

Applied Principles of Ultrasound Physics

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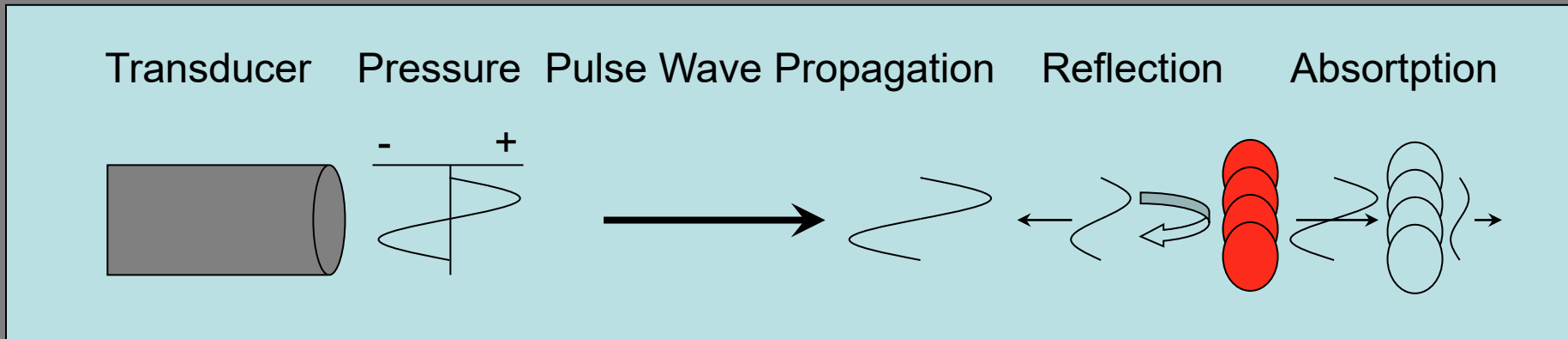
Semmes-Murphey Professor and Chairman

Department of Neurology

The University of Tennessee Health Science Center

Memphis, TN

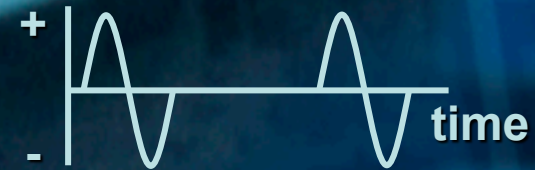
Ultrasound Propagation thru Tissues



The reflected wave (echo) carries information about tissues where it originated.

