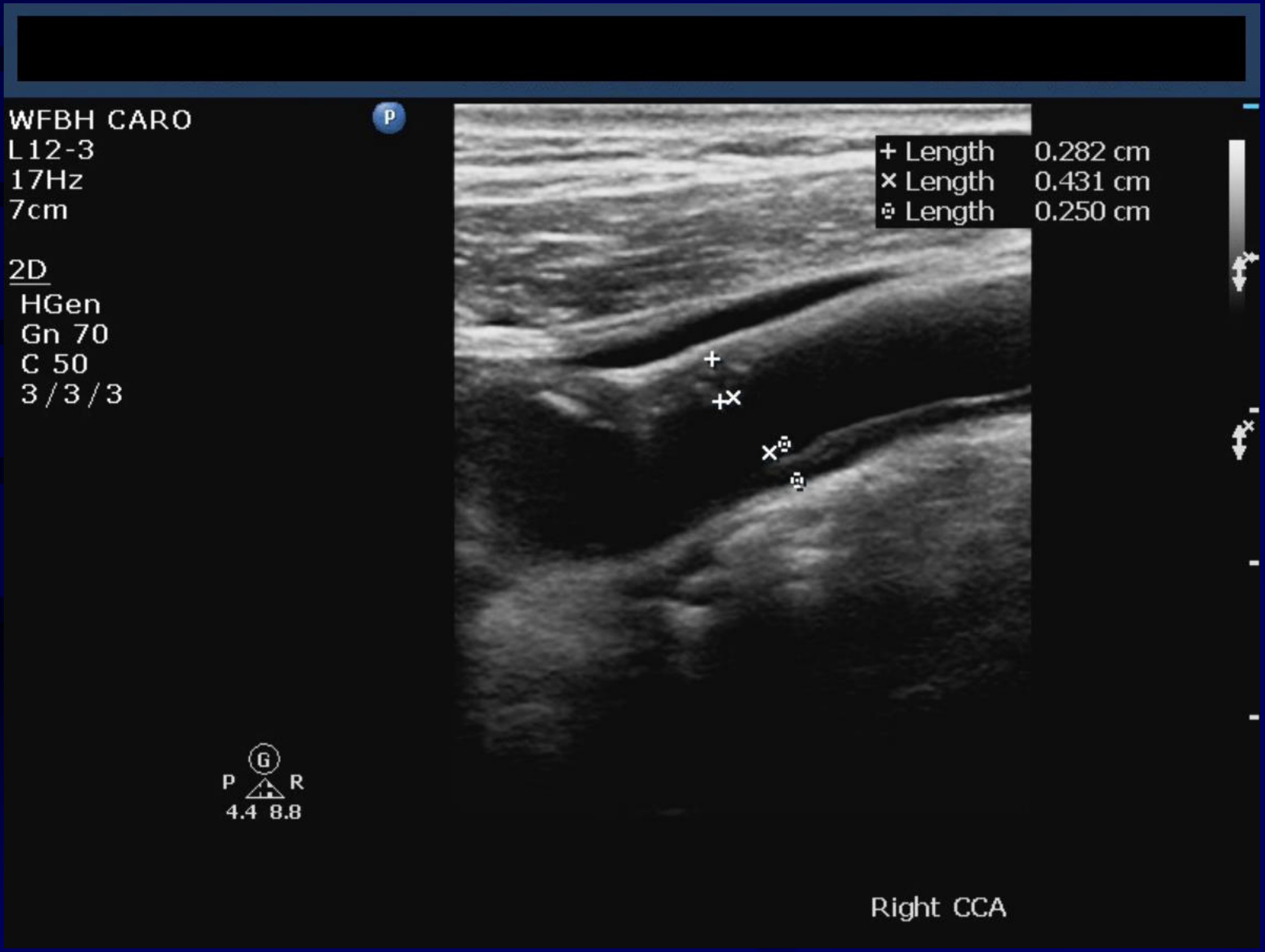


Distal Take-off of Superior Thyroidal



Distal CCA Cut-off from Prior CEA

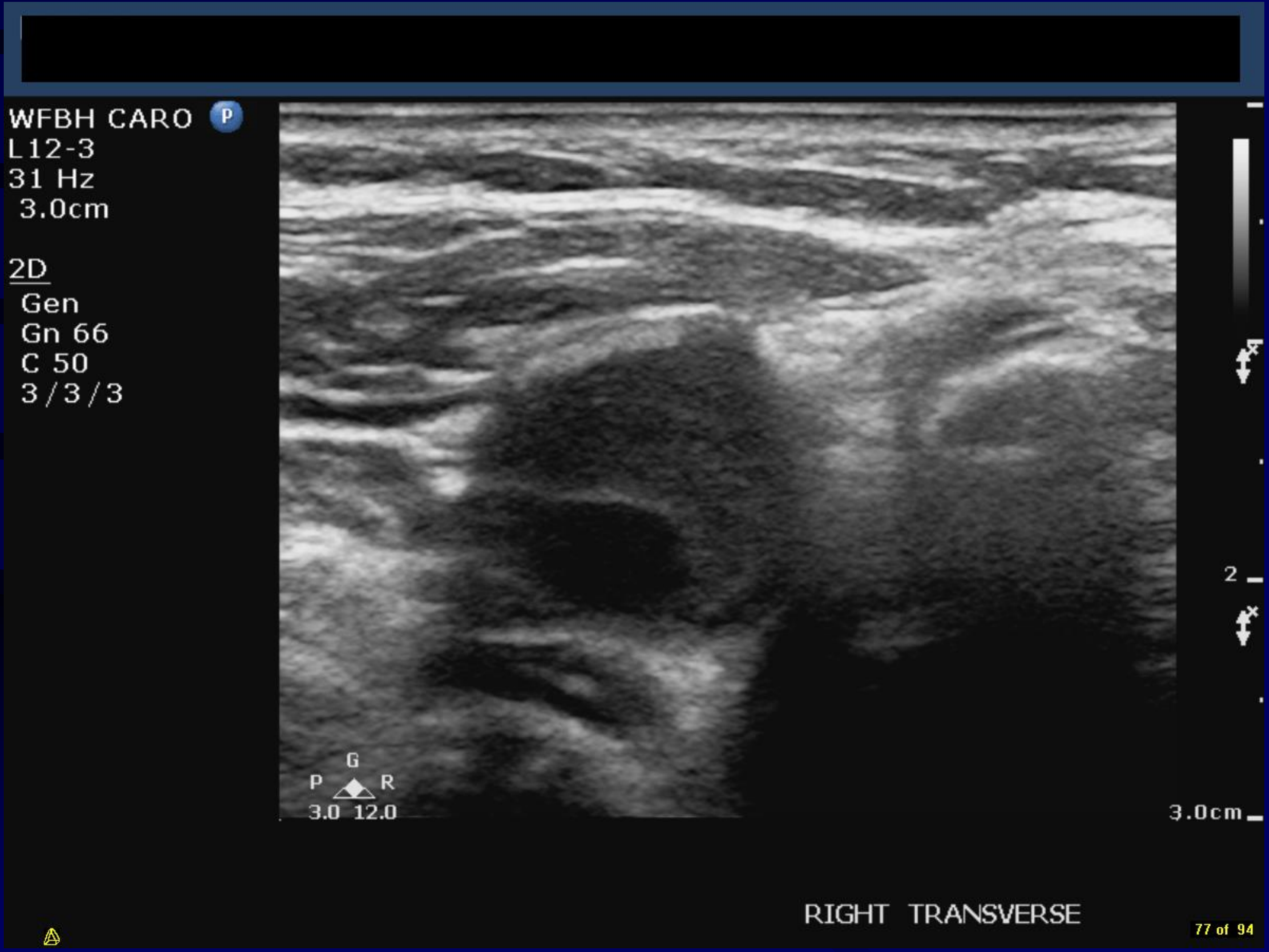
Abrupt CCA Cut-off From Prior CEA



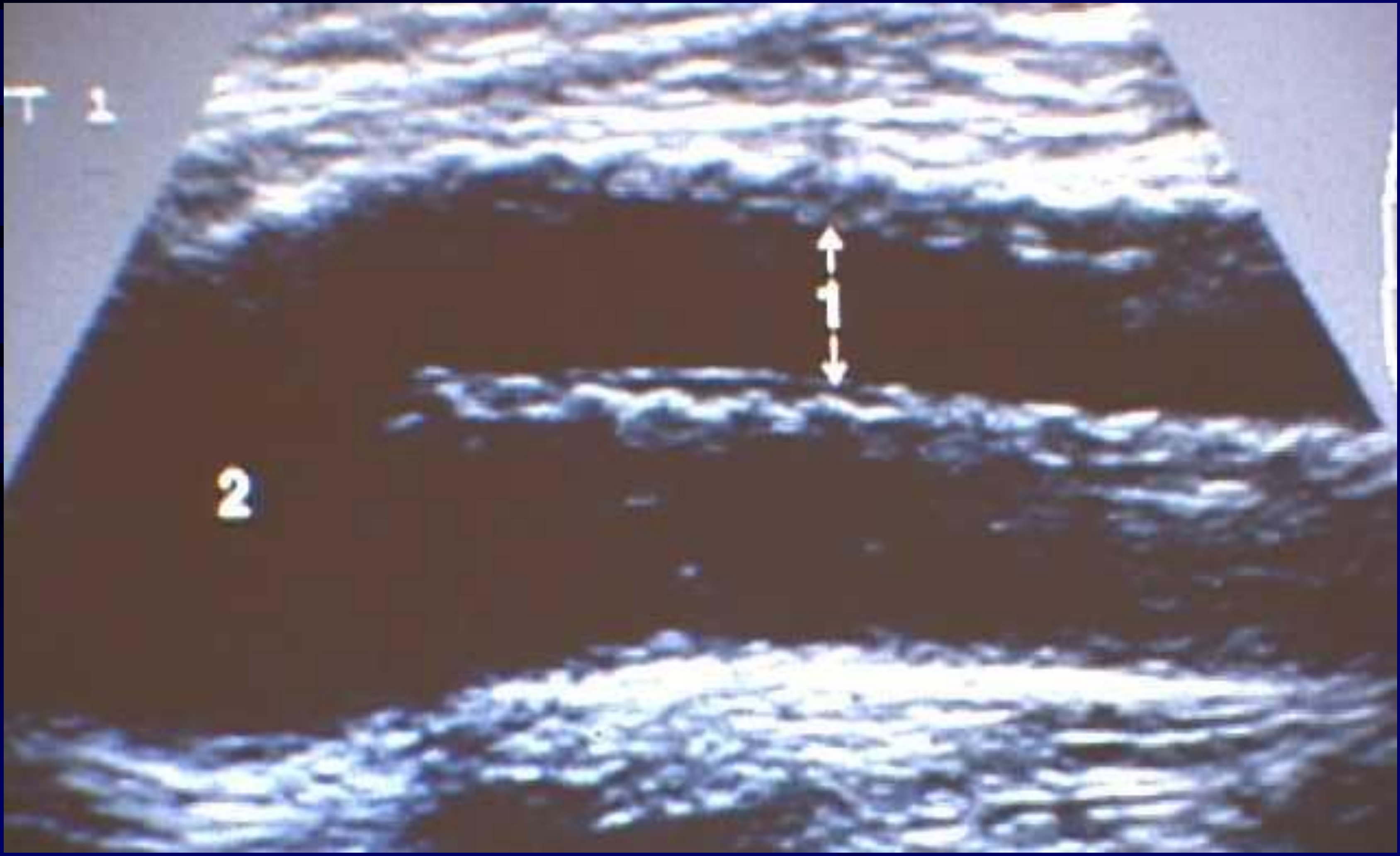
Dacron Patch Graft ICA Post-CEA

Dacron Patch Graft Post-CEA

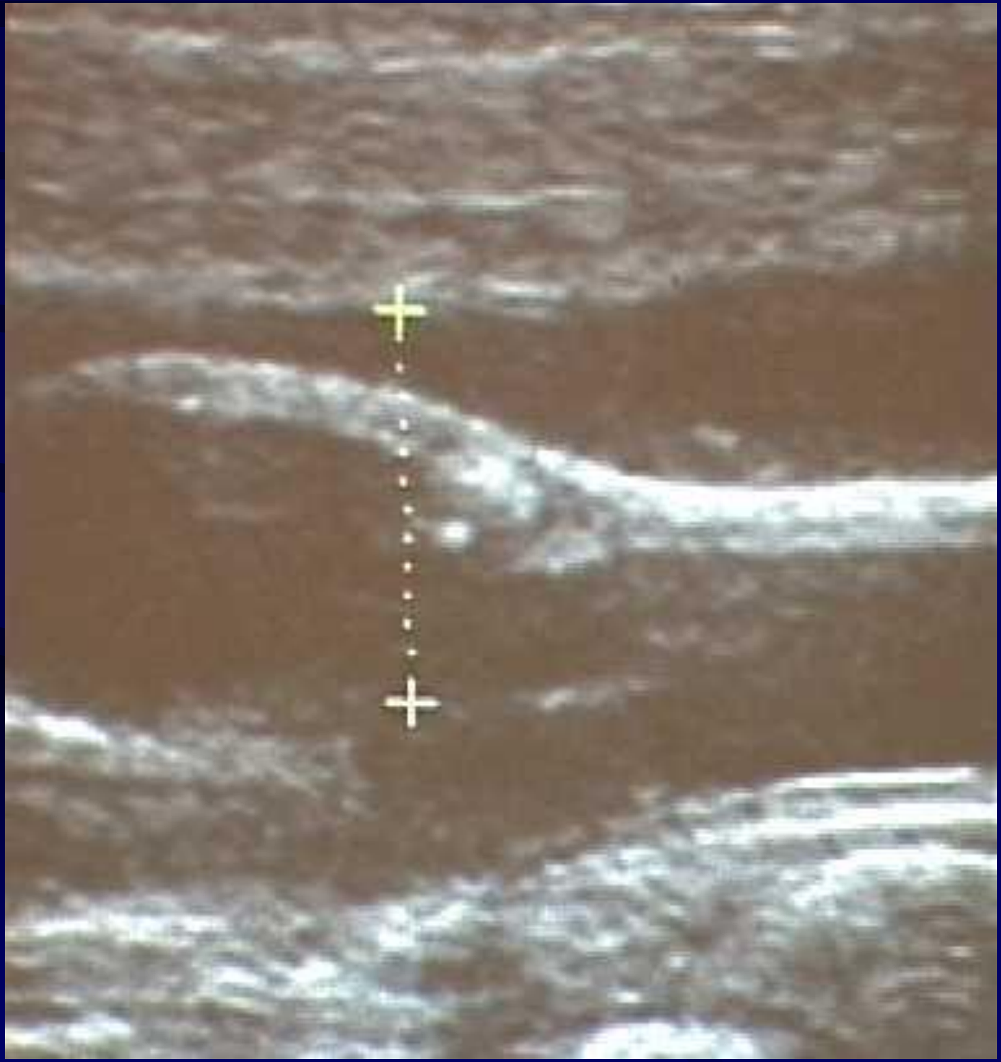
Proximal, Transverse, with Plaque



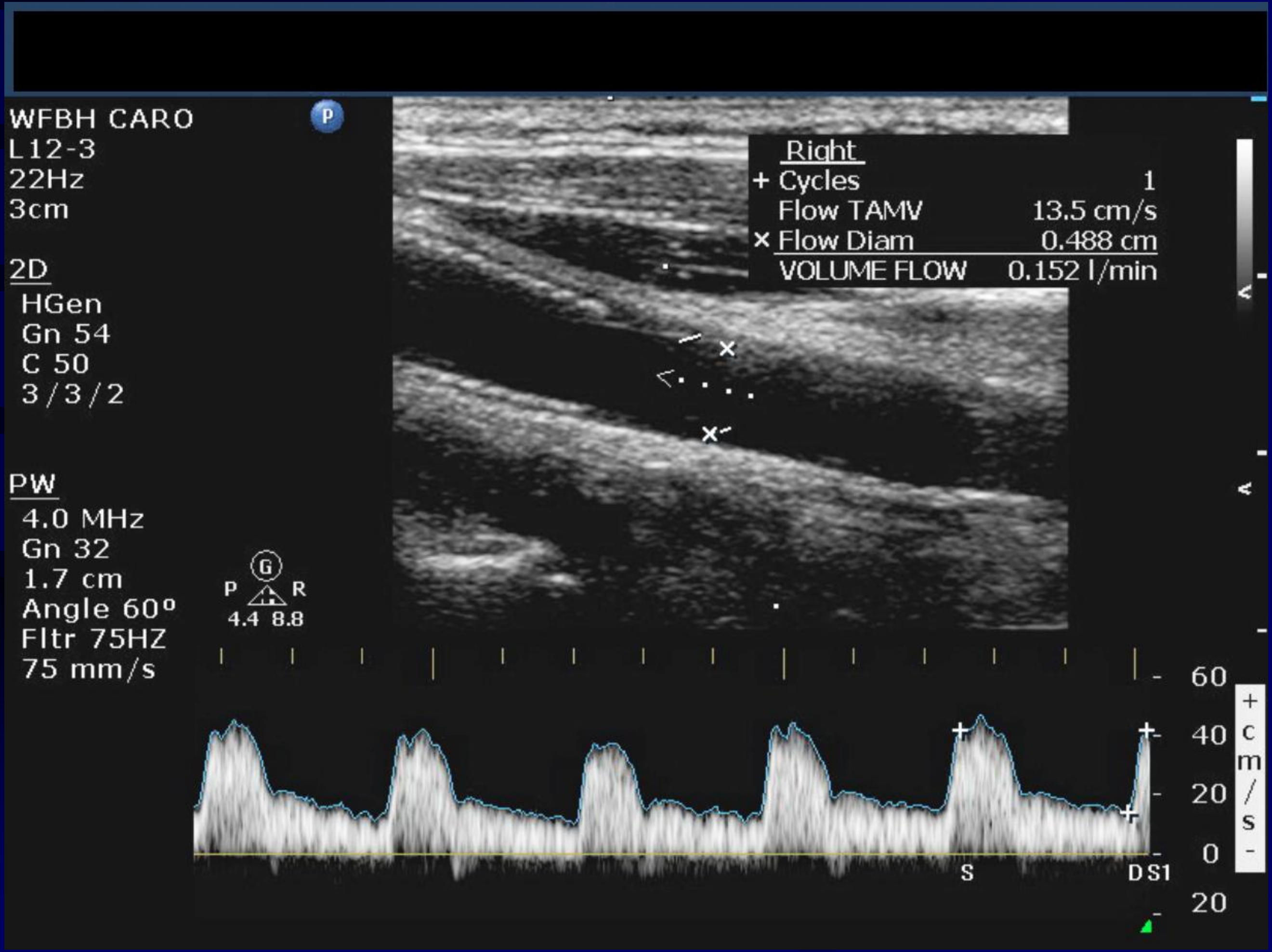
Carotid Bypass Graft



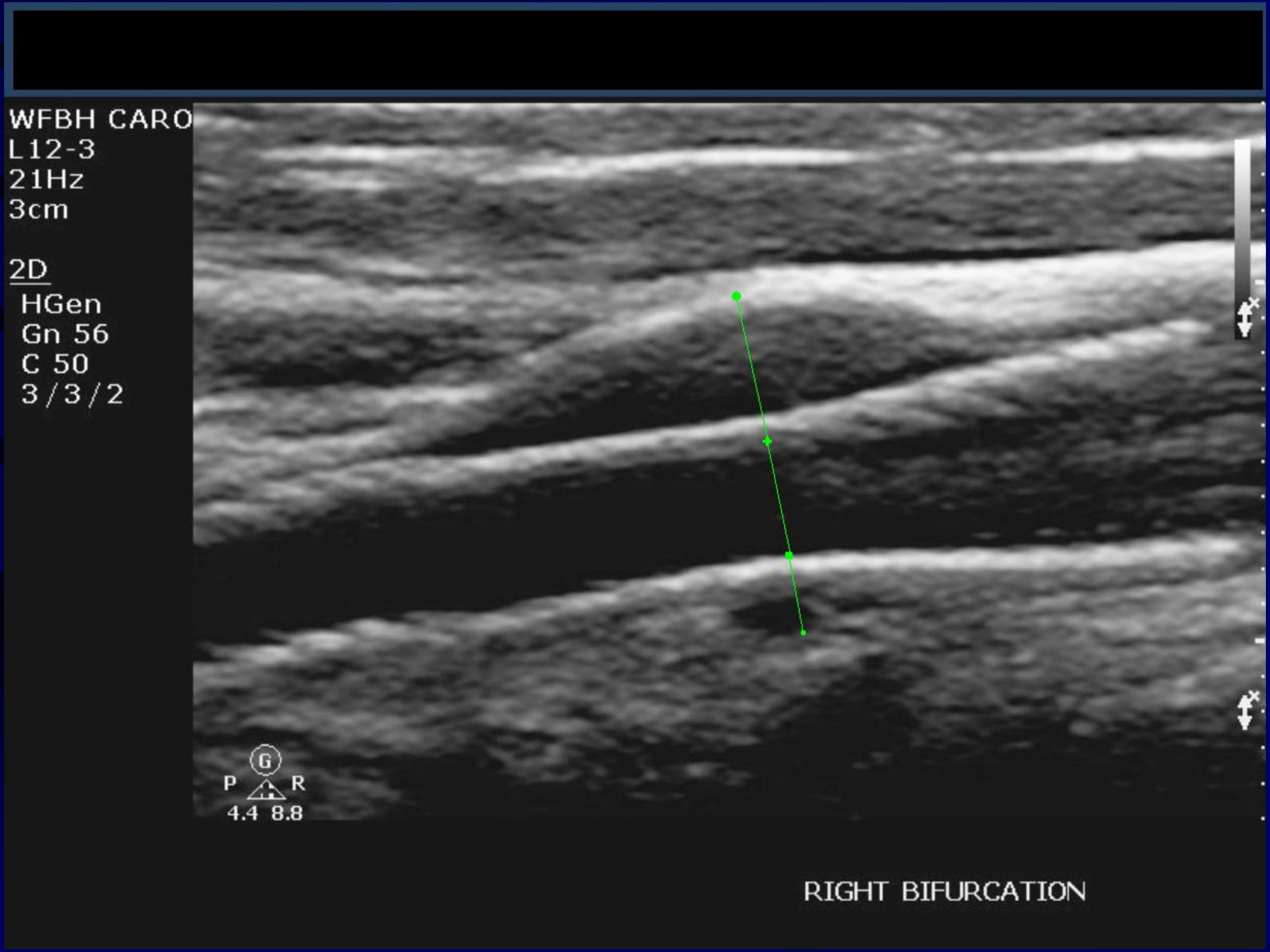