Seven Acoustic Variables describing sound waves

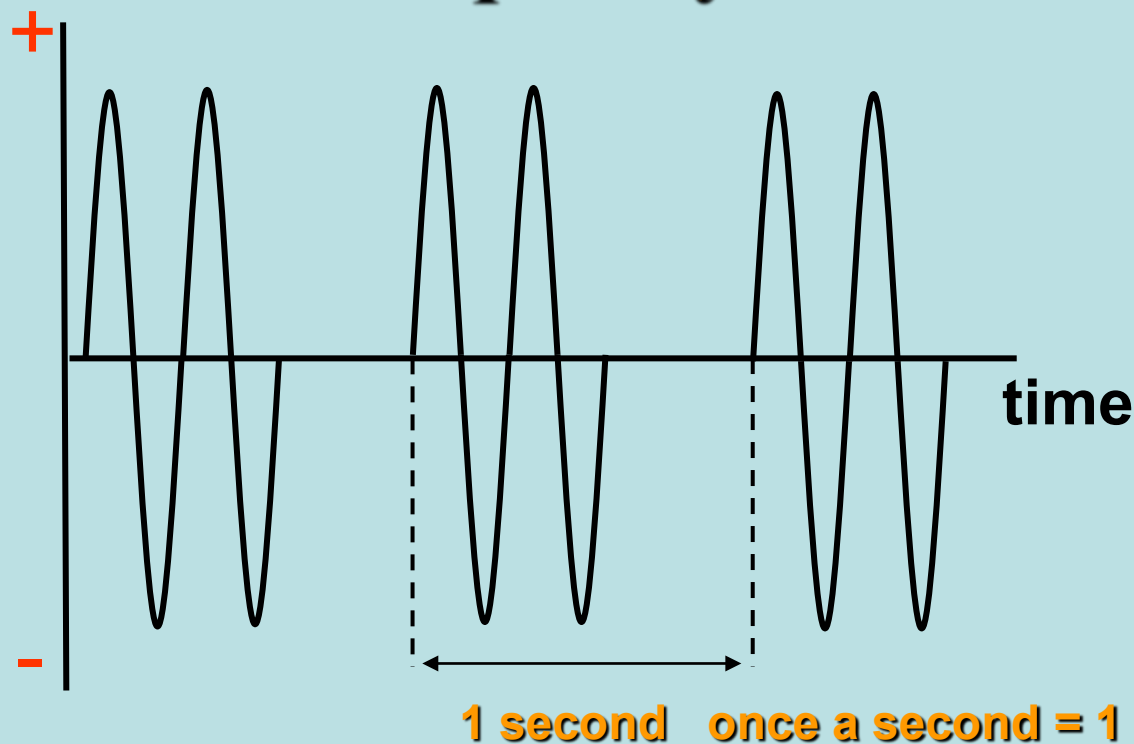
Pressure



Period	Time that it takes a wave to vibrate in a single cycle (single pulse duration), or the time from the start of a cycle to the start of the next cycle (pulse repetition period); measured in microseconds for medical diagnostic ultrasound.
Frequency	The number of cycles that occur in one second; measured in Hertz (1 cycle / 1 second = 1 Hertz); range kHz (therapeutic) and MHz (therapeutic and diagnostic ultrasound).
Amplitude	The difference between the maximum positive or negative values over un-disturbed value for pressure (measured in Pascals), density (measured in g/cm^3), or particle motion or distance (measured in mm or cm).
Power	The rate of energy transfer, i.e. rate at which work is performed; measured in Watts; range under 700 mW for diagnostic ultrasound.
Intensity	The concentration of energy in the sound beam, i.e. power distribution in the area the beam is applied to; measured in W/cm^2 .
Wavelength	The spatial length of a single complete pulse cycle; inversely related to frequency; measured in mm or cm.
Propagation speed	The distance that ultrasound travels in one second; measured as in m/s; average speed of ultrasound in soft tissues is 1540 m/s or “a mile a second”.

Pressure

Frequency

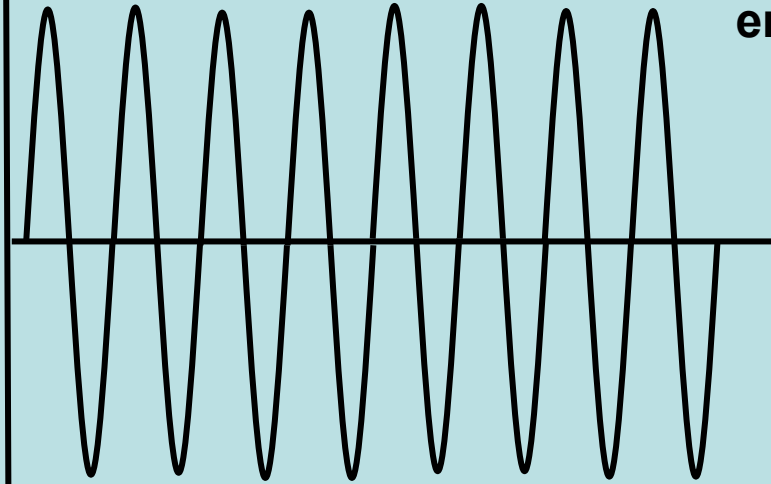


Diagnostic Ultrasound
range 1 MHz – 15 MHz
(Intravascular ultrasound >20 MHz)