Vein Wall Artifact



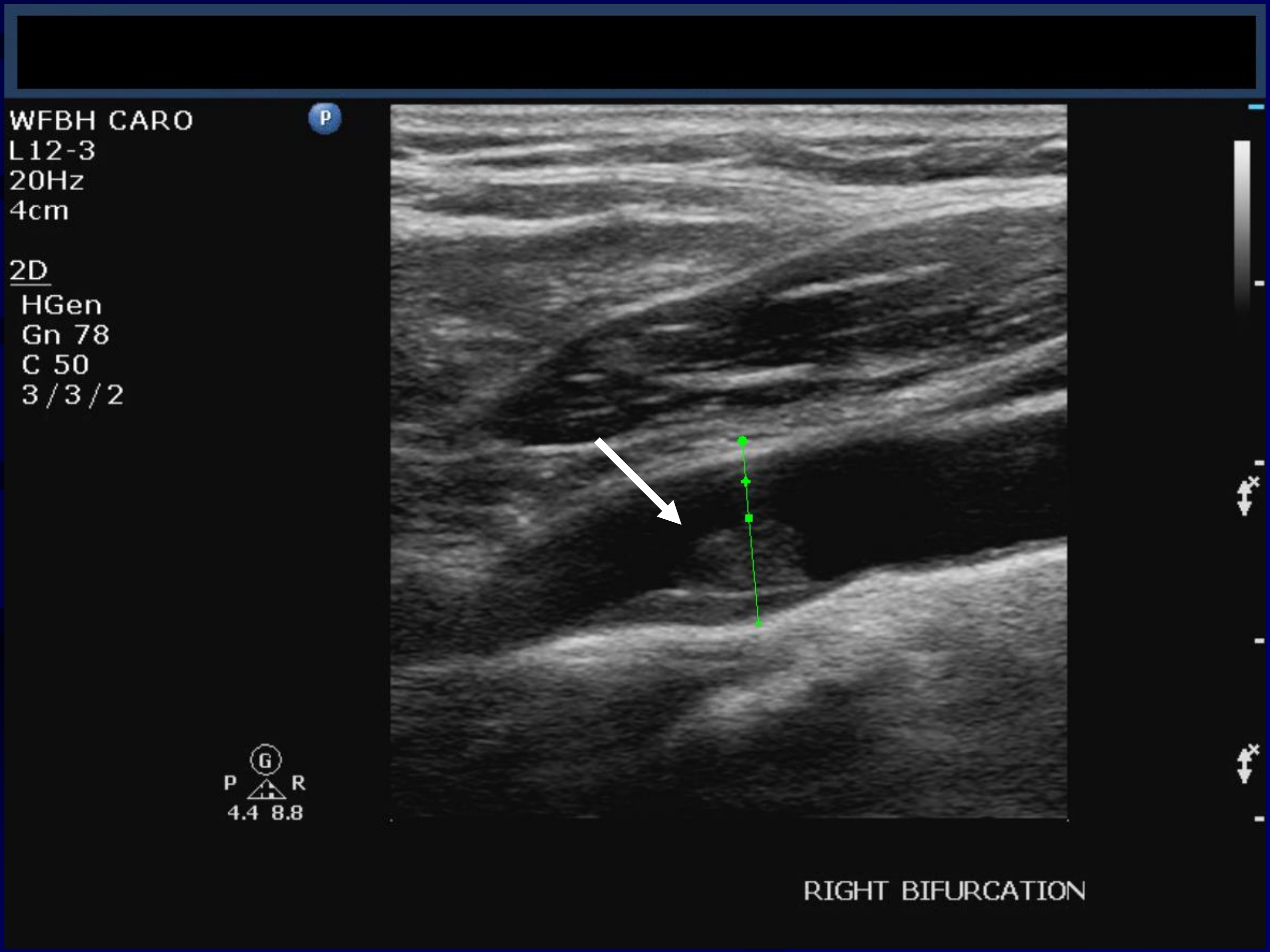
Stent: Proximal End



Stent: Lumen Measurement

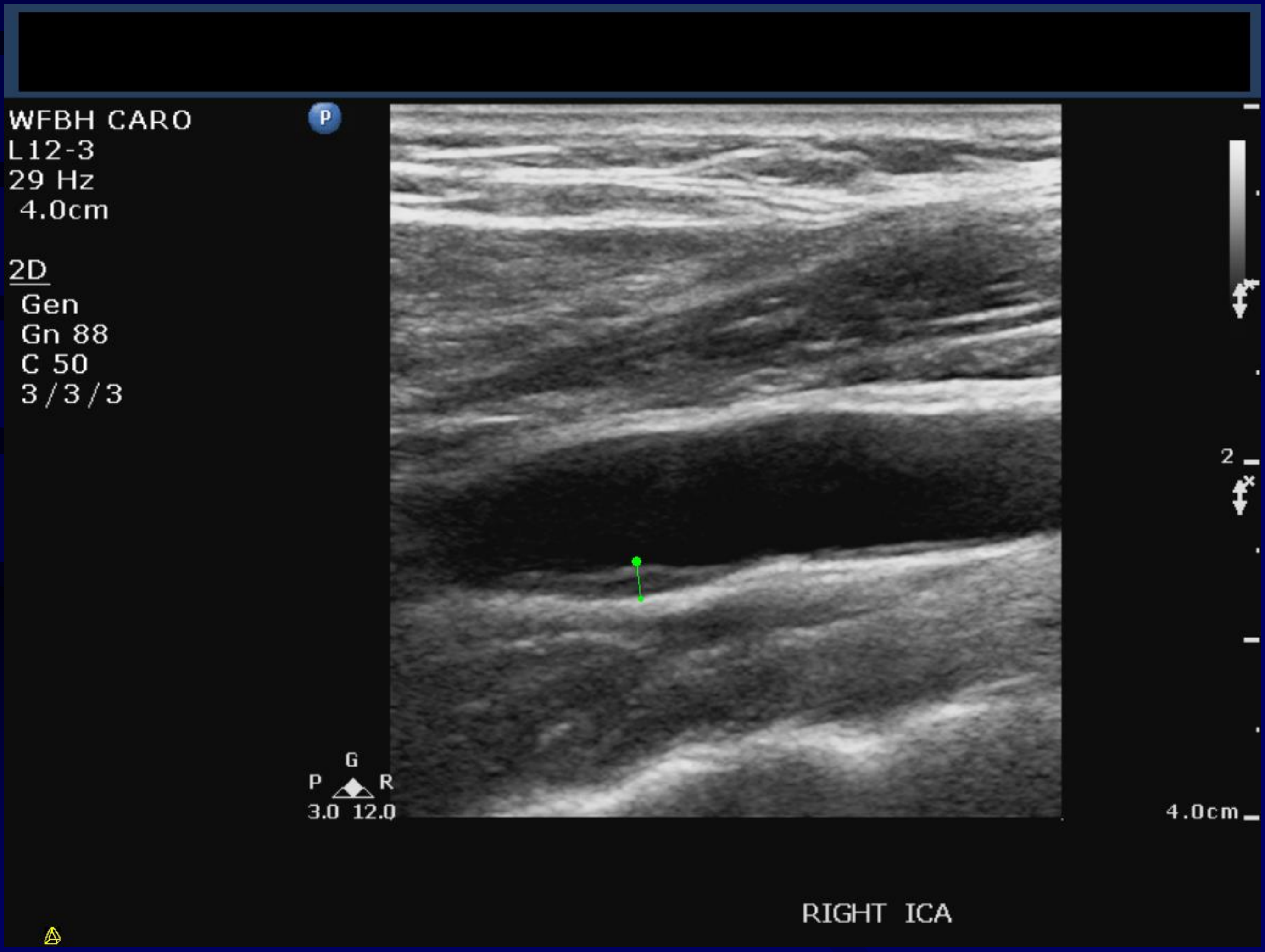


Thrombus on ICA Plaque

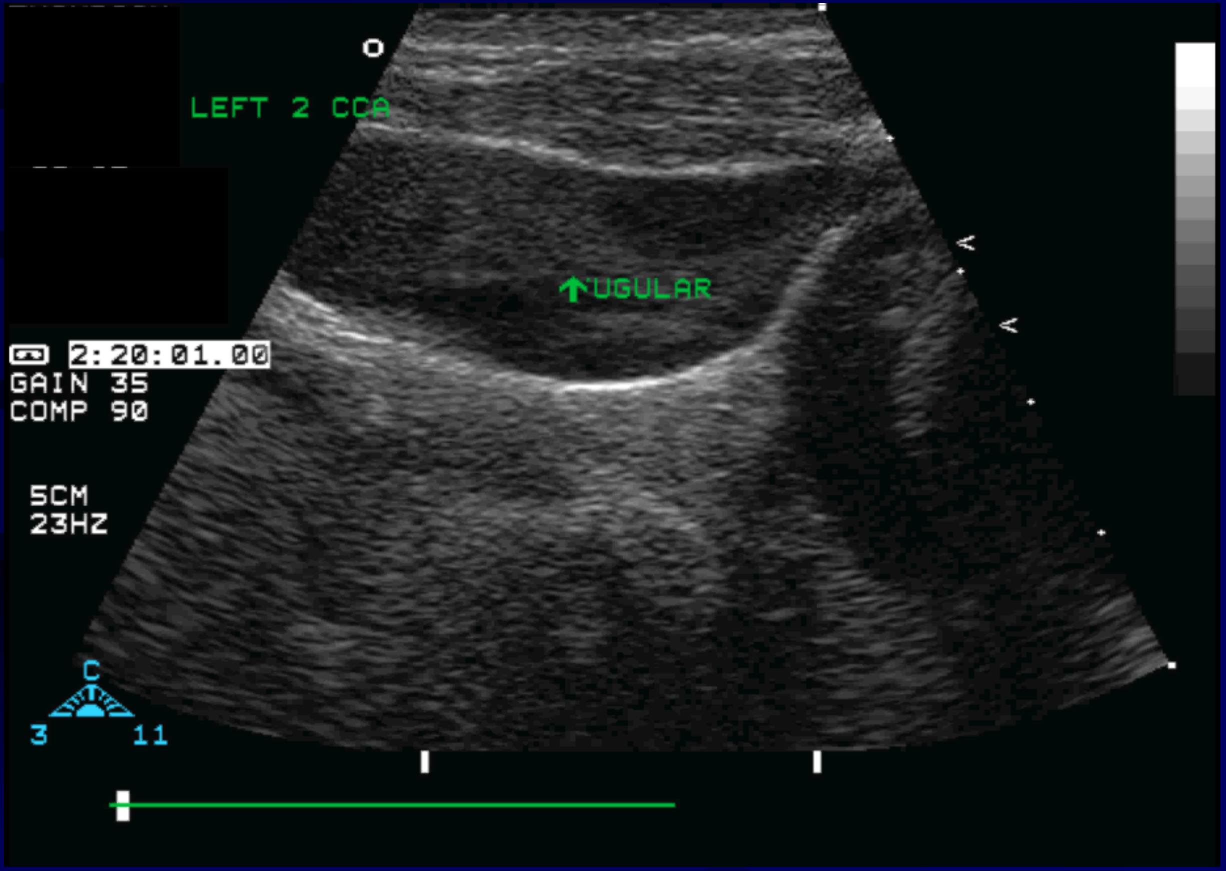


Follow-up for ICA Thrombus

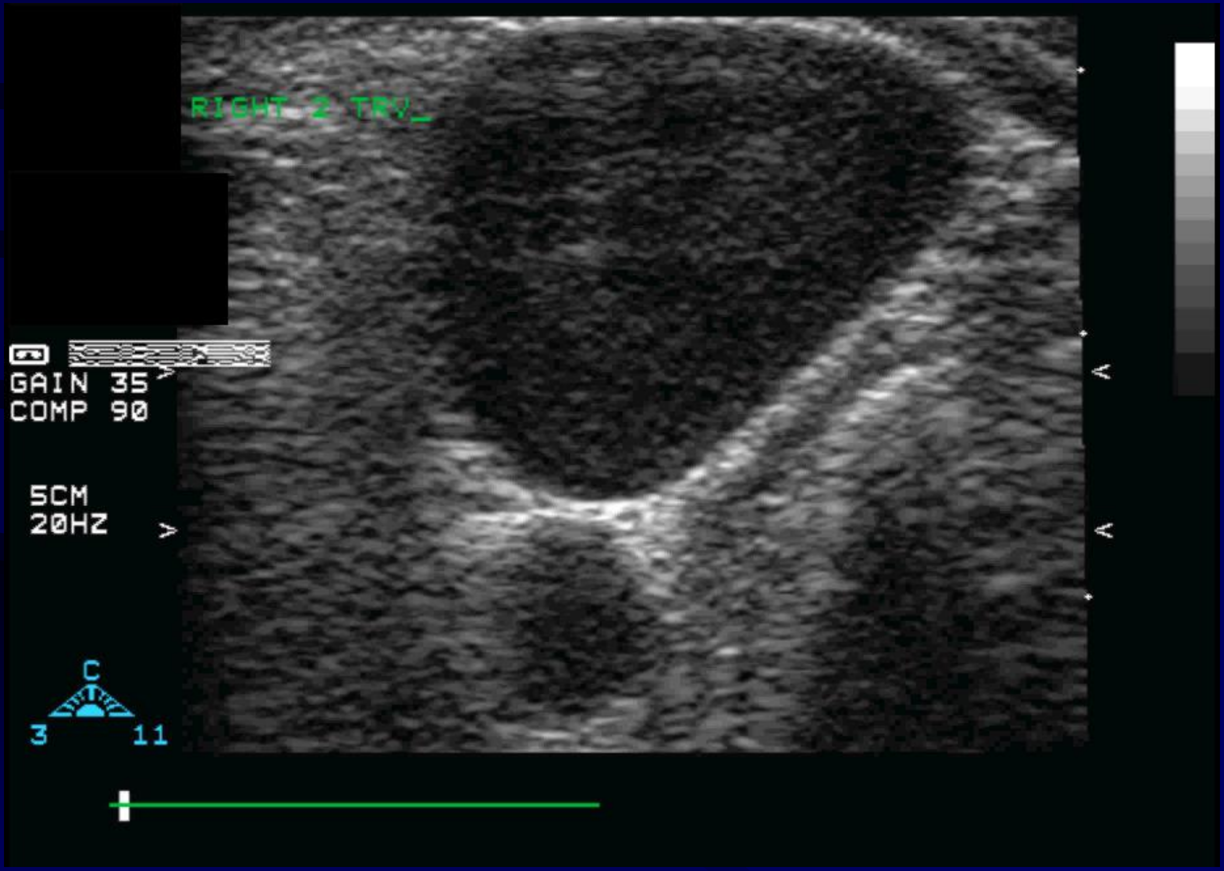
3 Months Later



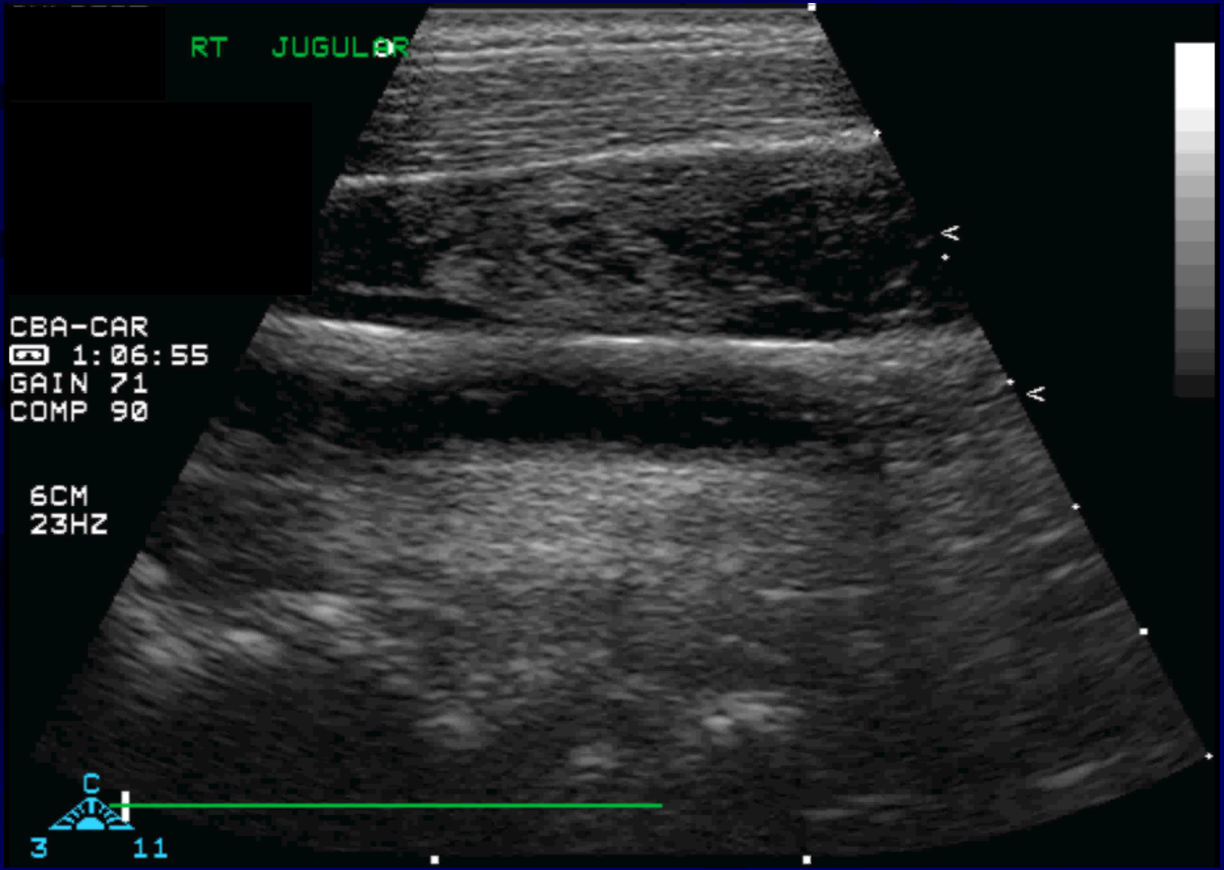
Internal Jugular Spontaneous Echo Contrast



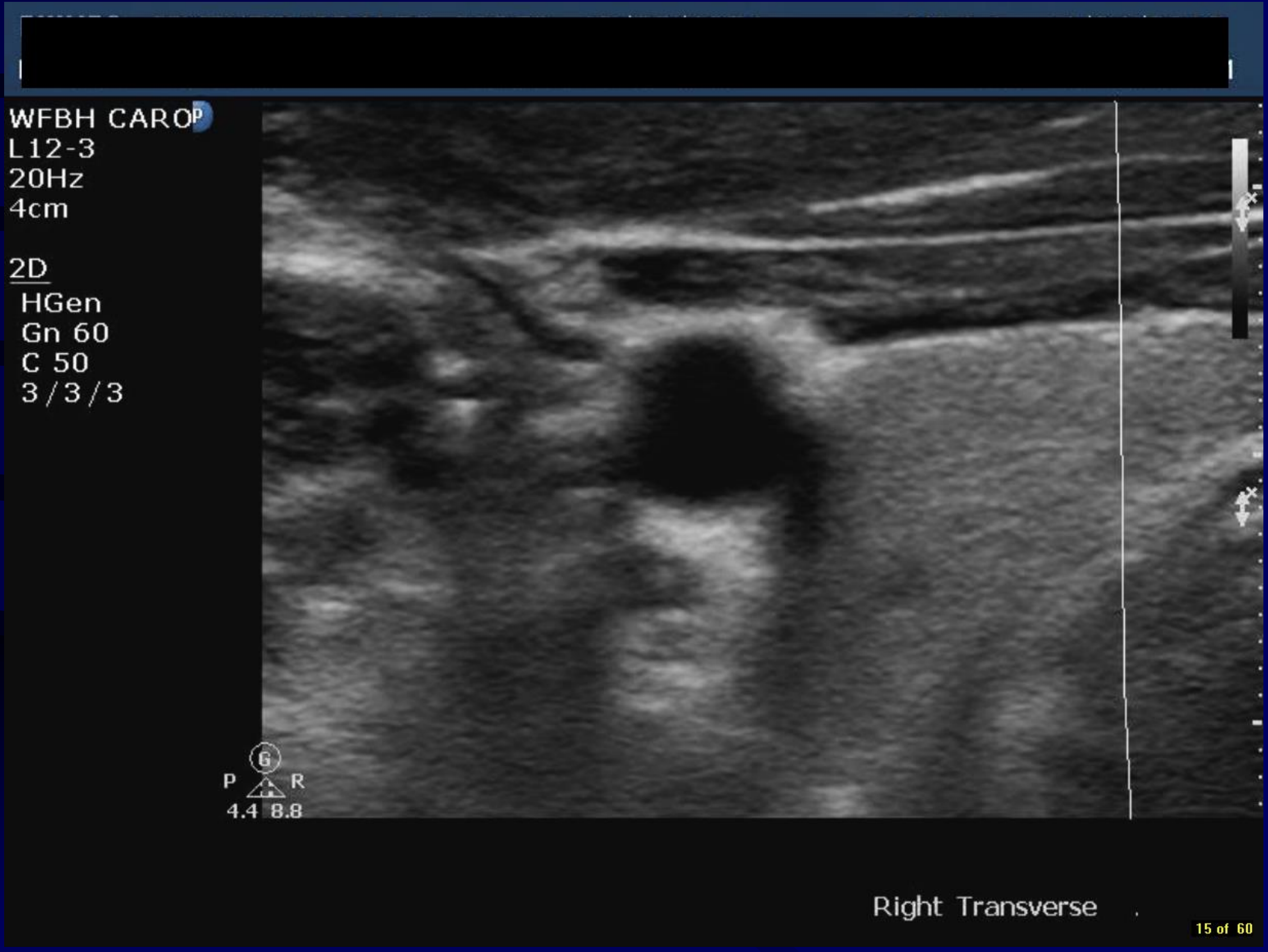
Internal Jugular Transverse Spontaneous Echo Contrast