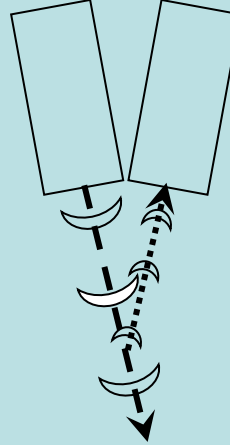
thousand times a second = 1 kHz

million times a second = 1 MHz

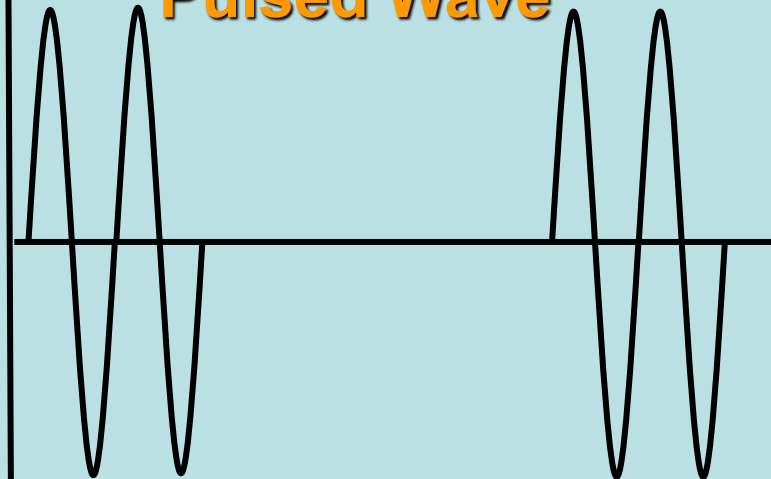
Continuous Wave



Two transducers emitting and receiving



Pulsed Wave



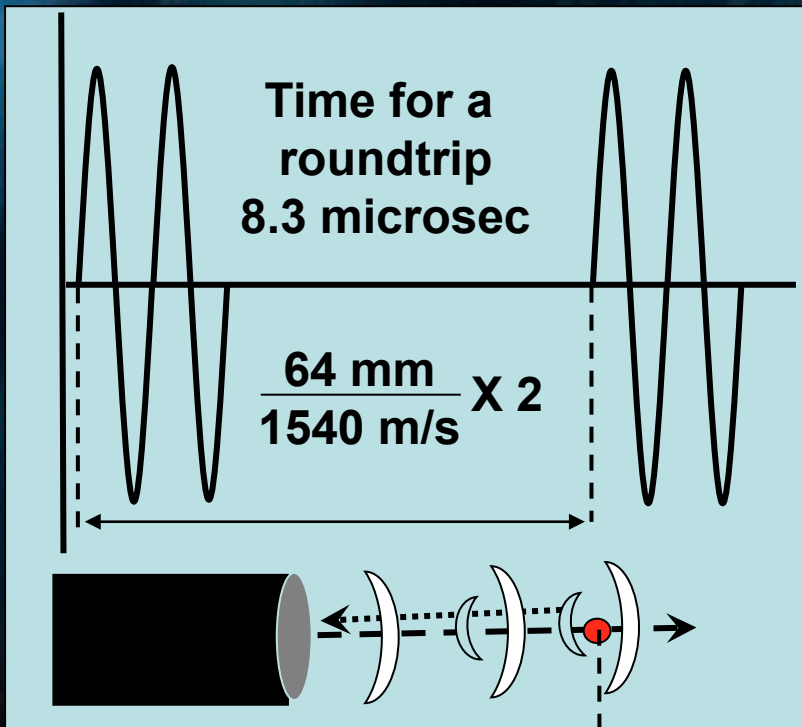
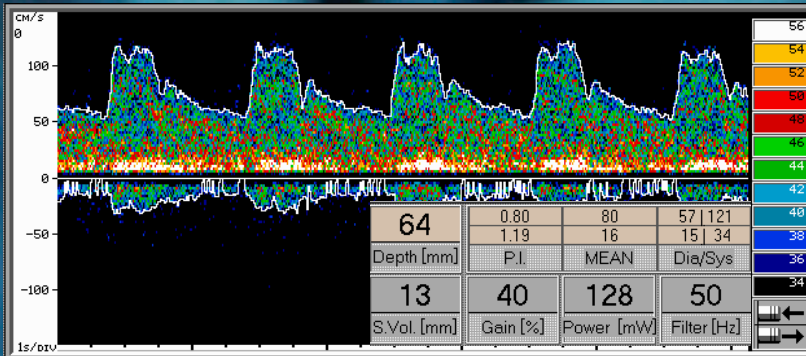
One transducer emits then receives



- No depth information
- No imaging possible
- Only flow detection

- Depth discrimination
- Imaging (echo strength)
- Flow detection

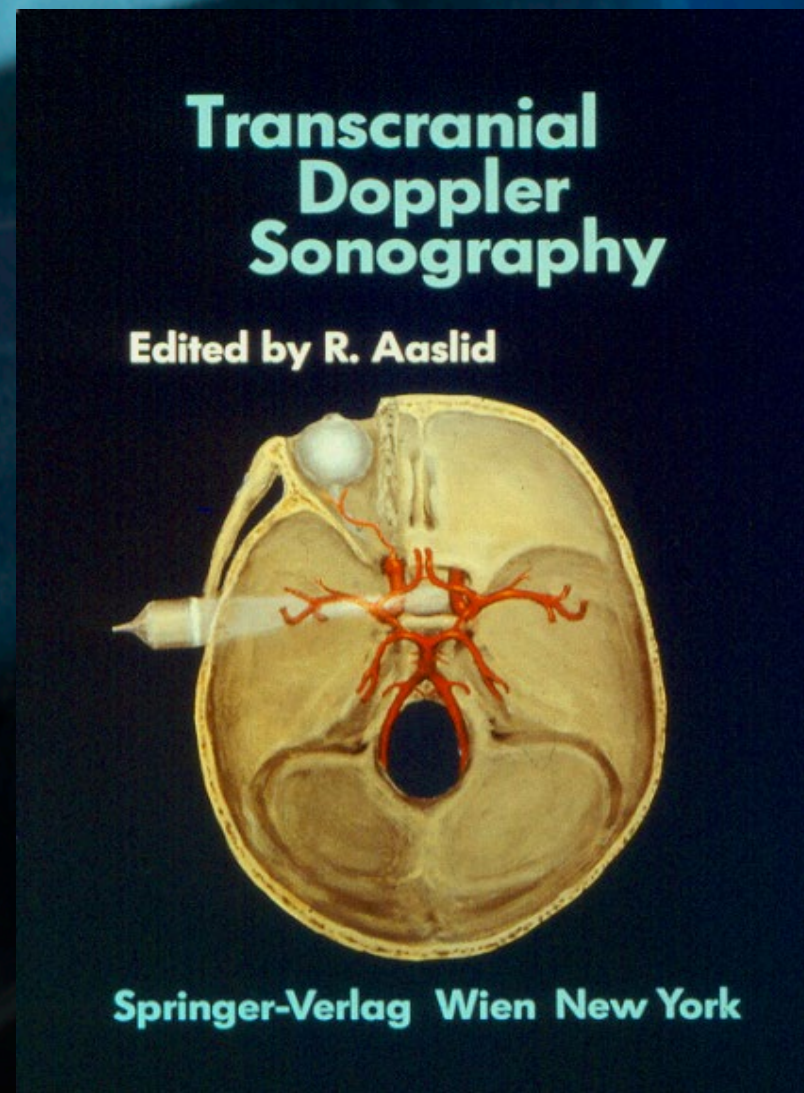
Pulsed Wave Spectral Doppler



Depth is calculated from the average speed of sound in soft tissues:
1540 m/s (a mile a second)
and time from firing a pulse to registering returned echos (i.e. round trip time).



**Christian
Doppler
1803-1853**



1982



GEBURTSHAUS DES PHYSIKERS
CHRISTIAN DOPPLER
ENTDECKERS DES NACH IHM BENANNTEIN
ASTROPHYSISCHEN PRINZIPS
GEB. 29. NOVEMBER 1803 - GEST. 17. MÄRZ 1853
Zu seinem hundertsten Geburtsfeste
die Gesellschaft für Salzburger Landeskunde.