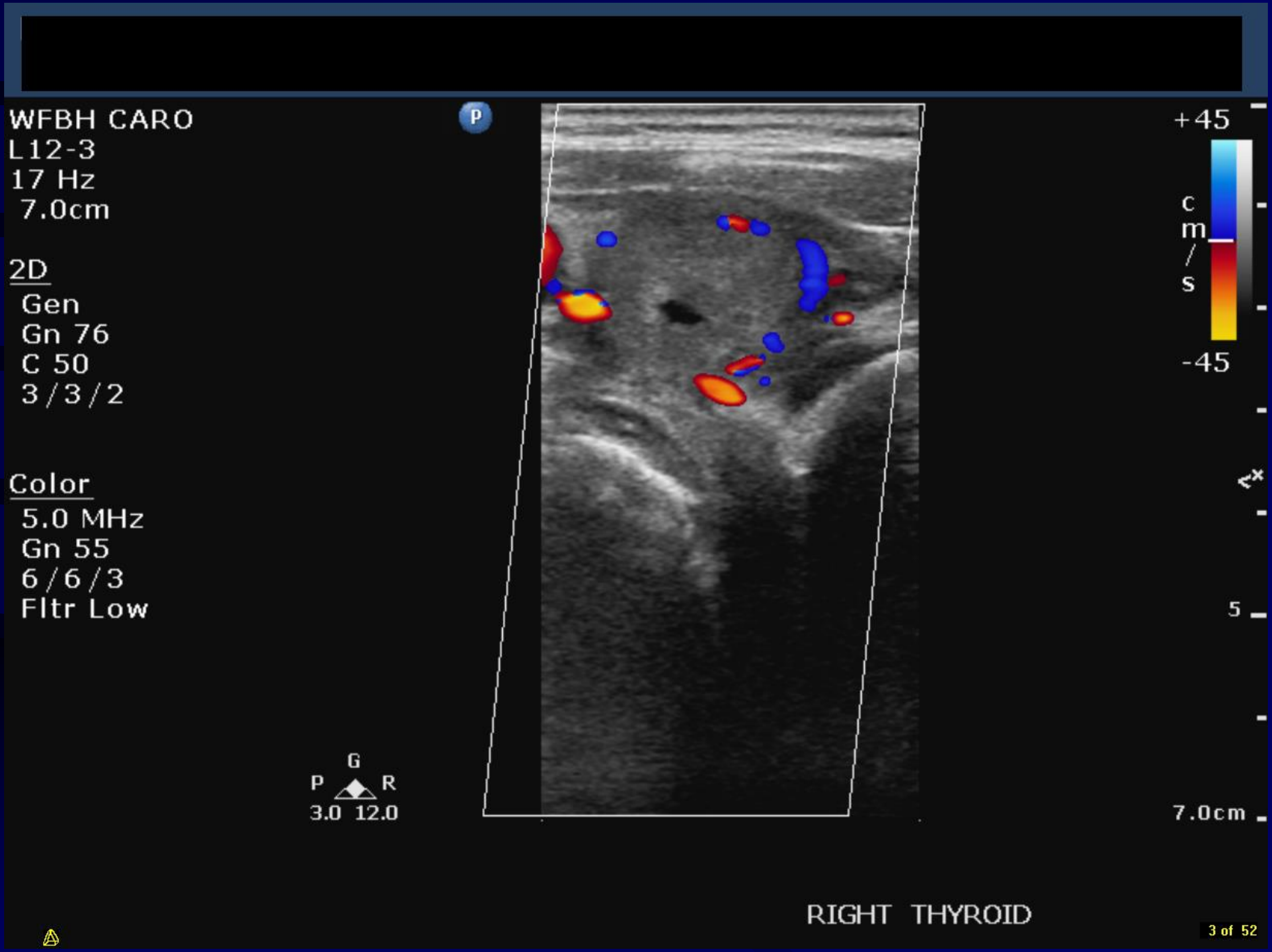
Internal Jugular Thrombosis



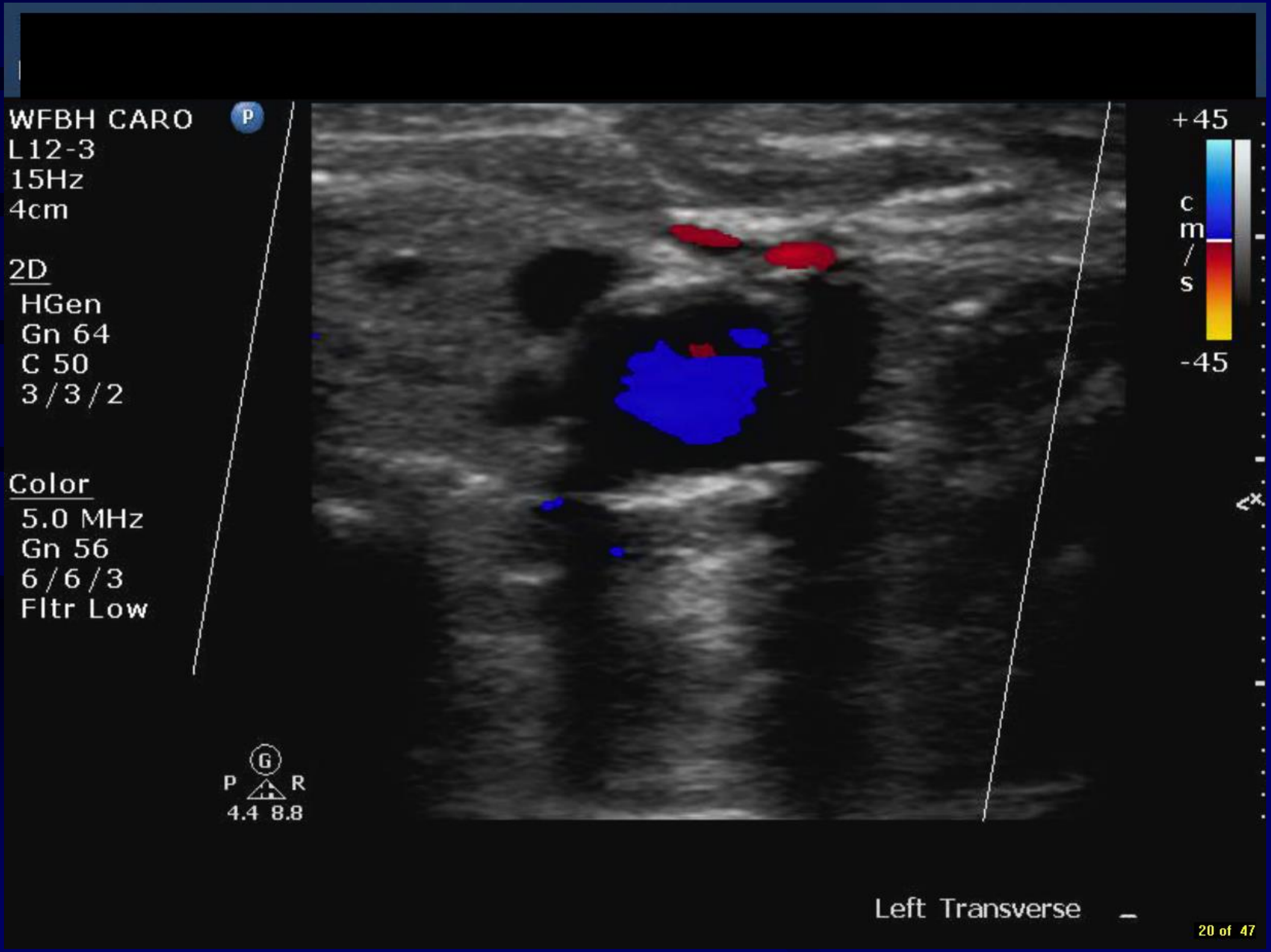
Normal Appearing Thyroid - Right



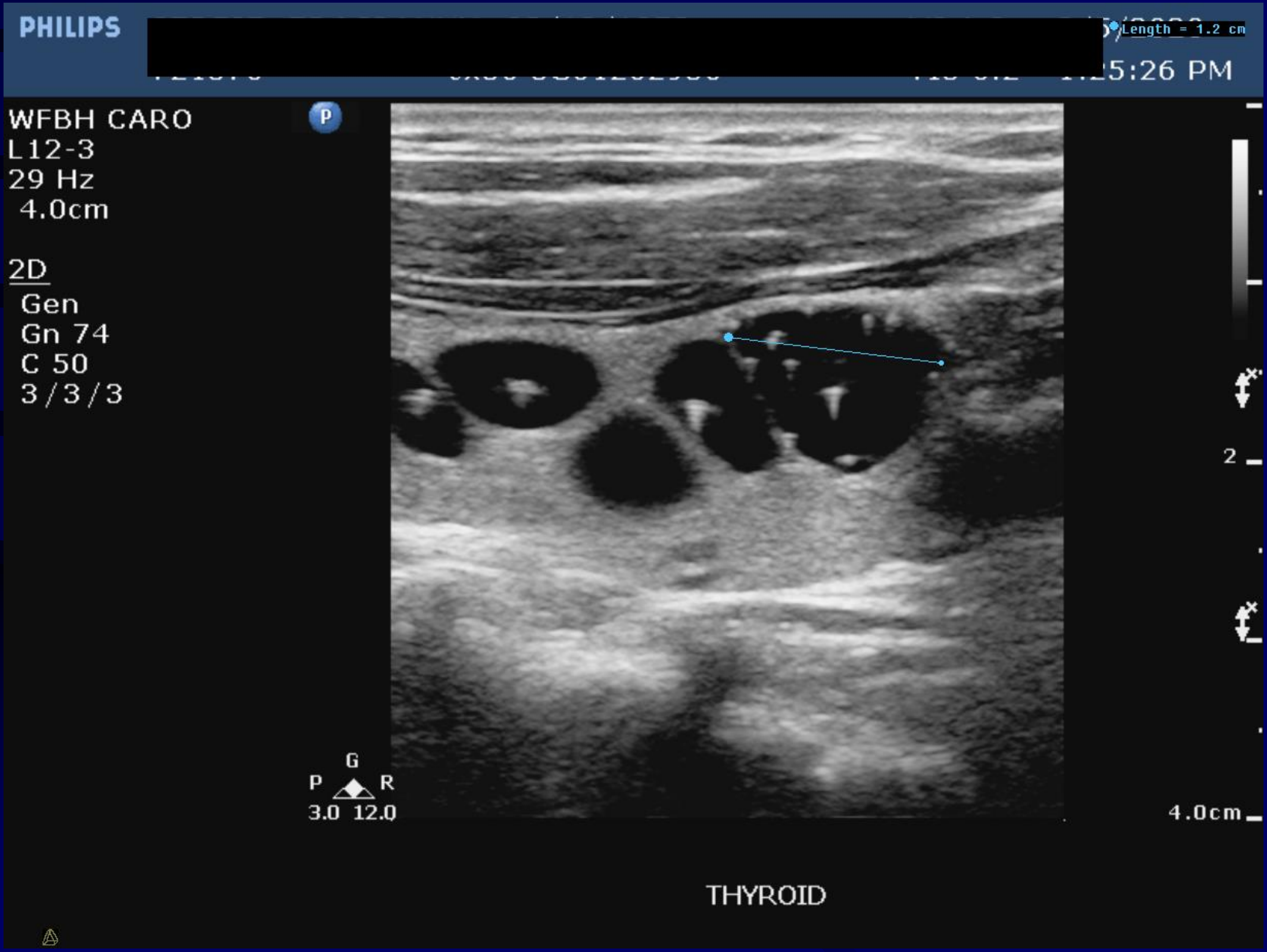
Thyroid – Increased Vascularity, Small Cyst



Multiple Small Thyroid Cysts

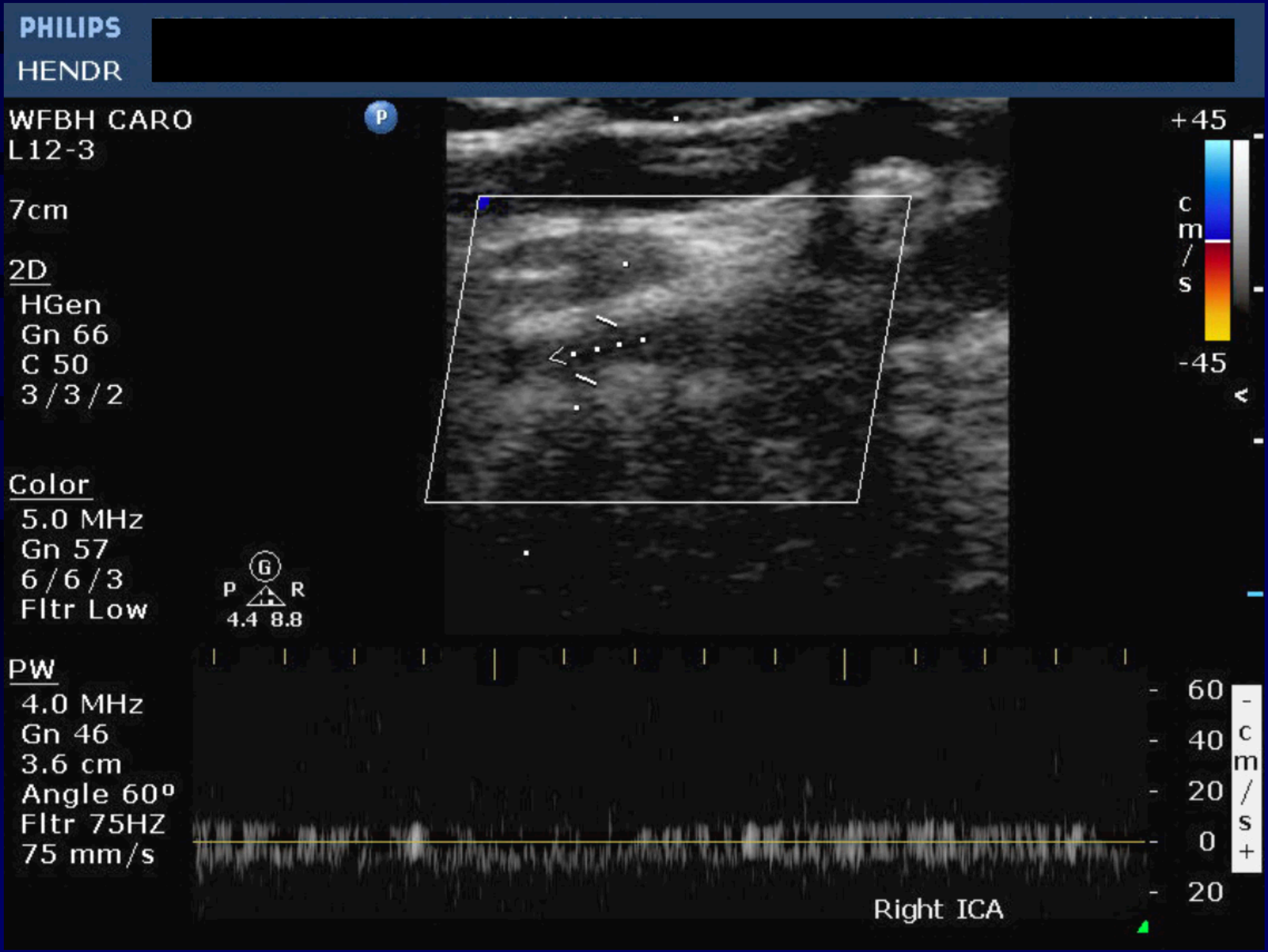


Cystic Thyroid



Small Caliber Distal ICA

Suggests more chronic occlusion



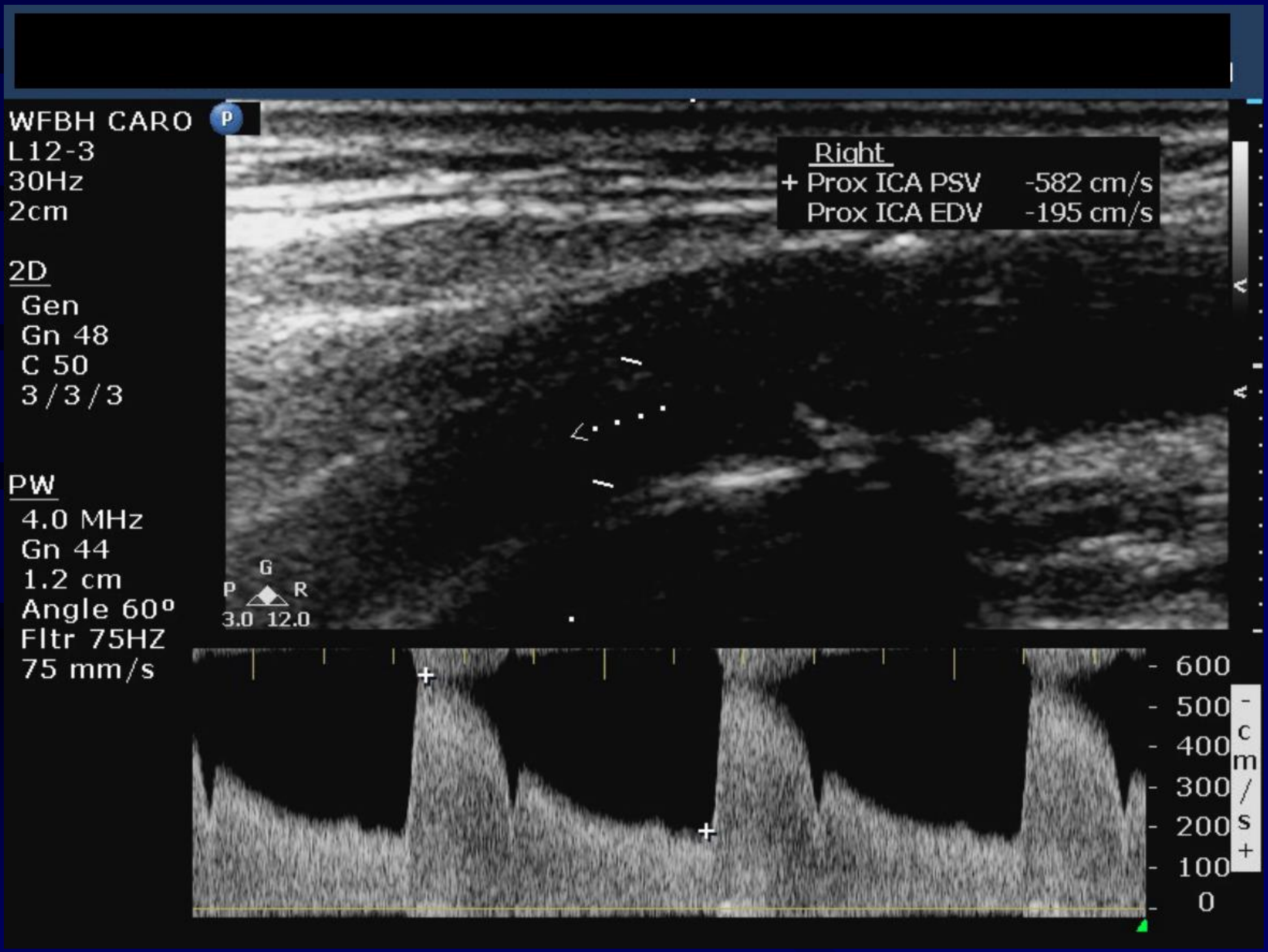
Carotid Protocol & Techniques
B-mode suggestions

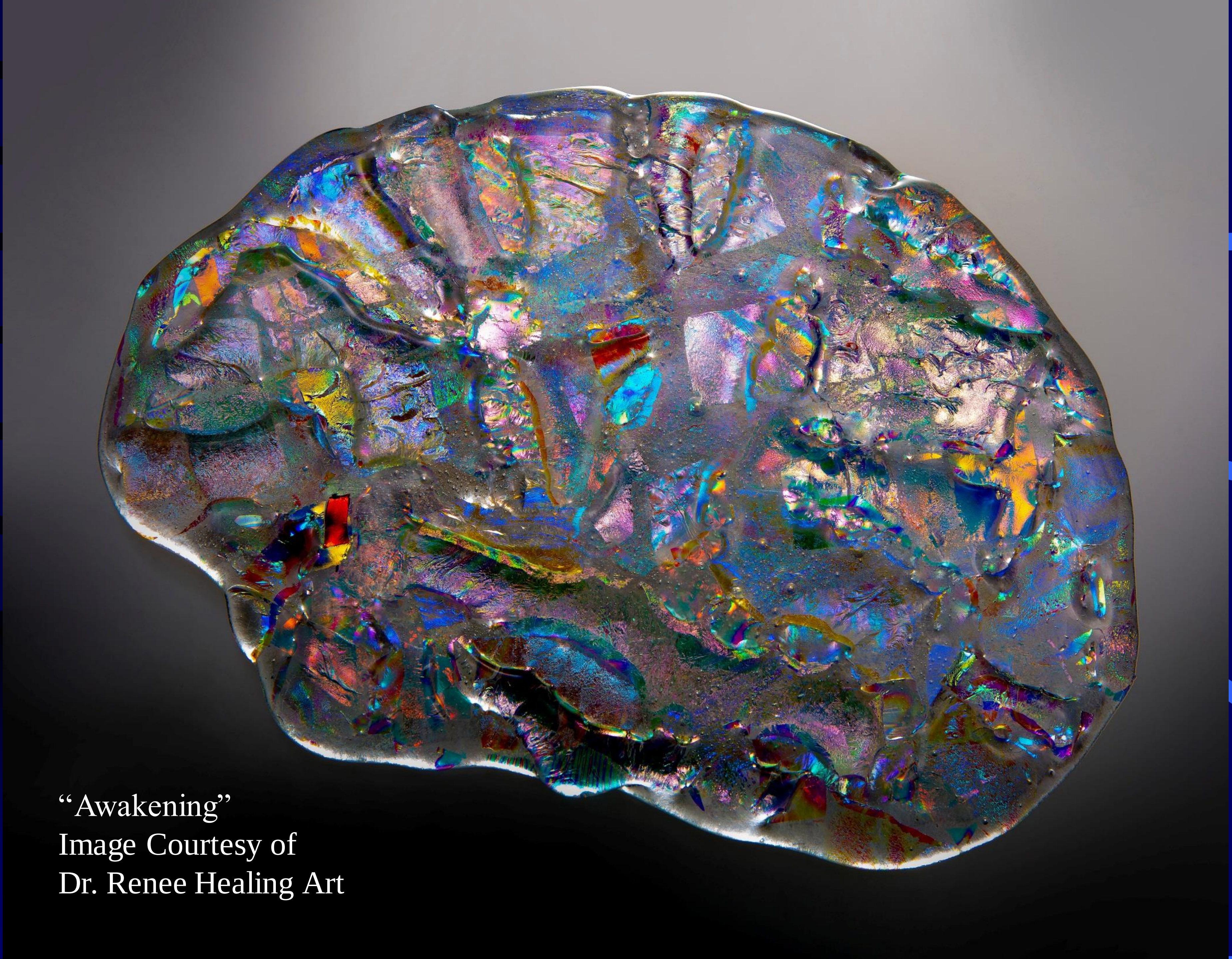
- Transverse image if unclear or large plaque
- ICA usually post/lat; ECA ant/medial
- Quick interrogation of internal jugular vein with B-mode and/or color flow imaging
- Note appearance of thyroid on transverse view, and report cyst/lesions > 1 cm dia.

Carotid Duplex Sonography

- Combines PW Doppler & B-mode imaging
- Image guided placement of sample gate
- Angle correction
- Option for color flow imaging
- Overcomes pitfalls of stand alone tests
- Expect 90% sens/spec for tight stenosis

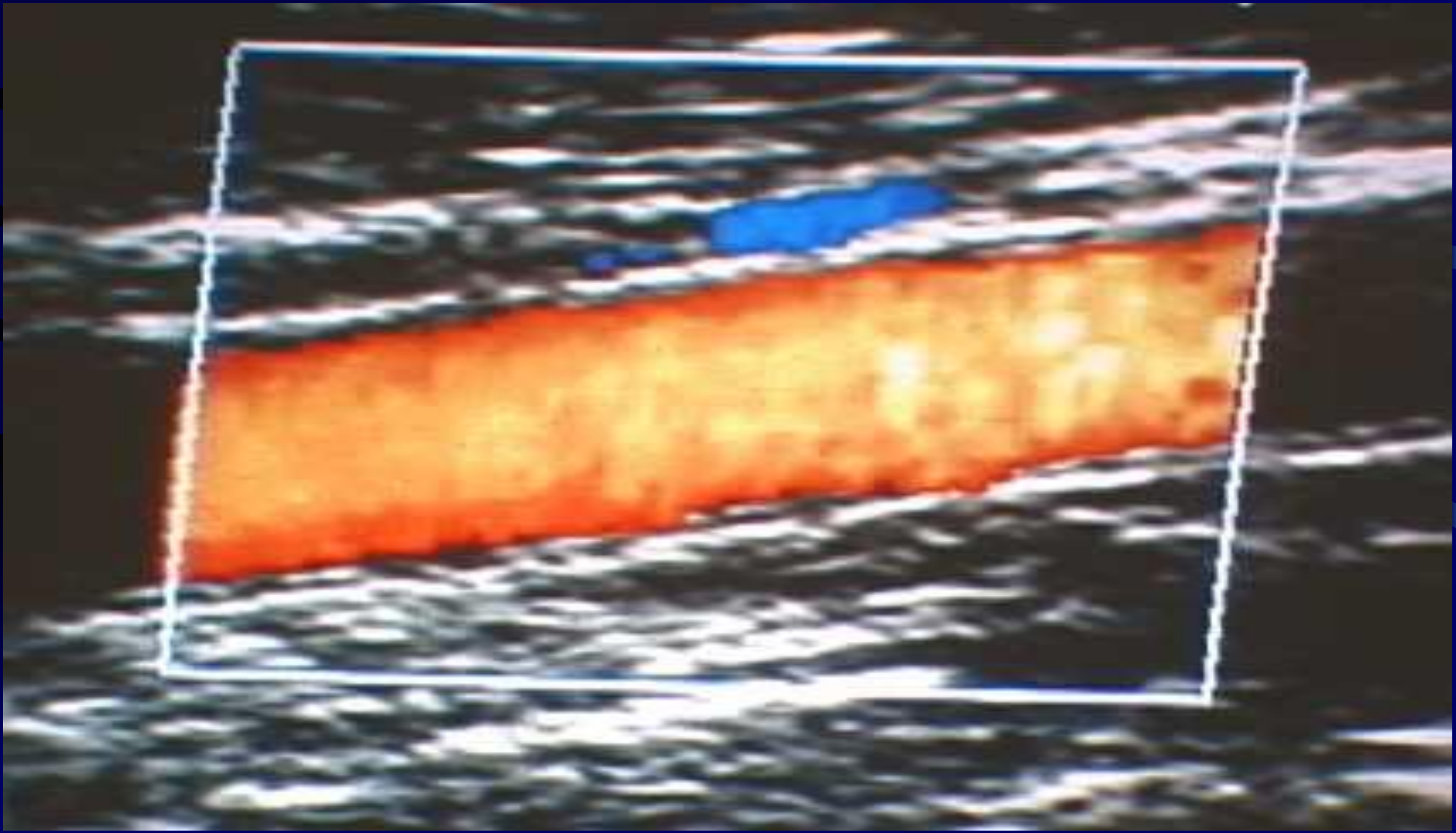
Severe ICA Stenosis Duplex





“Awakening”
Image Courtesy of
Dr. Renee Healing Art

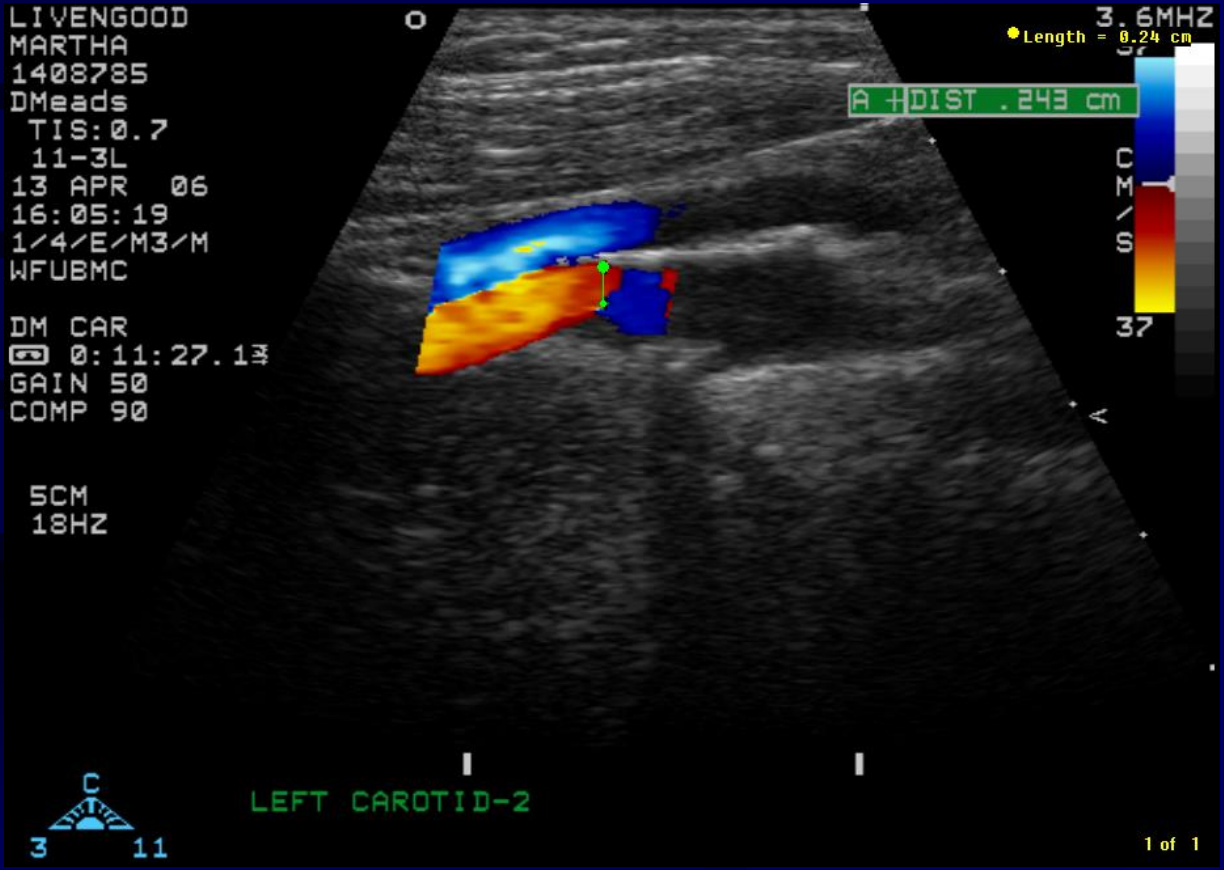
Color Flow Imaging CCA



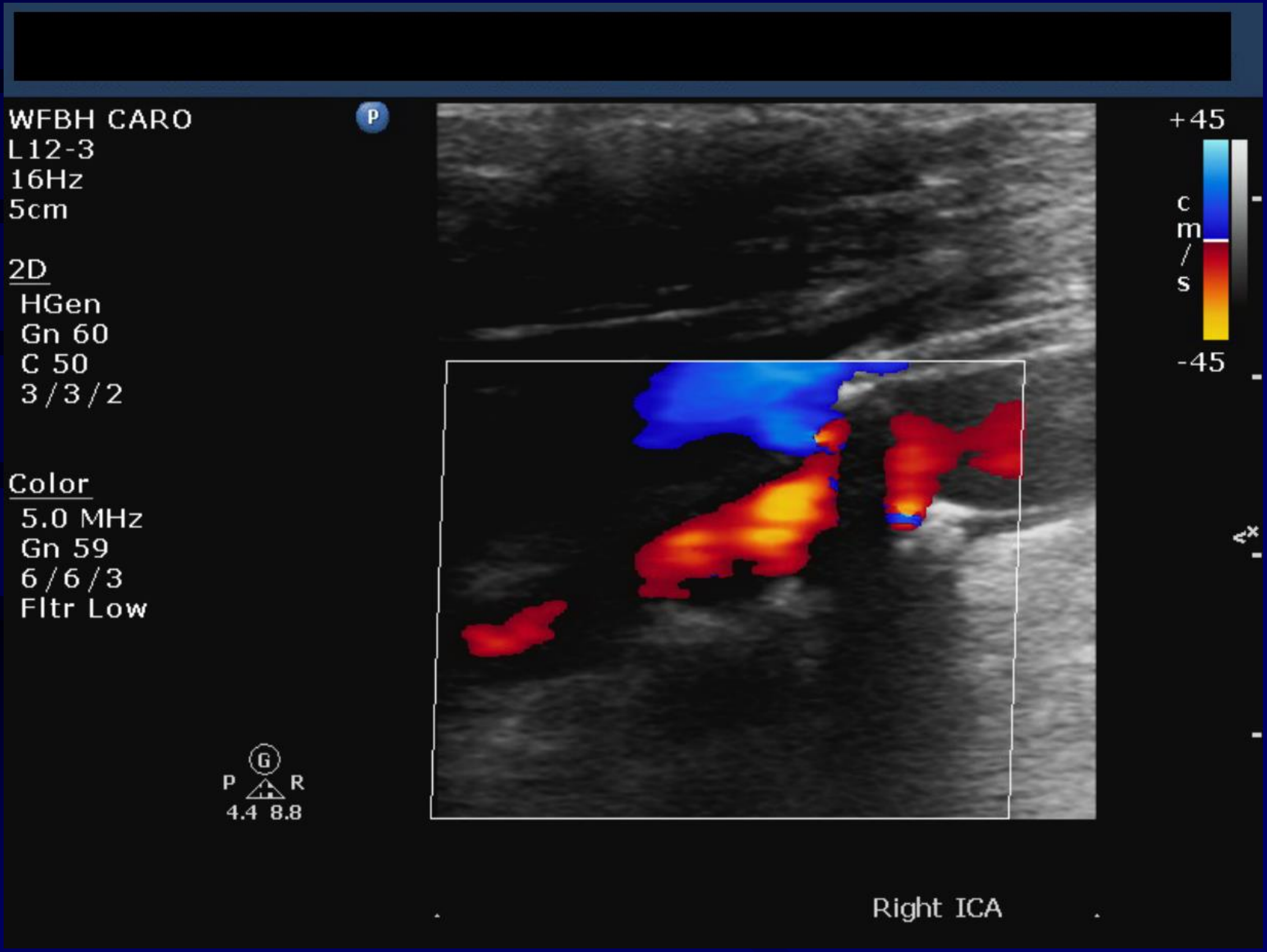
Color Flow Imaging

- Quick ID presence/direction of flow
- Road map for spectral Doppler
- More accurate angle of insonation
- Improved data on surface features
- ID of hypoechoic plaque (color void)
- ID string sign/near occlusions
- Speed up examination

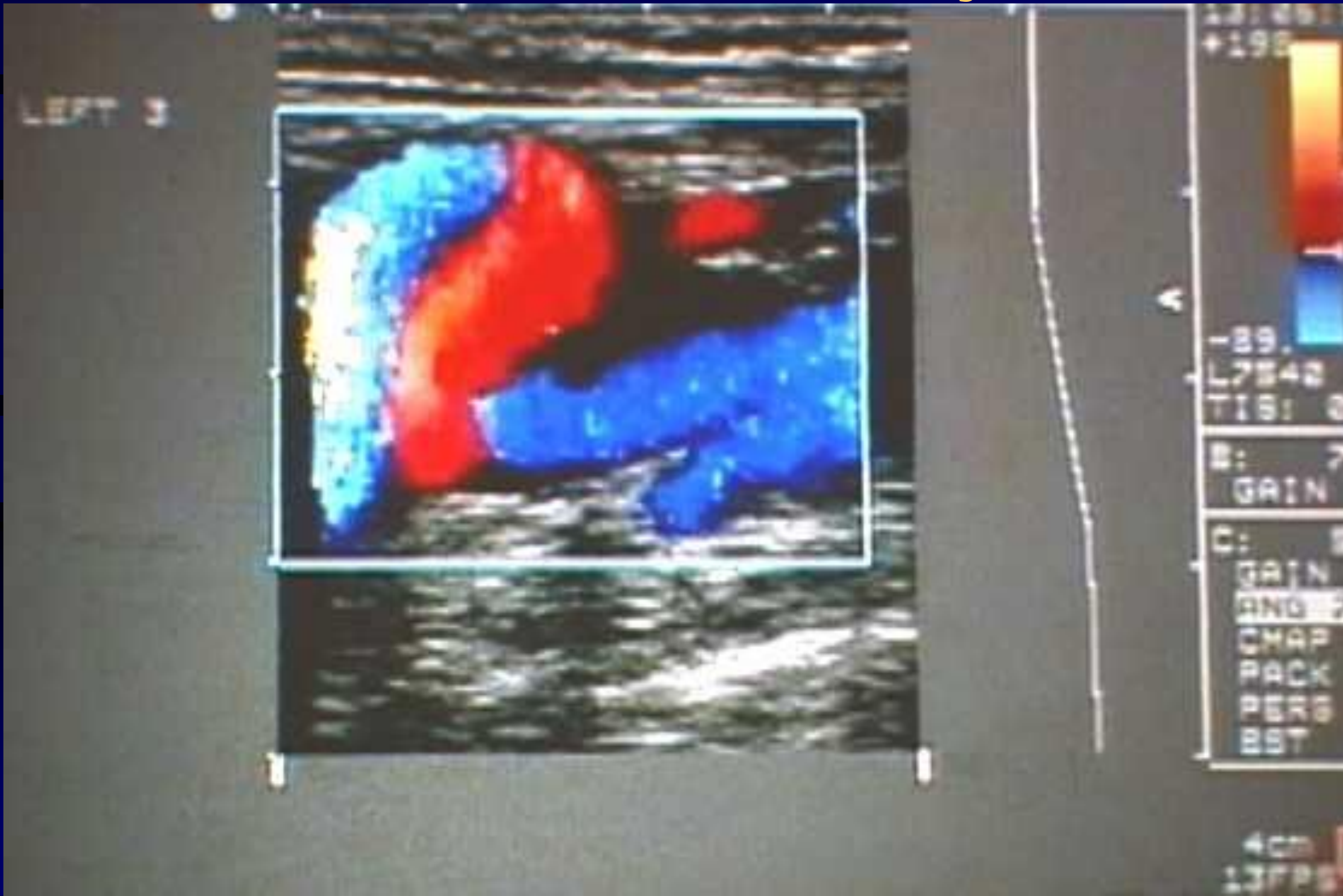
Color Changes
Direction of Flow Relative to Transducer



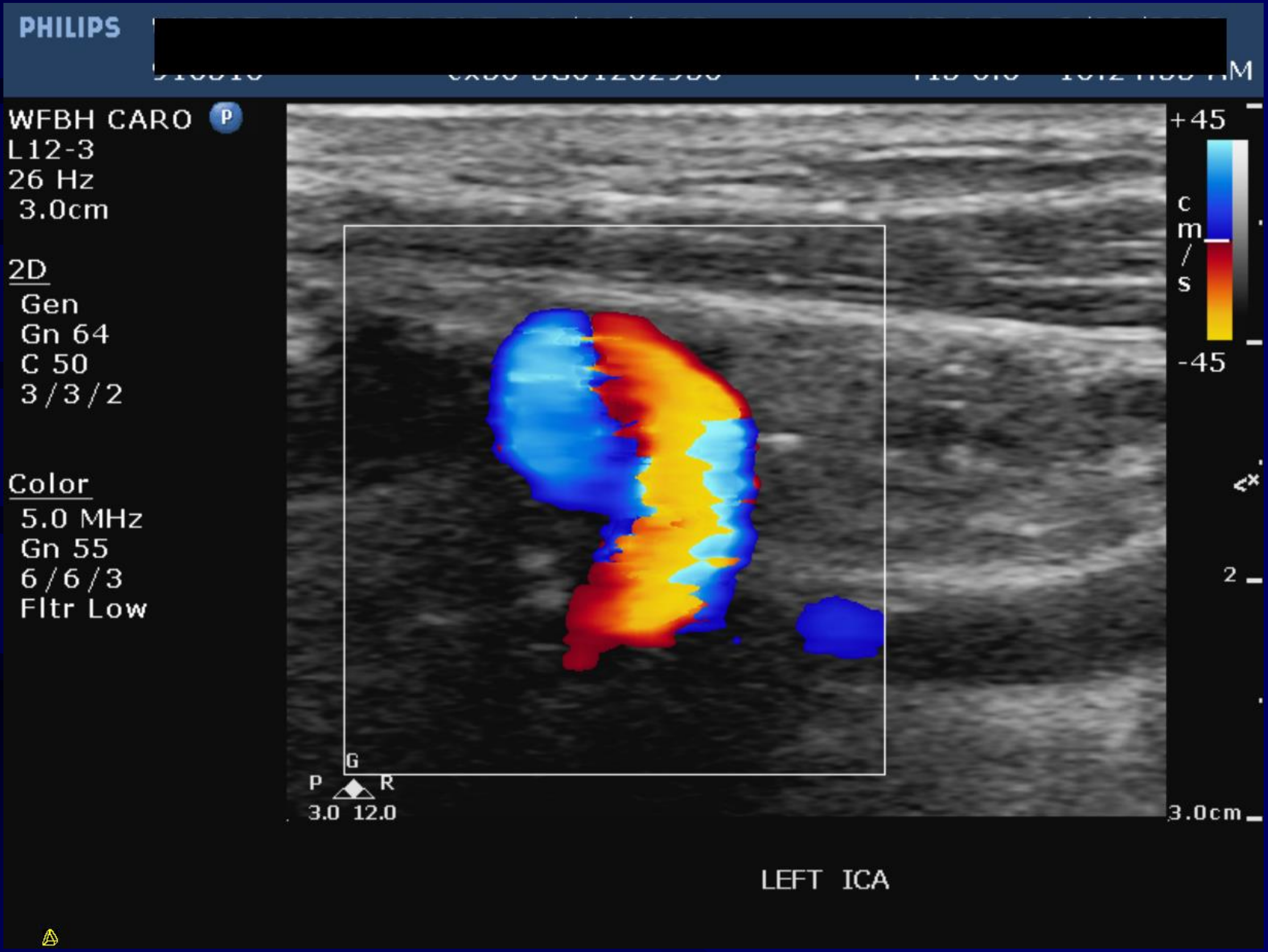
Shadowing Near Wall Affects Color Flow

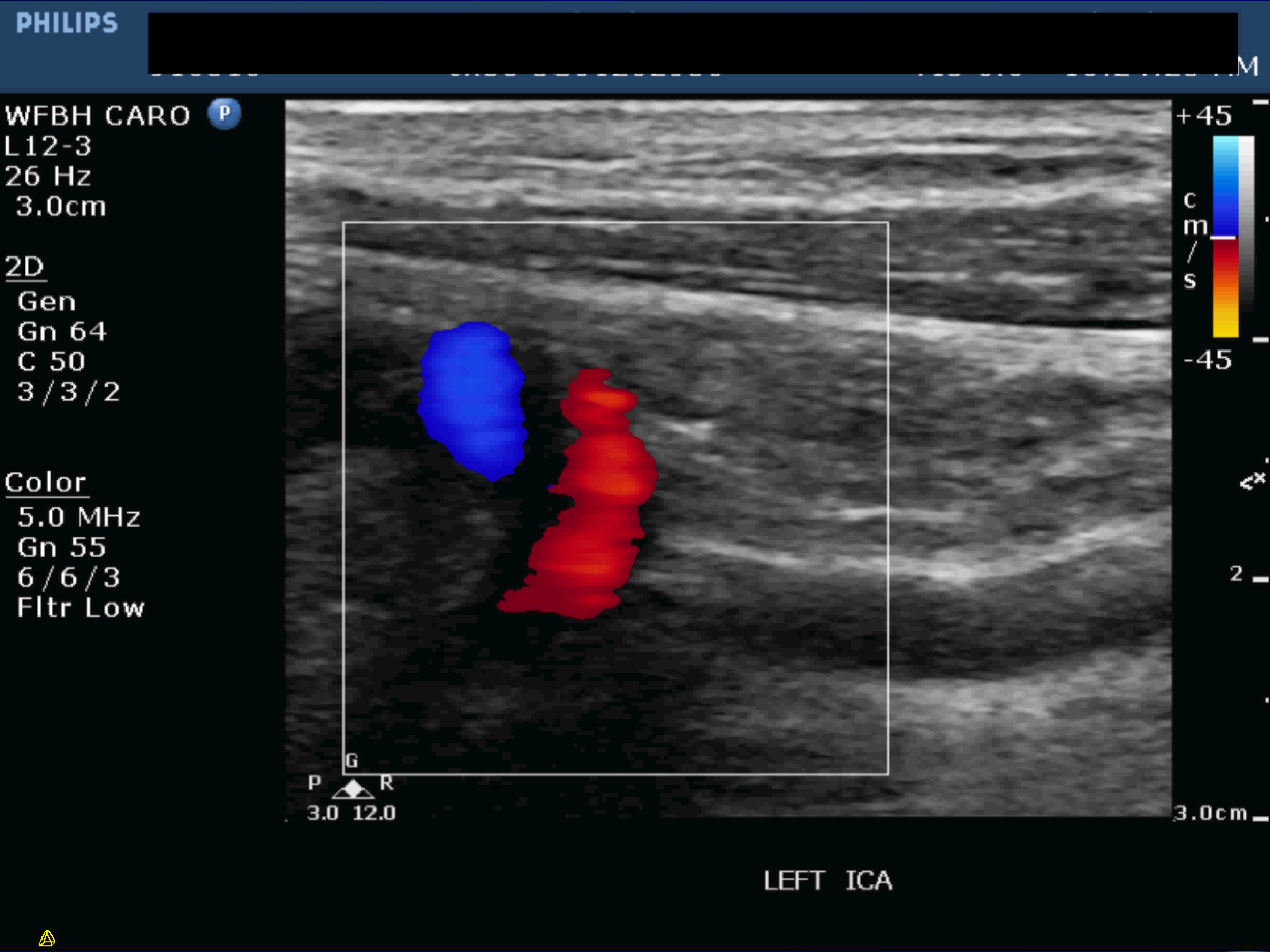


Color Flow: Tortuosity ICA



360^0 Loop in the ICA

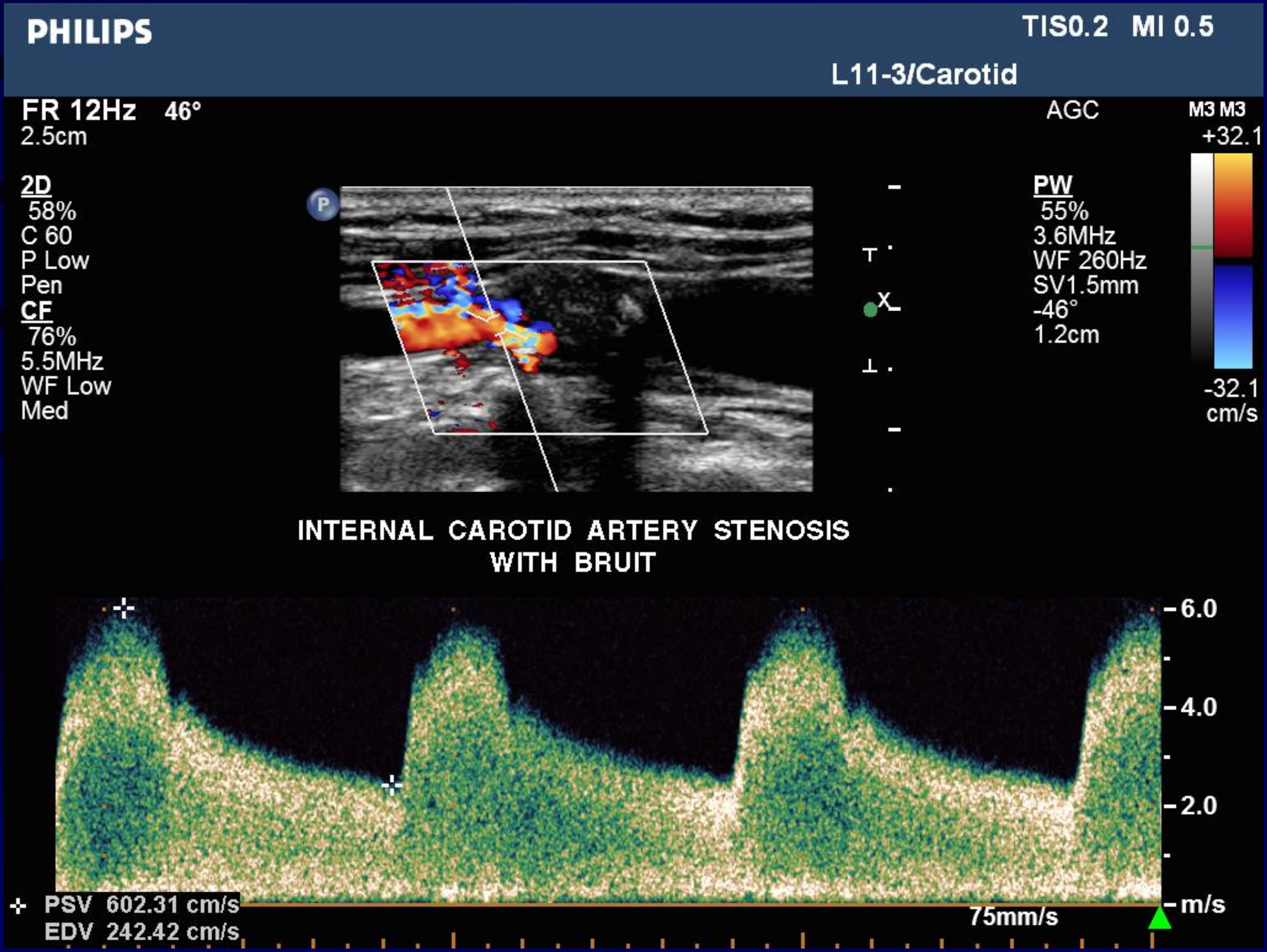




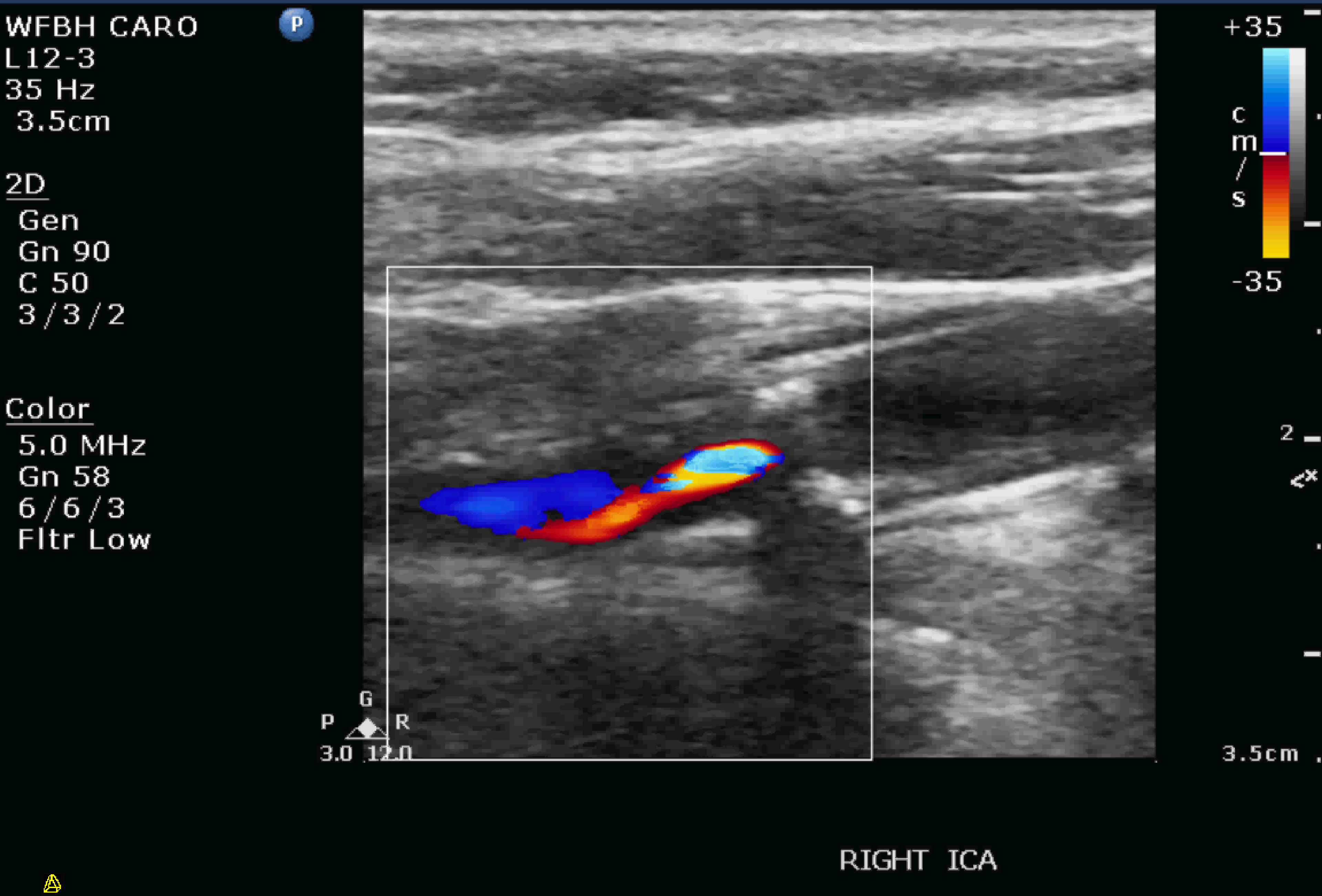
PHILIPS
[redacted]
WFBH CARO
P
L12-3
26 Hz
3.0cm
2D
Gen
Gn 64
C 50
3 / 3 / 2
Color
5.0 MHz
Gn 55
6 / 6 / 3
Fltr Low
+45
cm/s
-45
2
3.0cm
G
P
R
3.0 12.0
LEFT ICA

Color Flow ICA Stenosis

Color Duplex of ICA Stenosis

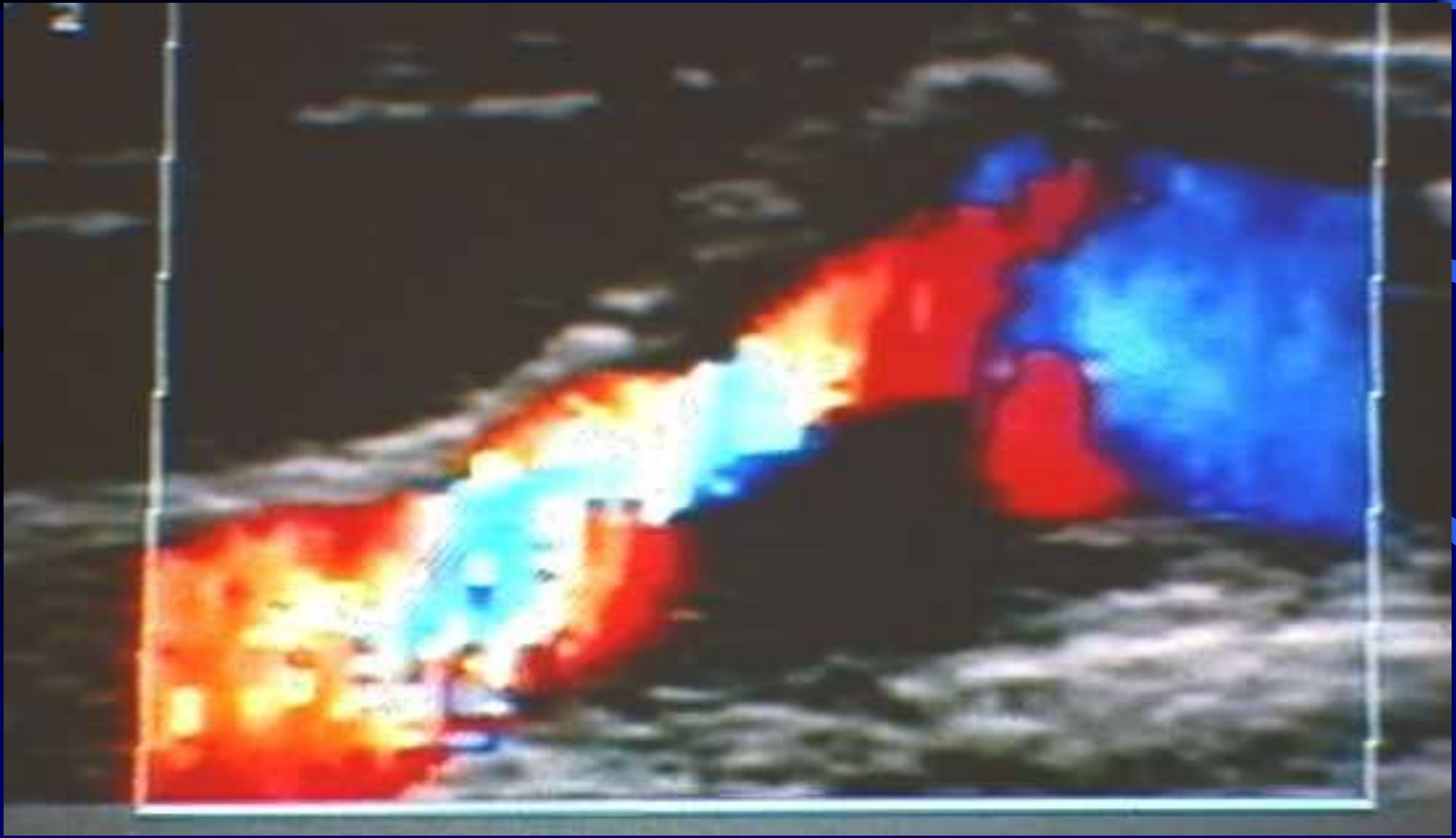


[redacted]


WFBH CARO
L12-3
35 Hz
3.5cm
2D
Gen
Gn 90
C 50
3 / 3 / 2
Color
5.0 MHz
Gn 58
6 / 6 / 3
Fltr Low
+35
cm/s
-35
2
3.5cm
G
P
R
3.0
12.0
RIGHT ICA

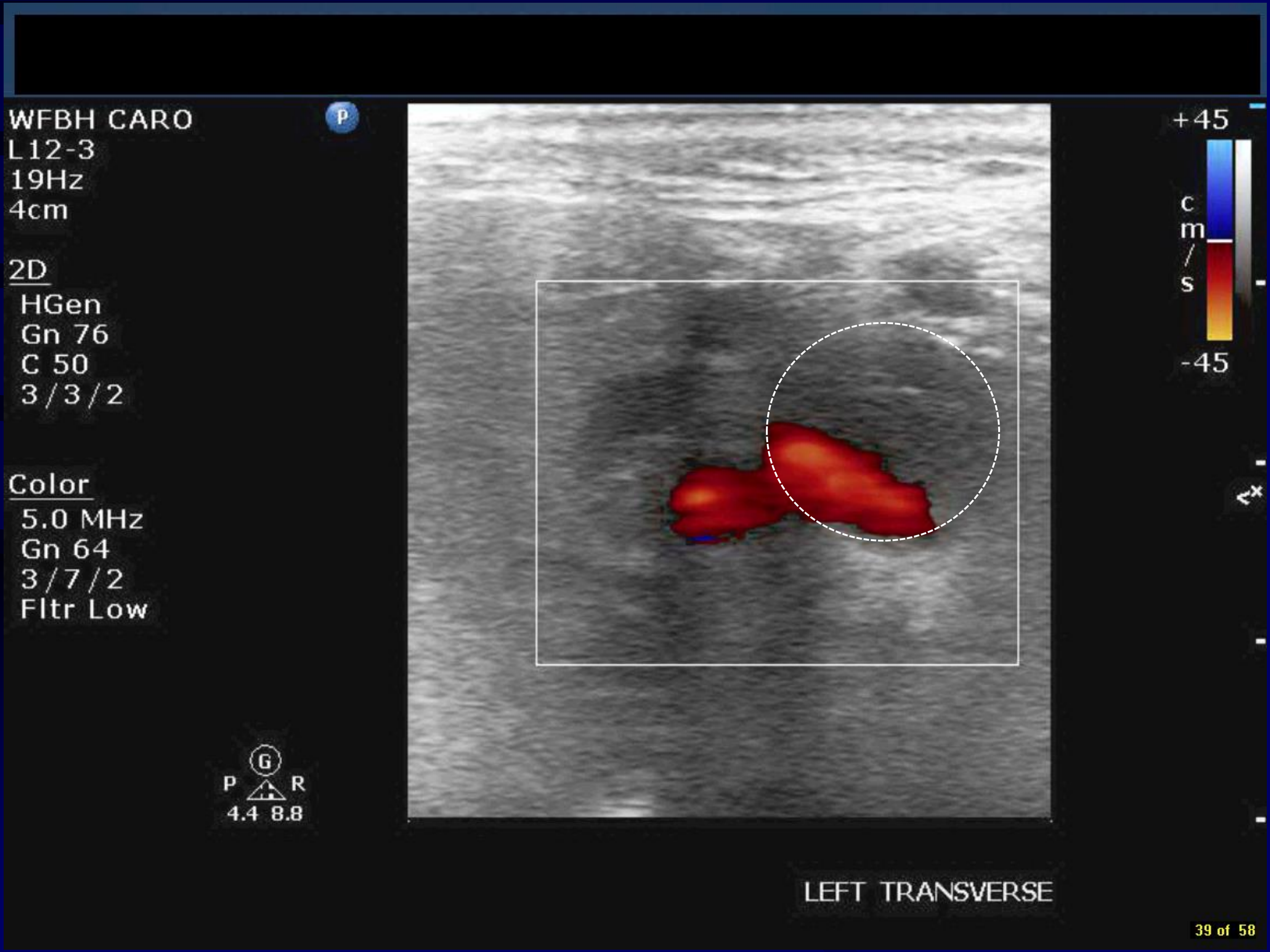
Color Flow Imaging

Color void of hypoechoic plaque



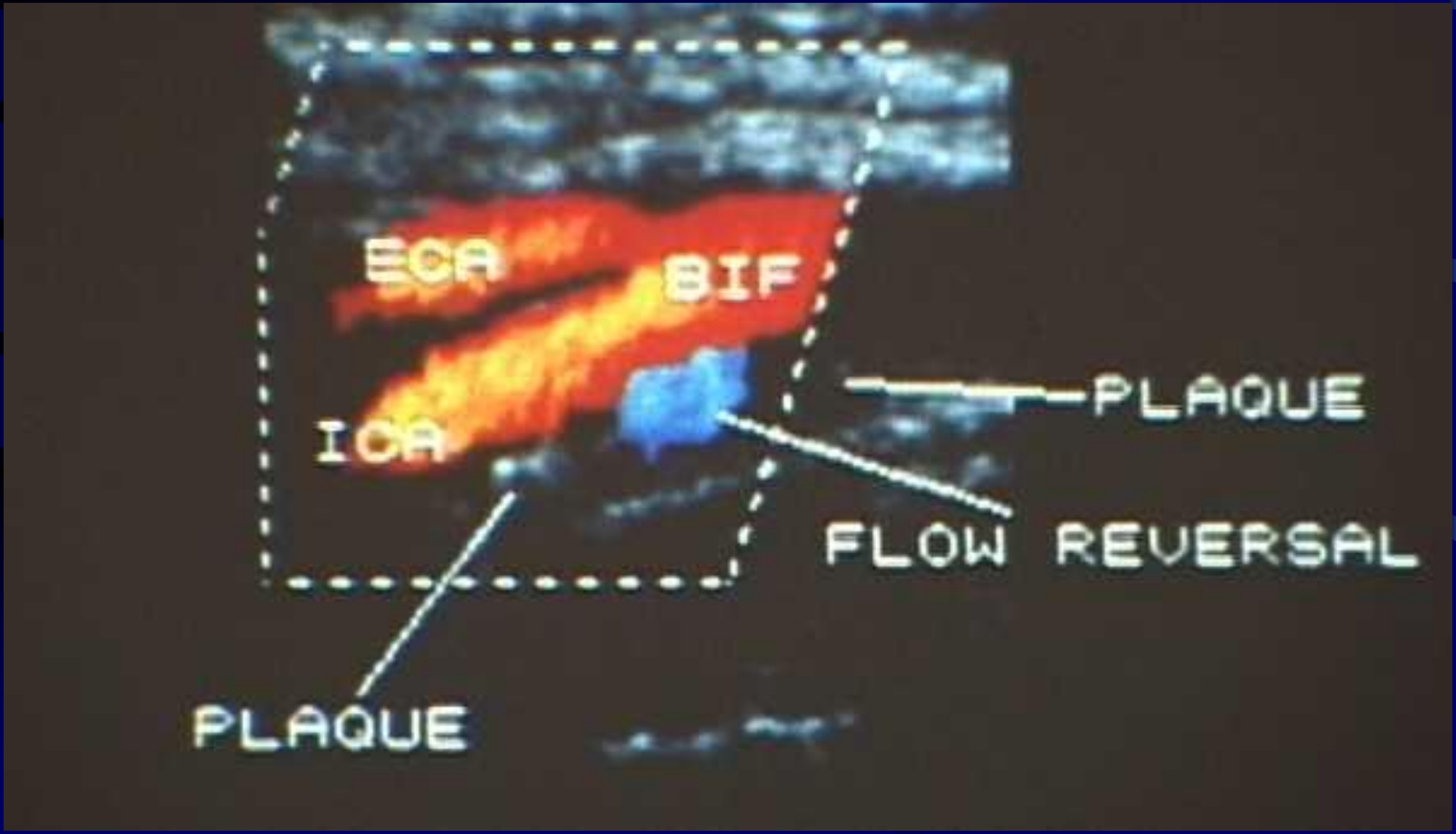
Color Flow Imaging

Color void of hypoechoic plaque - transverse



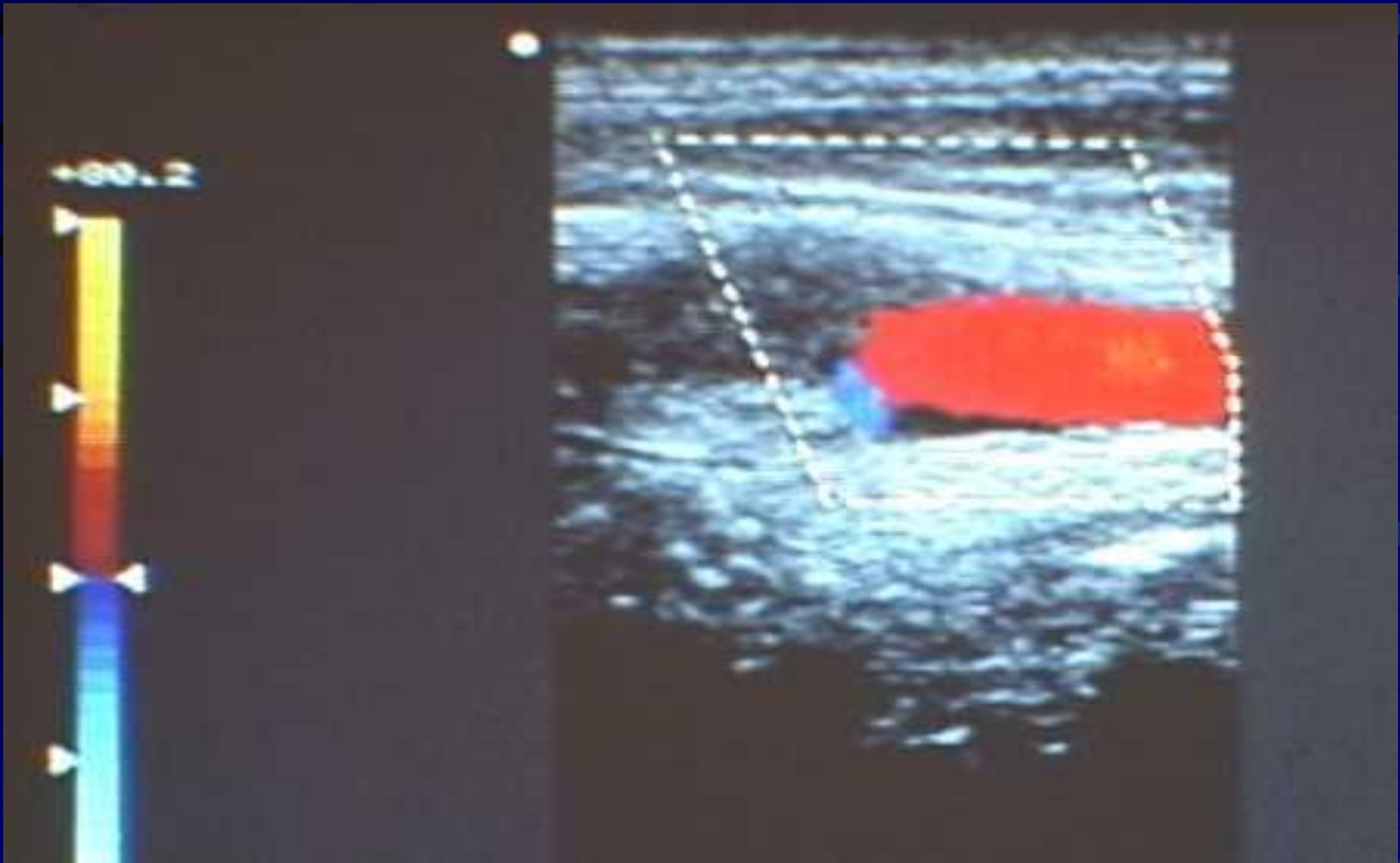
Color Flow Imaging

Surface features



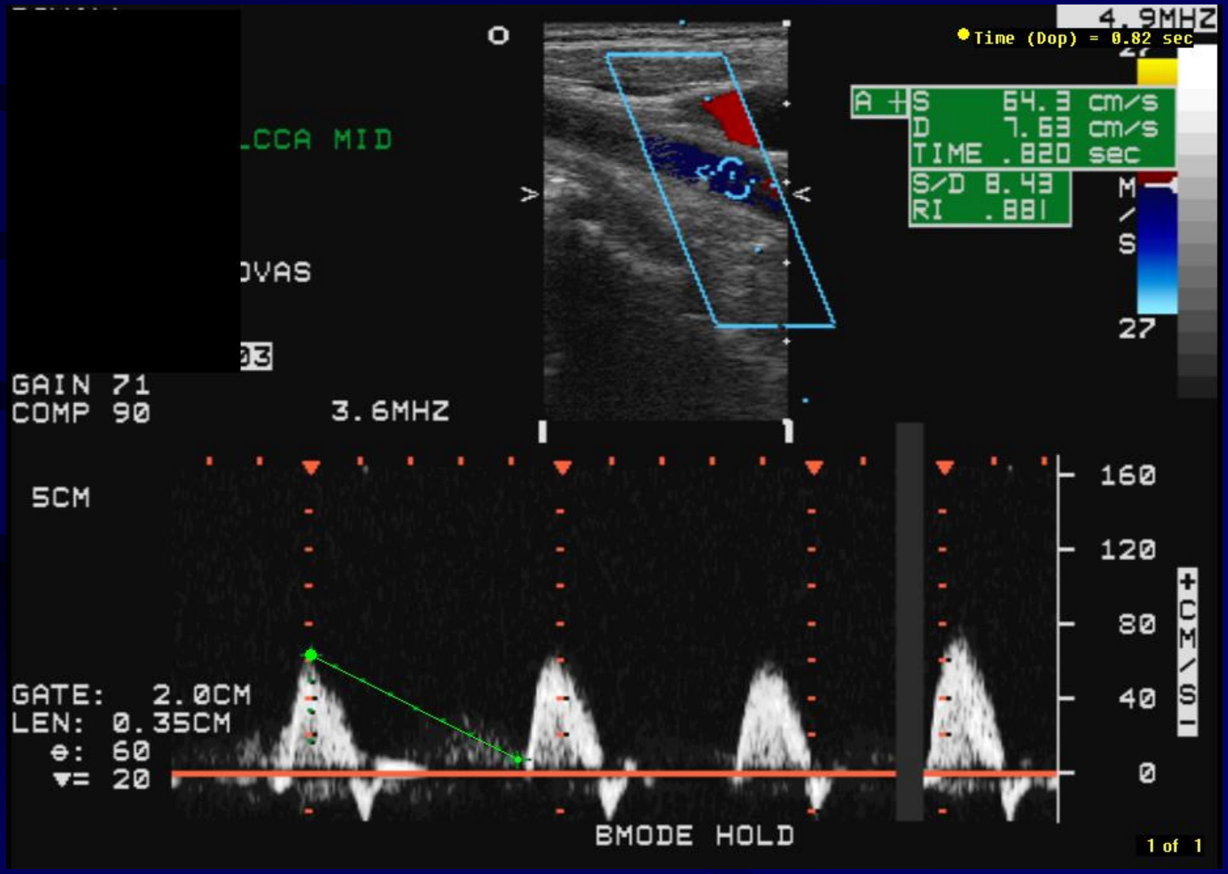
Color Flow Imaging

ICA Occlusion

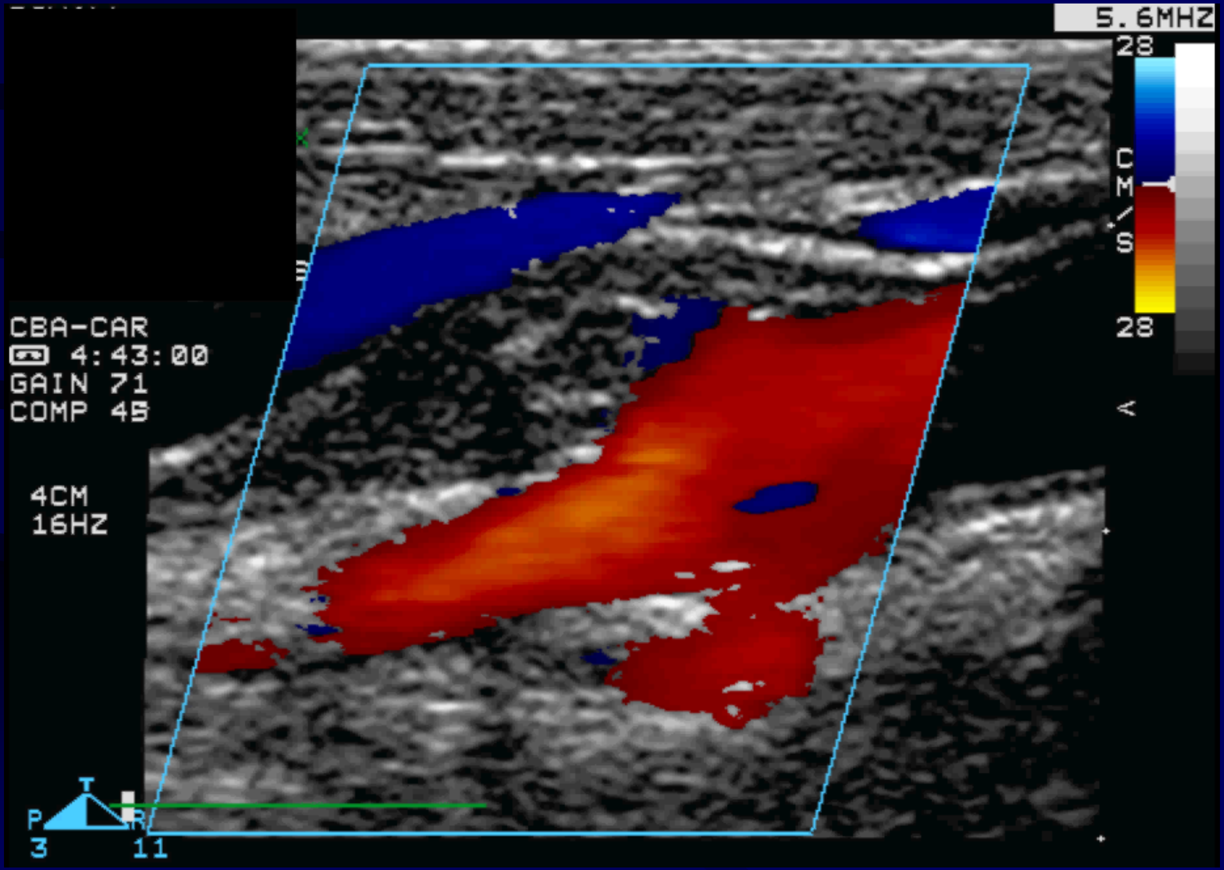


Indirect Changes

High Resistance Pattern –Distal Occlusion



Color Flow
ICA Occlusion

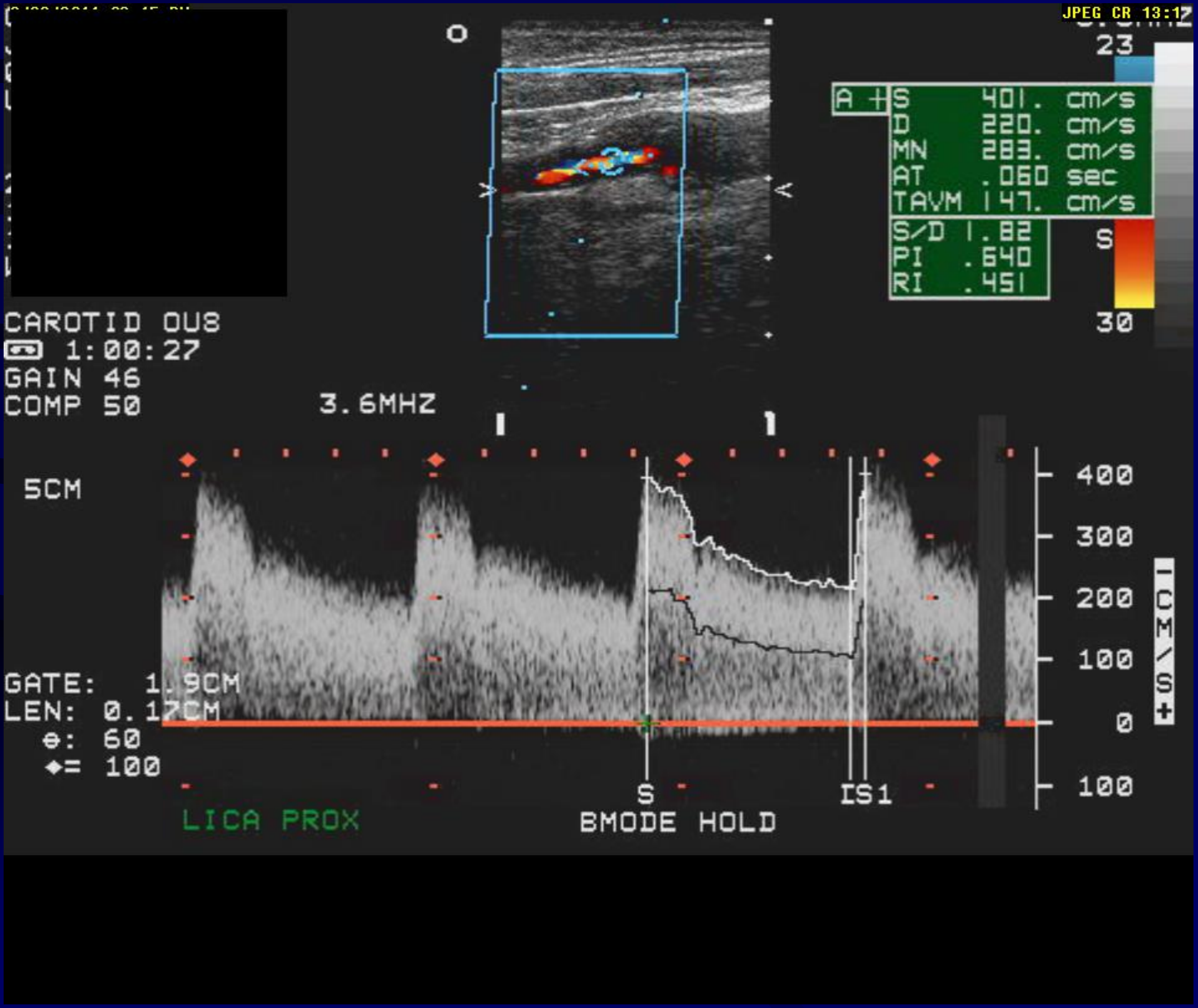


Color Flow Imaging

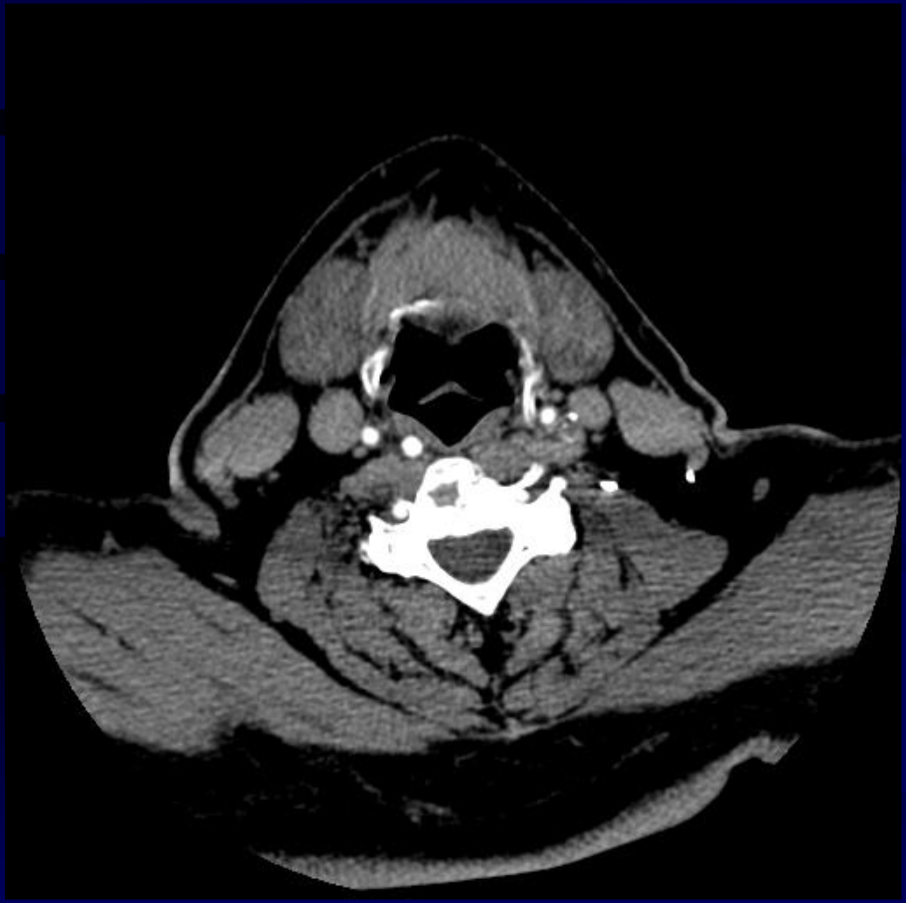
Distal flow confirms patency

Angiogram: Near occlusion ICA

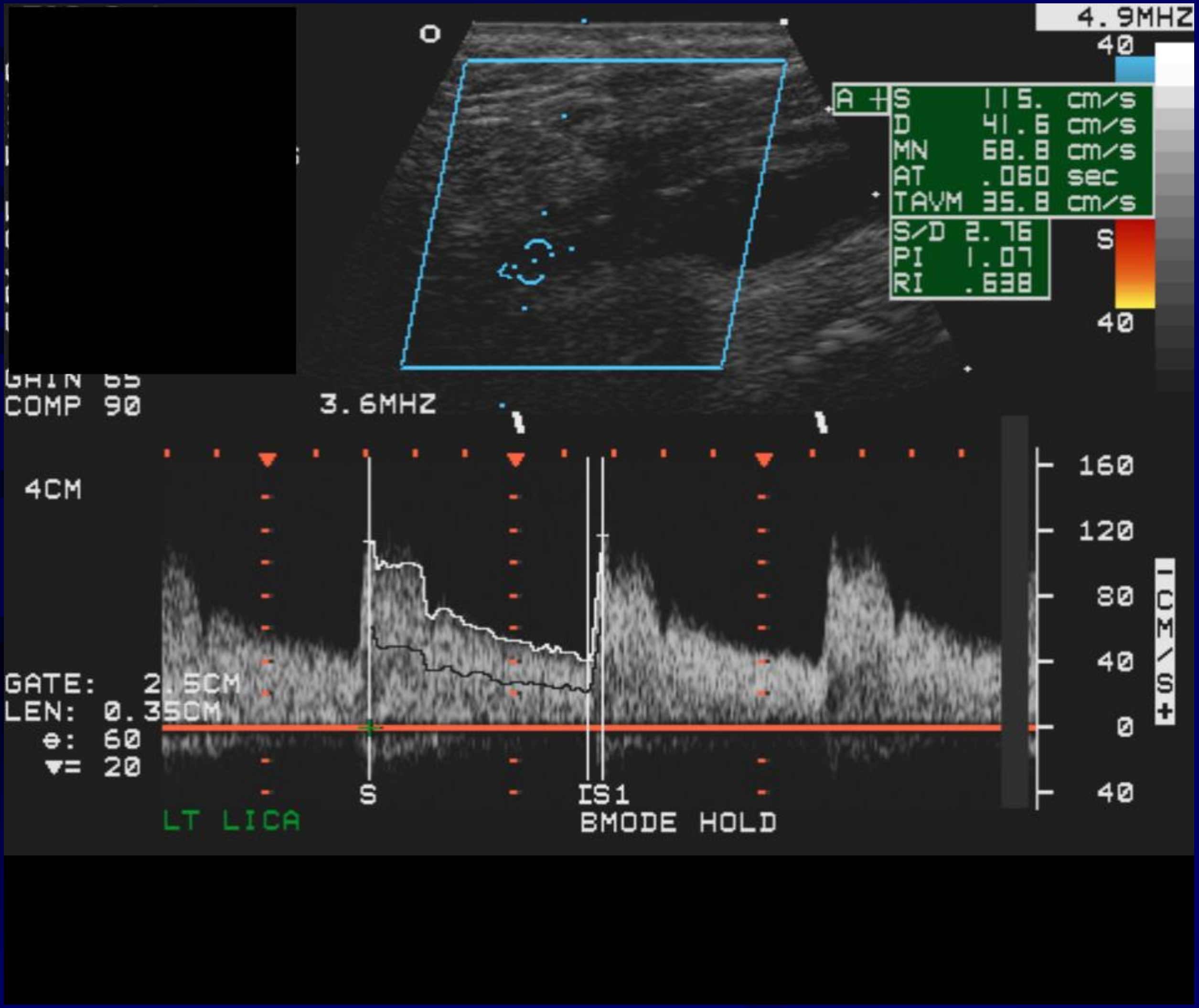
Left ICA Stenosis



CTA Left ICA Stenosis



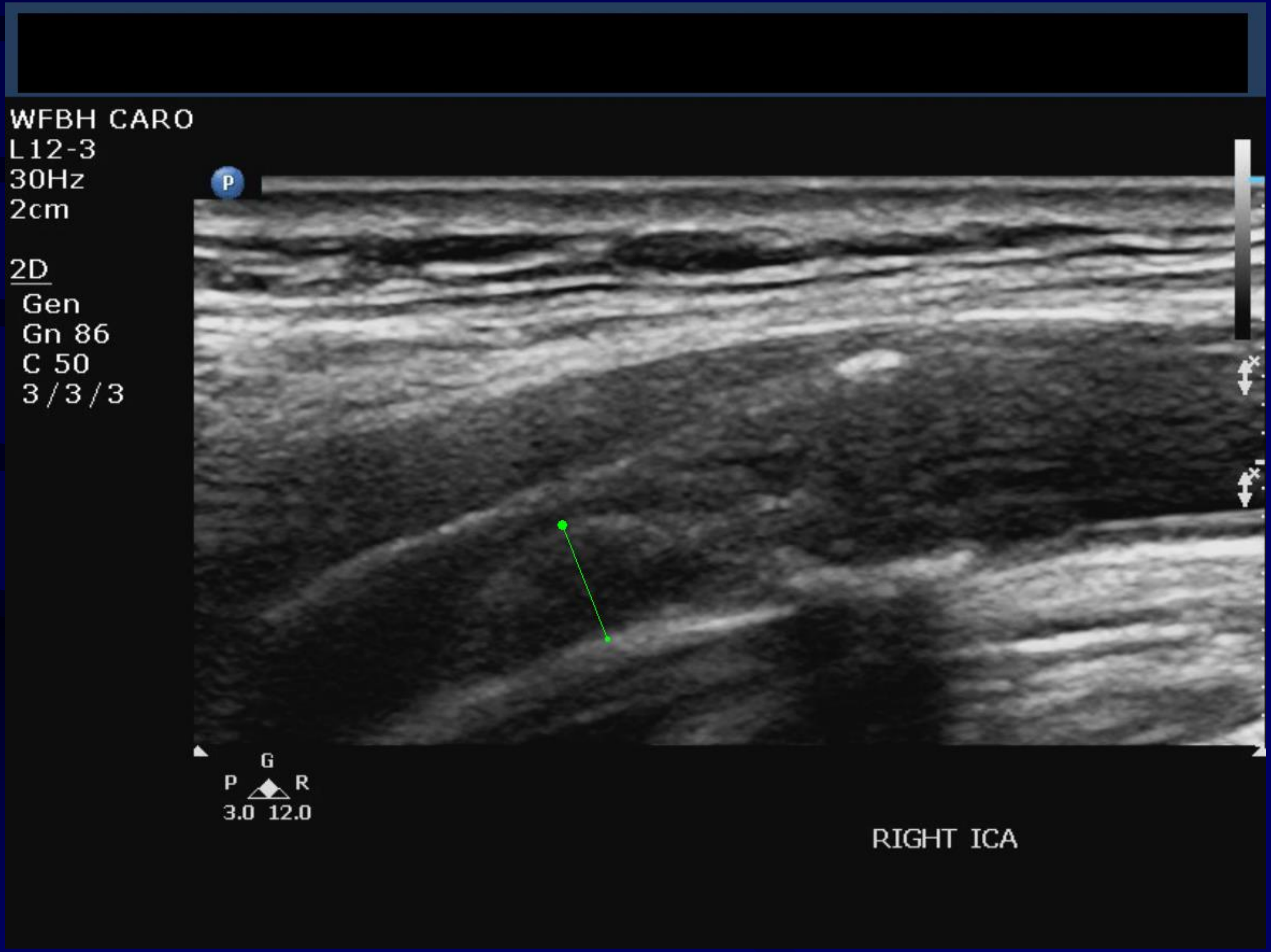
Post CEA



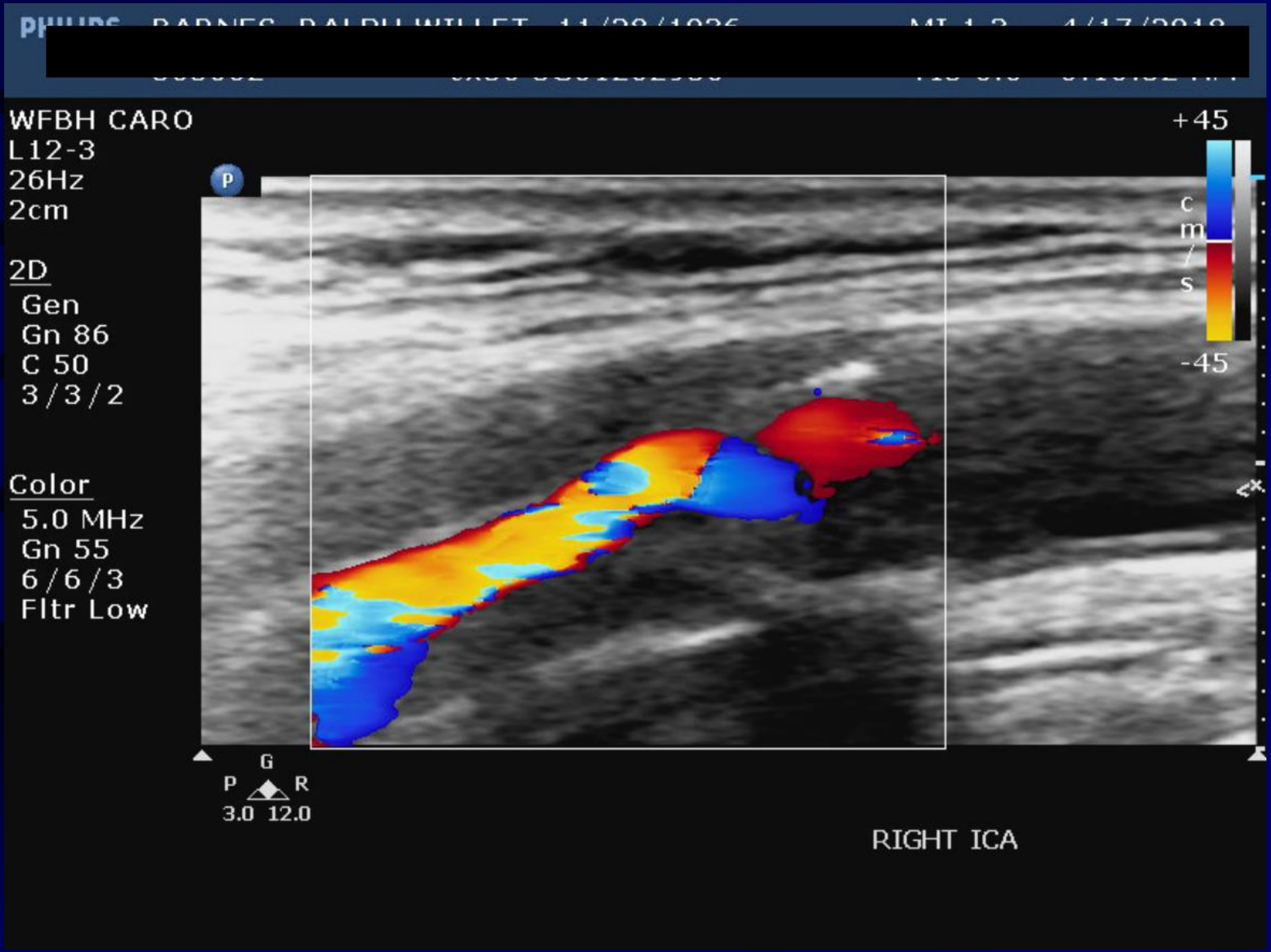
[redacted]
4.9MHZ
40
A
S 115. cm/s
D 41.6 cm/s
MN 68.8 cm/s
AT .060 sec
TAVM 35.8 cm/s
S/D 2.76
PI 1.07
RI .638
S
40
COMP 90
3.6MHZ
4CM
GATE: 2.5CM
LEN: 0.35CM
θ: 60
▼= 20
LT LICA
S
IS1
BMODE HOLD
160
120
80
40
0
40
-CM/S+

Color Blooimg

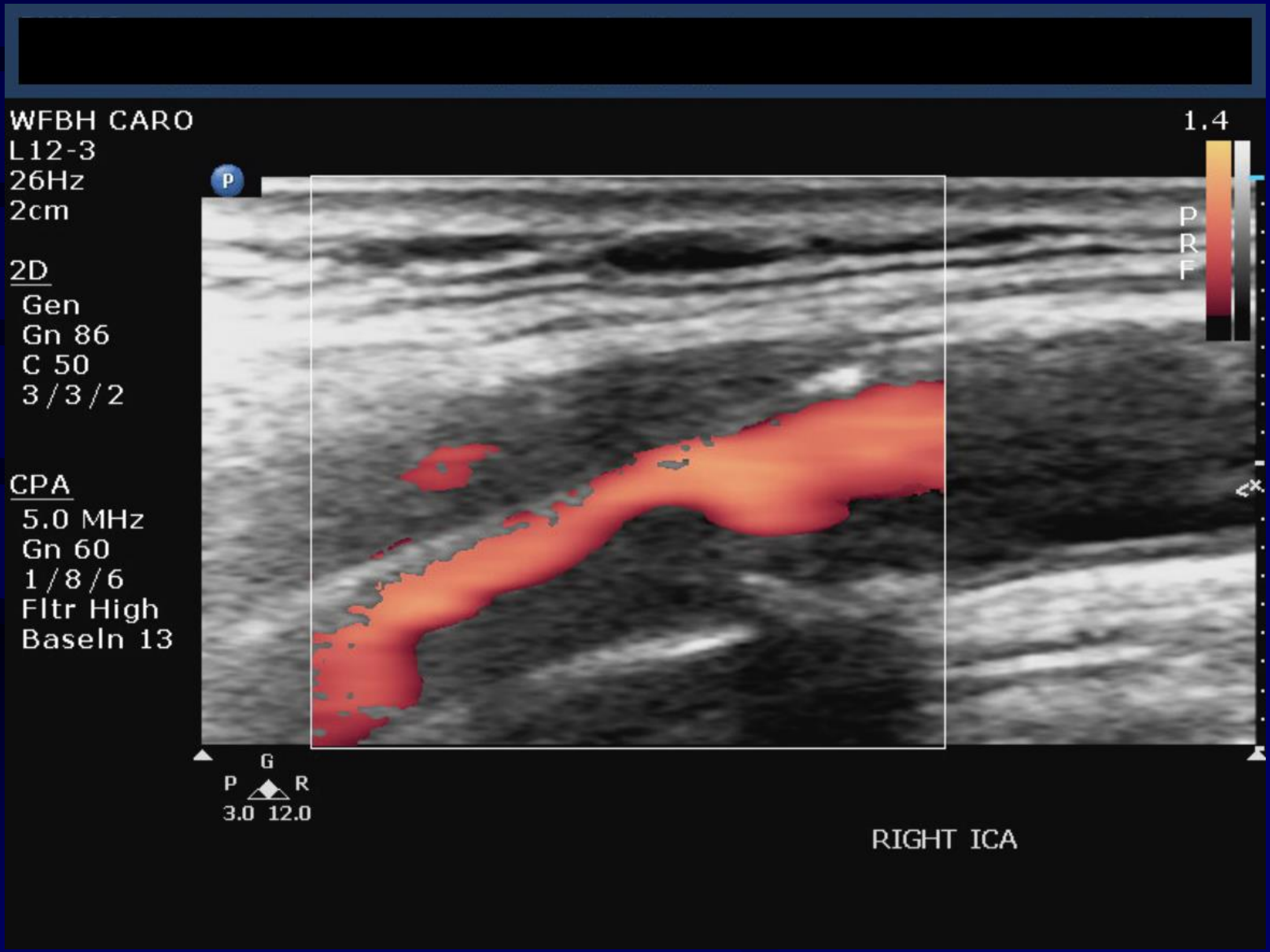
Large ICA Plaque



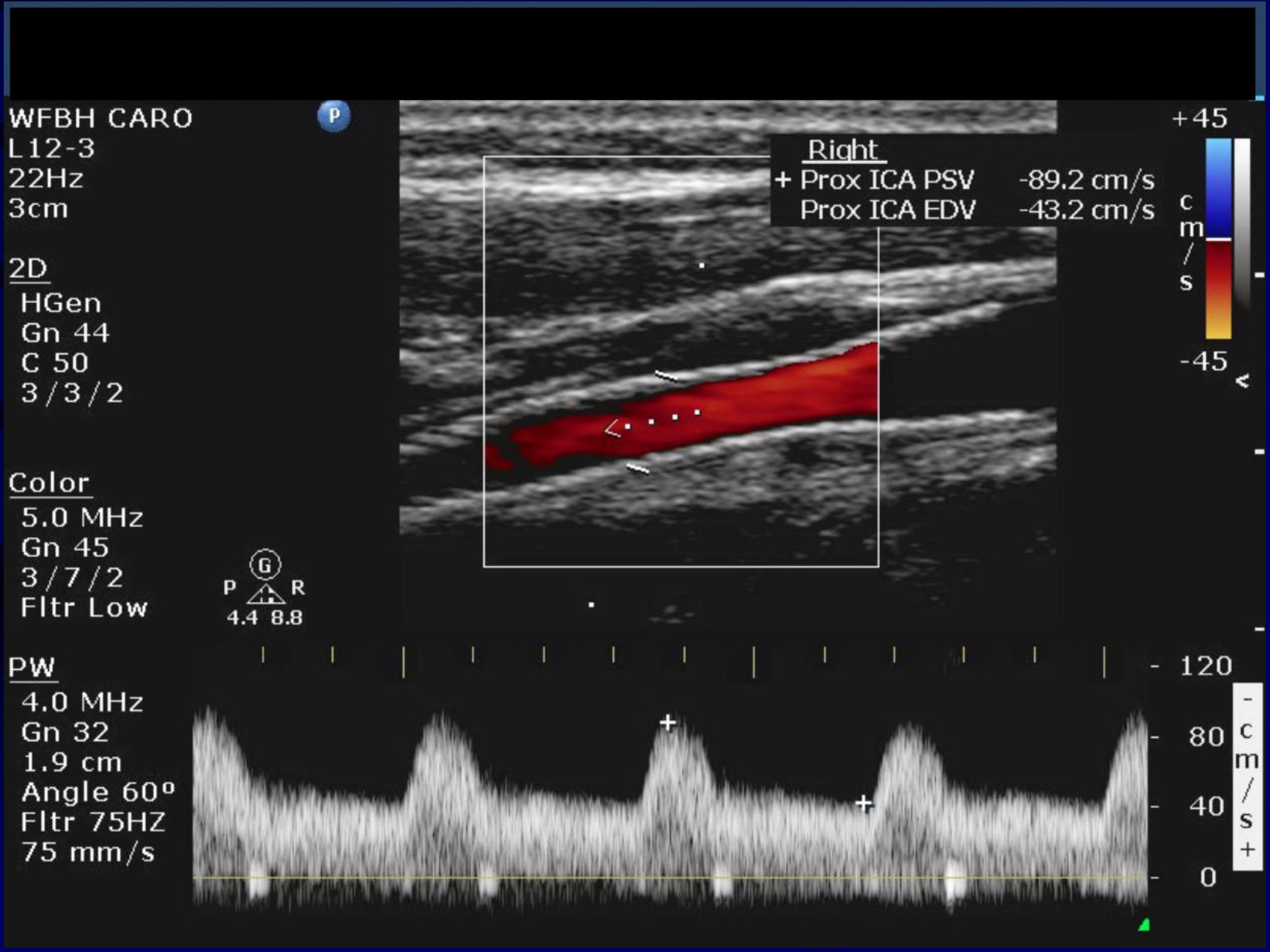
Color Blooming Beyond True Lumen



Color Blooming Power Doppler



Stent: Color Flow



Stent Stenosis

Post-Stenotic Turbulence

Stent Re-Stenosis Used at WFBMC

- Stent is stiff and not distensible
- Velocities are higher
- Ratio helpful to identify severe re-stenosis

% Stenosis	Peak Systolic Velocity	End Diastolic Velocity	ICA:CCA ratio
50-69%	175-299 cm/s	----	----
≥ 70%	≥300	≥140	≥3.8

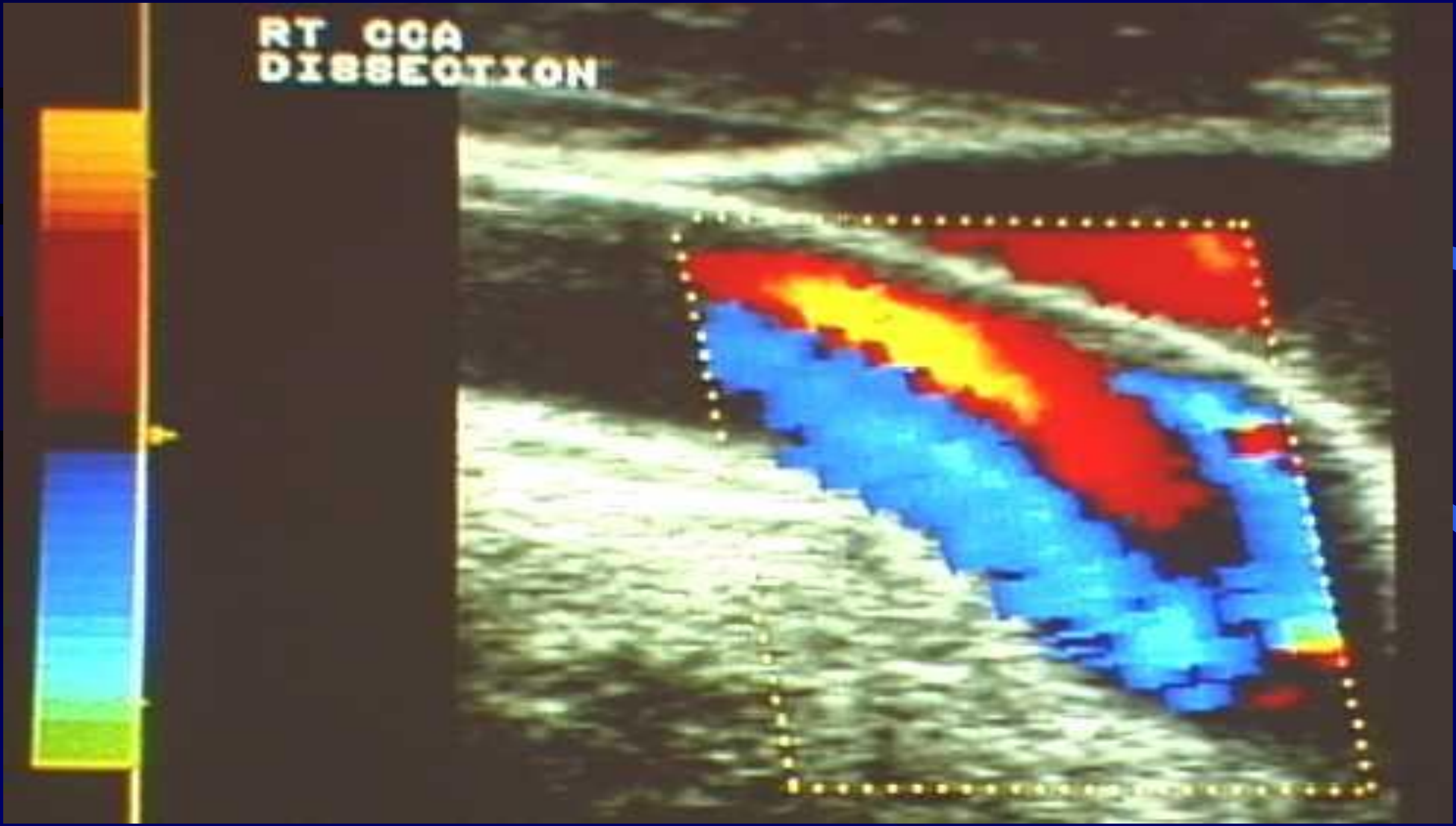
Setacci C, et al., Stroke, 2008;39:1189-96

Carotid Dissection

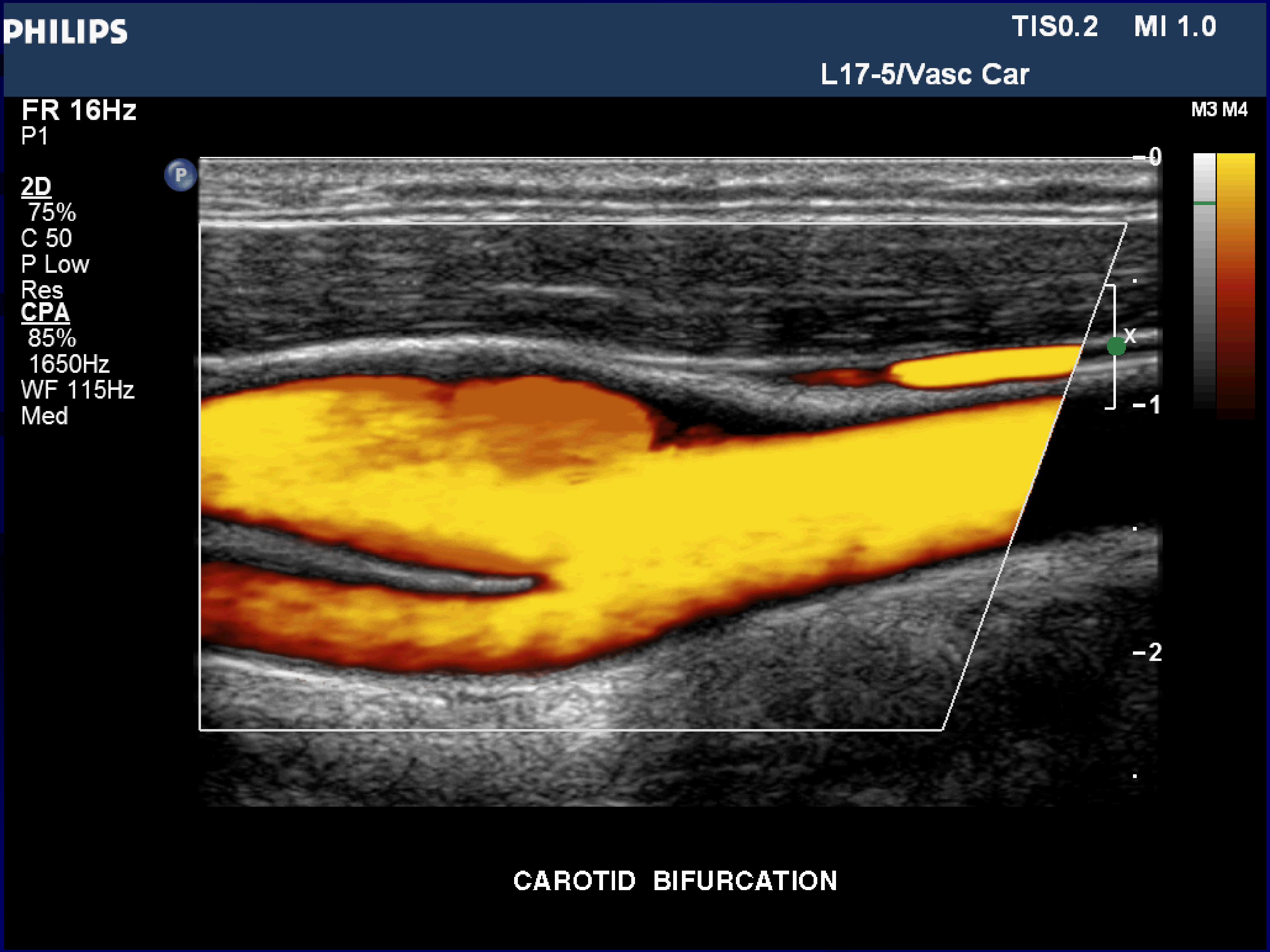
B-mode appearance

Carotid Dissection

Color Flow shows double lumen

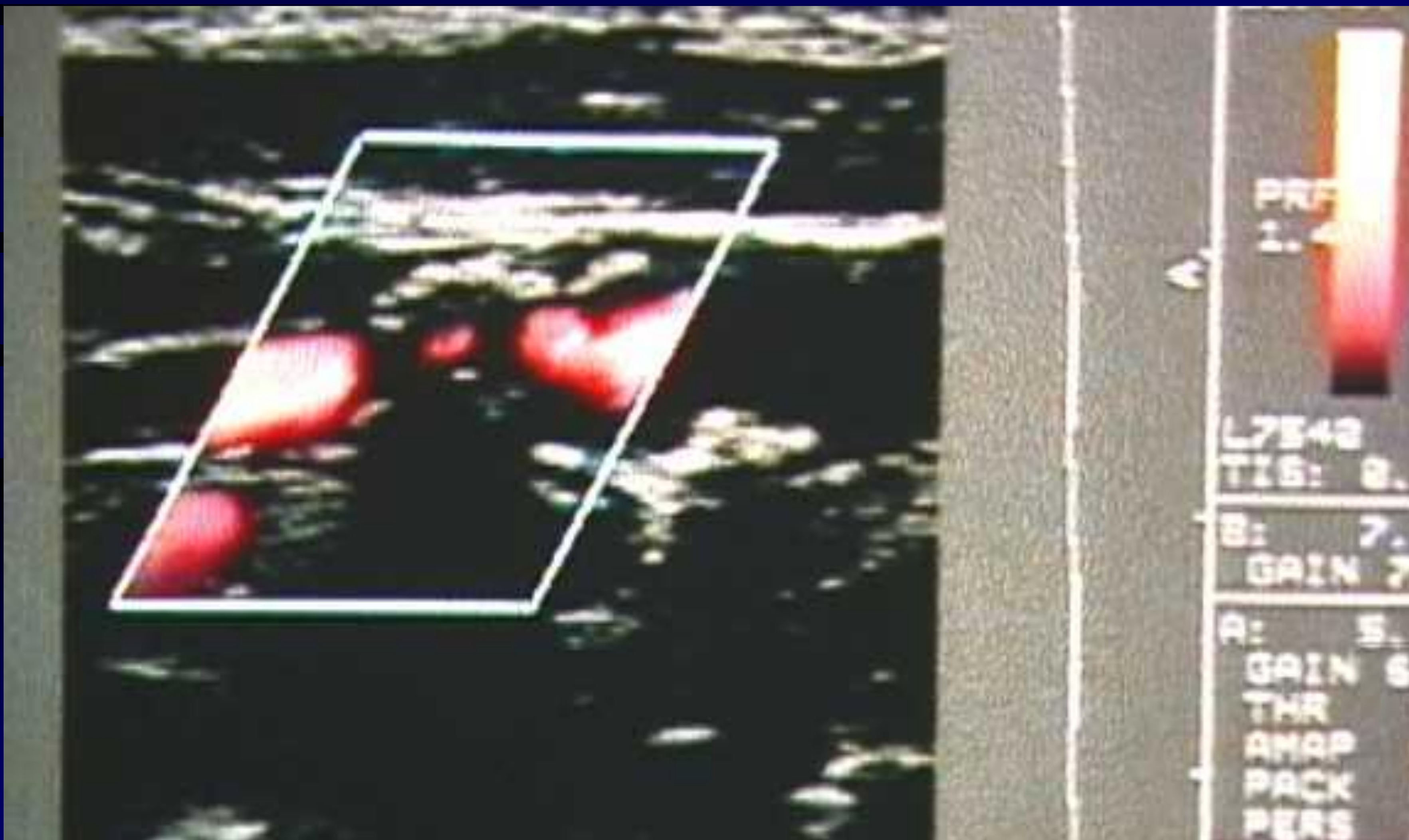


Power Doppler Imaging



Power Imaging

ICA Stenosis and Shadowing



Vertebral System

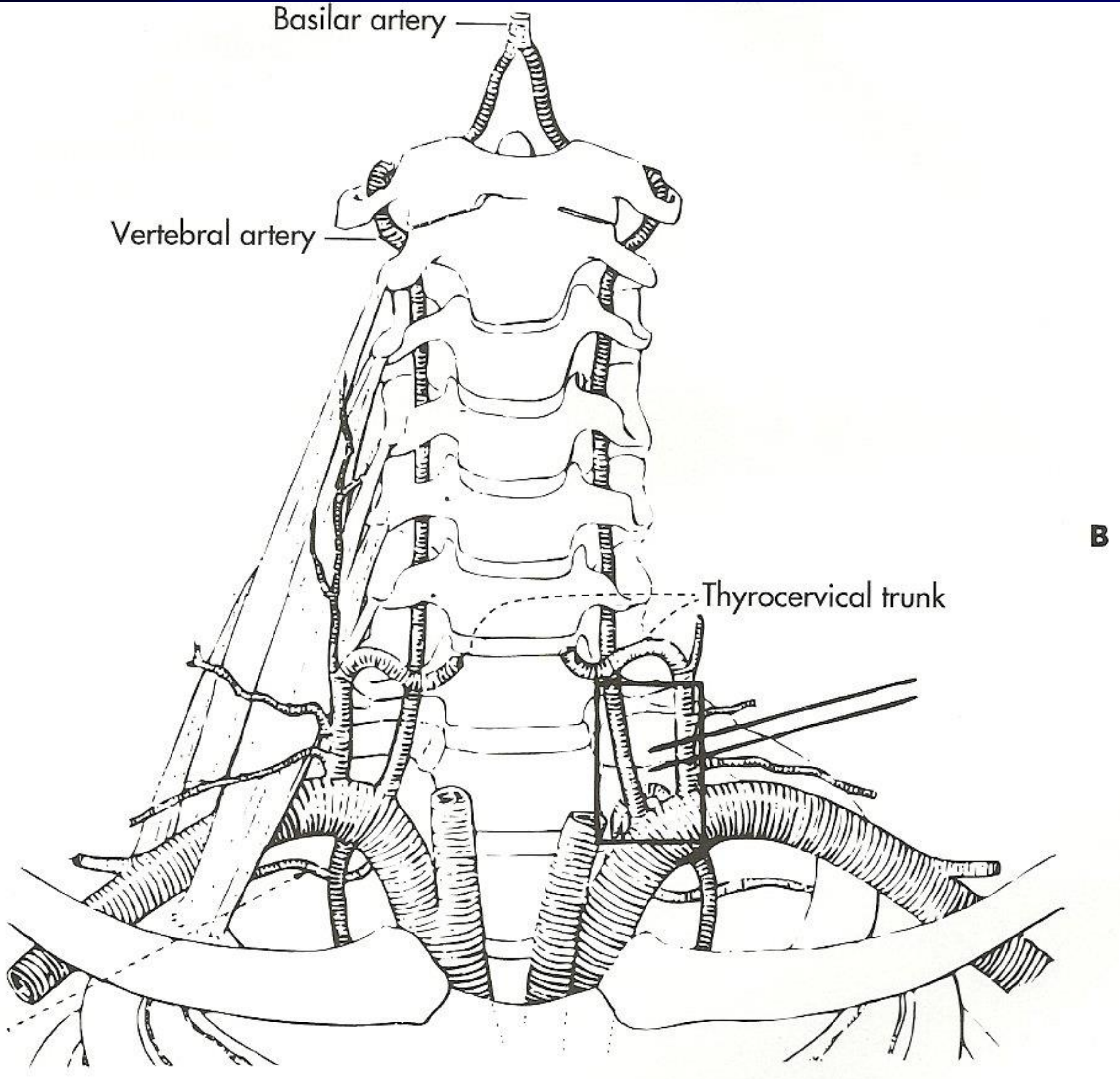
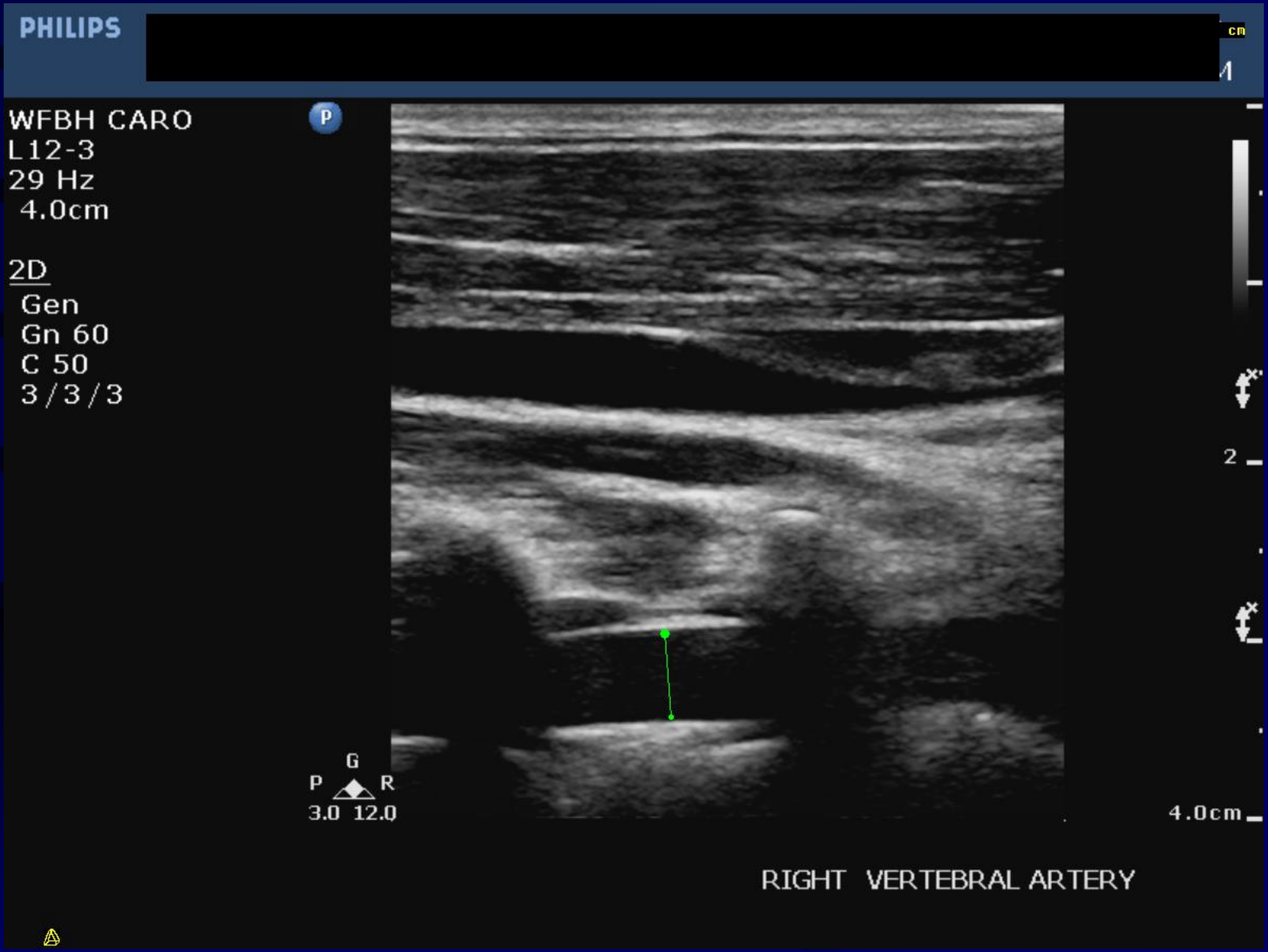


Fig. 10-1. A, Transducer position for the visualization of the vertebral origin; **B,** corresponding anatomic view. Thyrocervical trunk is located laterally from the origin of the vertebral artery.

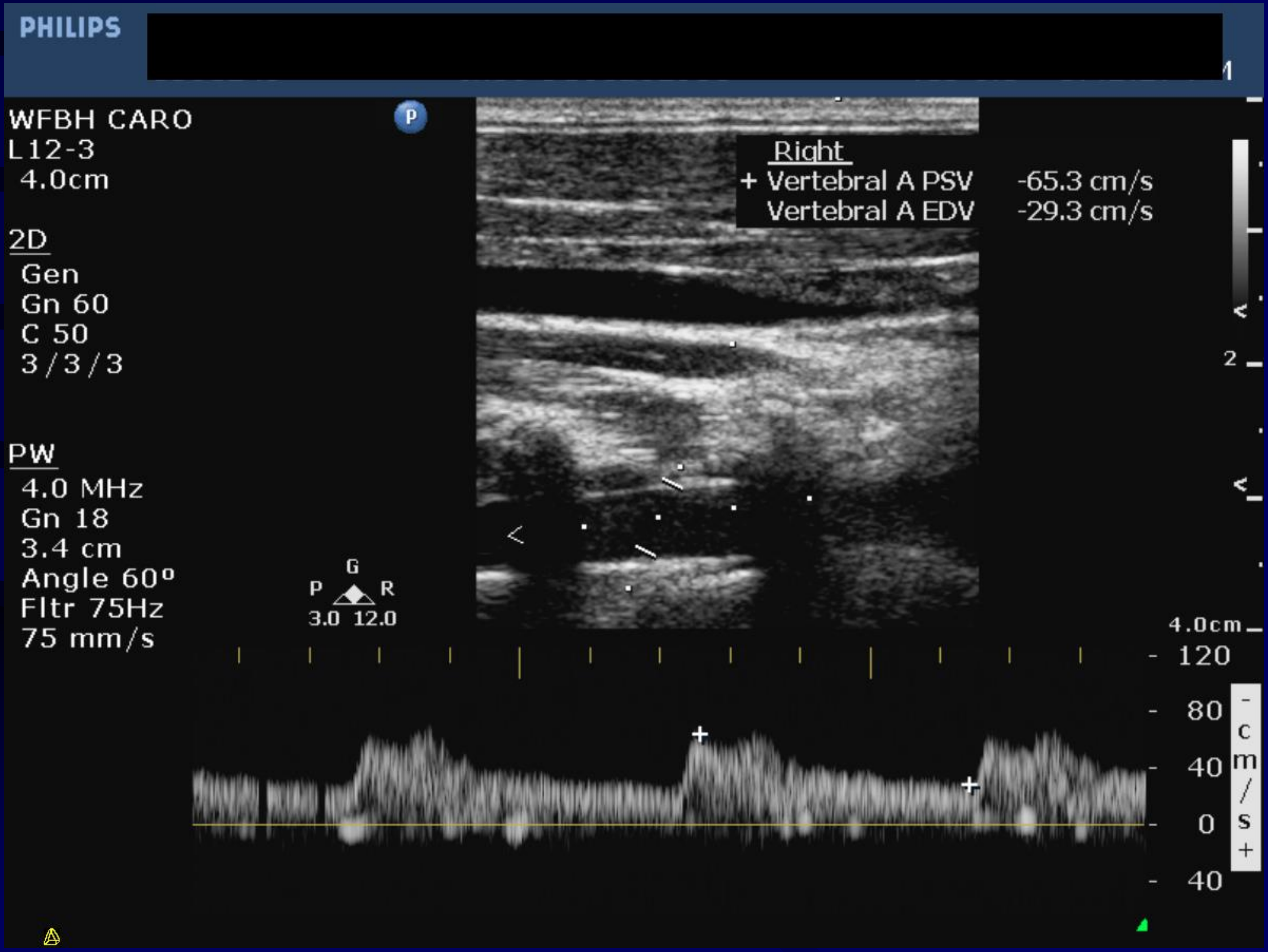
Color Duplex Subclavian Artery

Color Flow Vertebral Origin

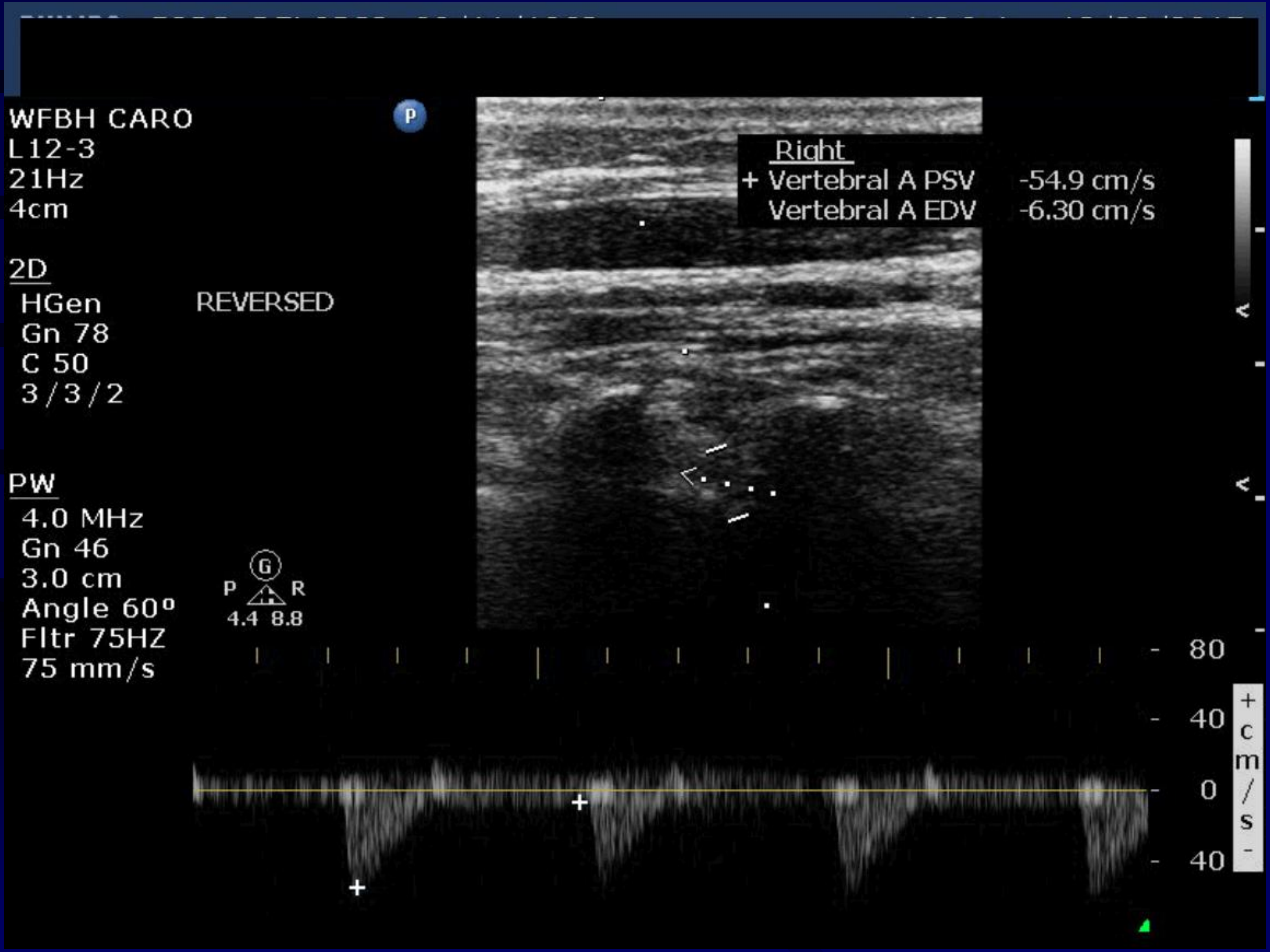
Longitudinal B-Mode Right VA



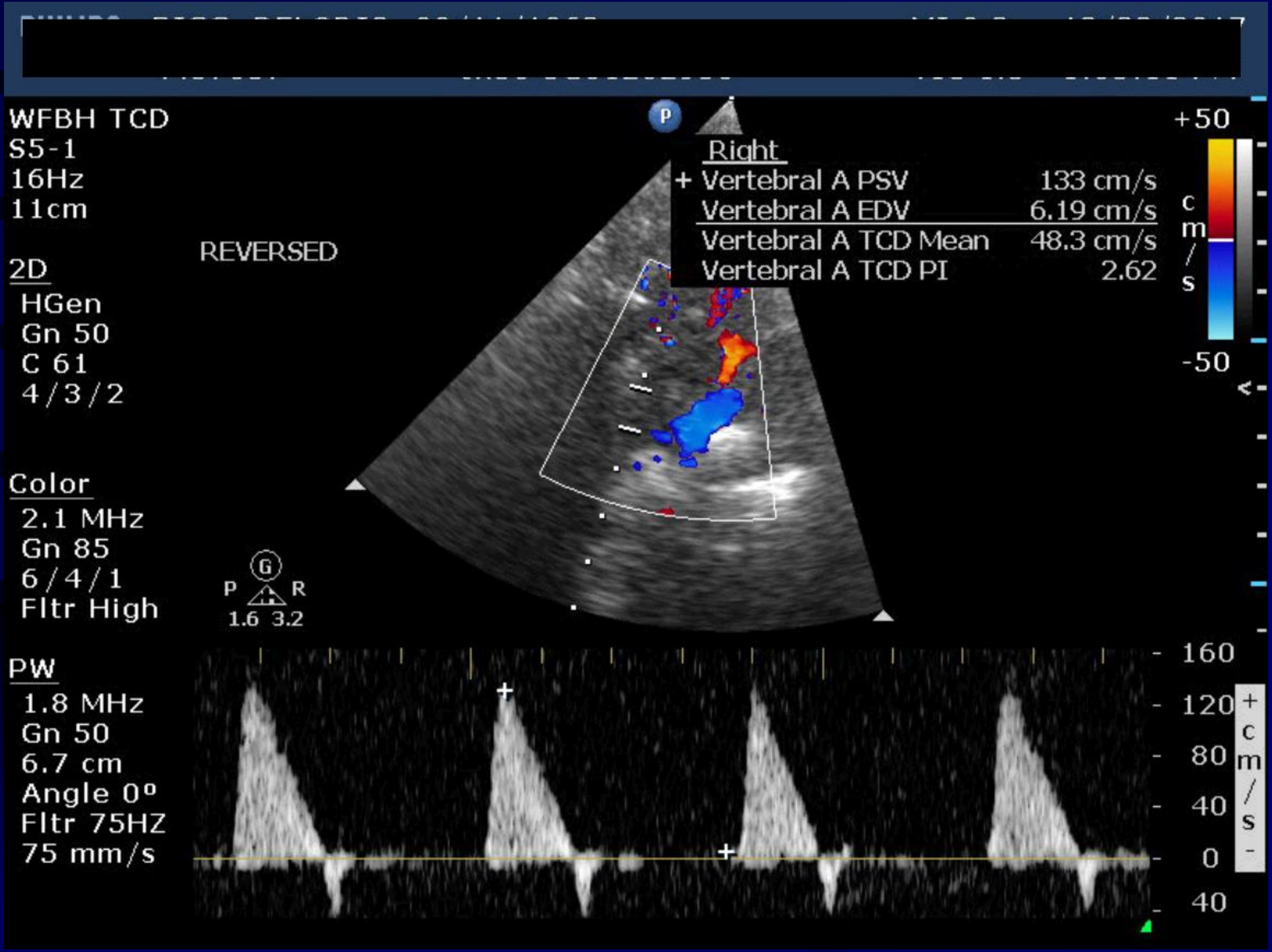
Duplex Right VA



Subclavian Steal Extracranial VA



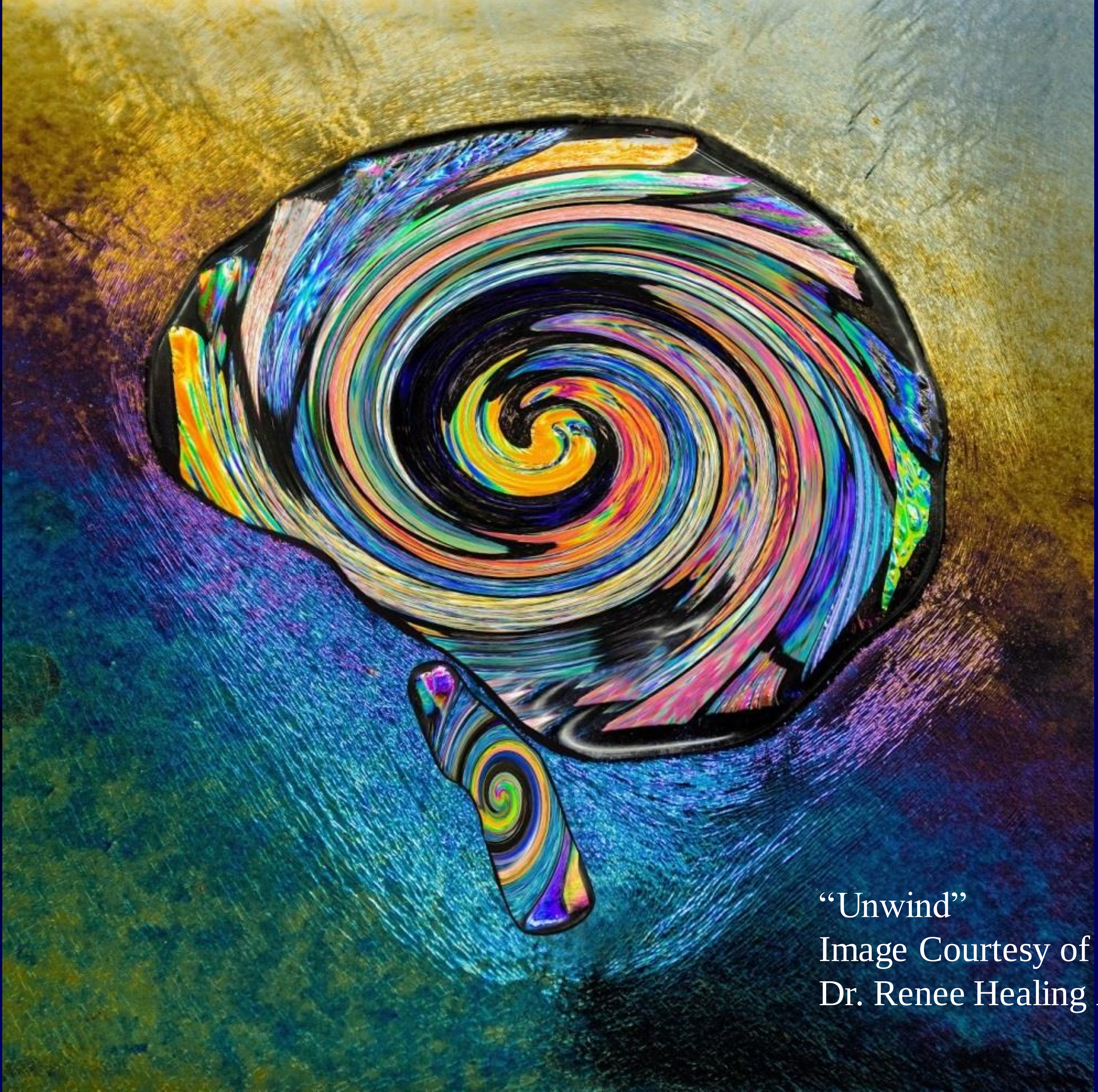
Subclavian Steal Distal VA on TCD



Carotid Ultrasound

Applied Principles and Physics, and Foundation for Interpretation

- Doppler
- B-mode
- Color flow
- Lots of information shared so time to:


“Unwind”
Image Courtesy of
Dr. Renee Healing Art