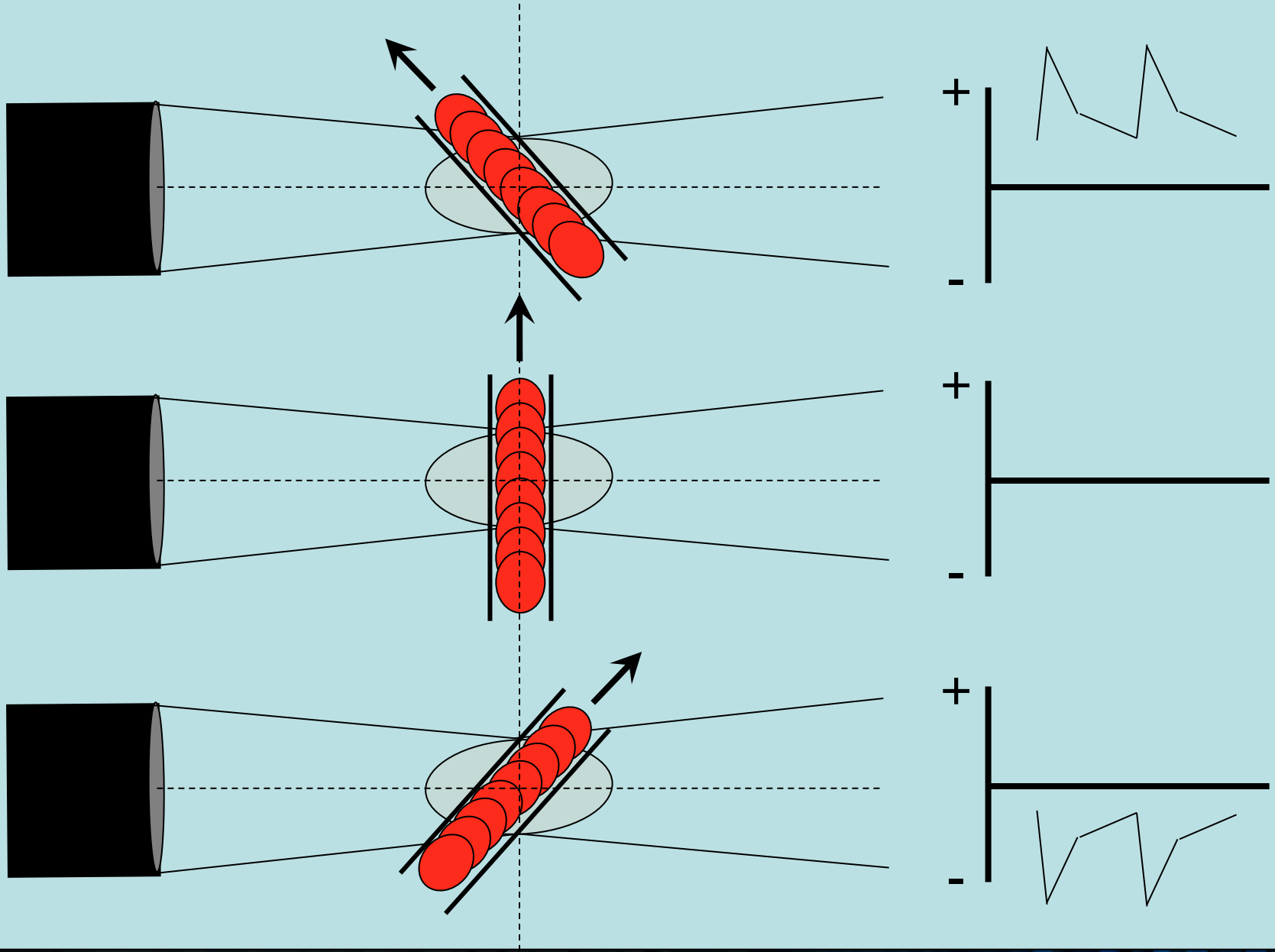
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What is Doppler Shift?

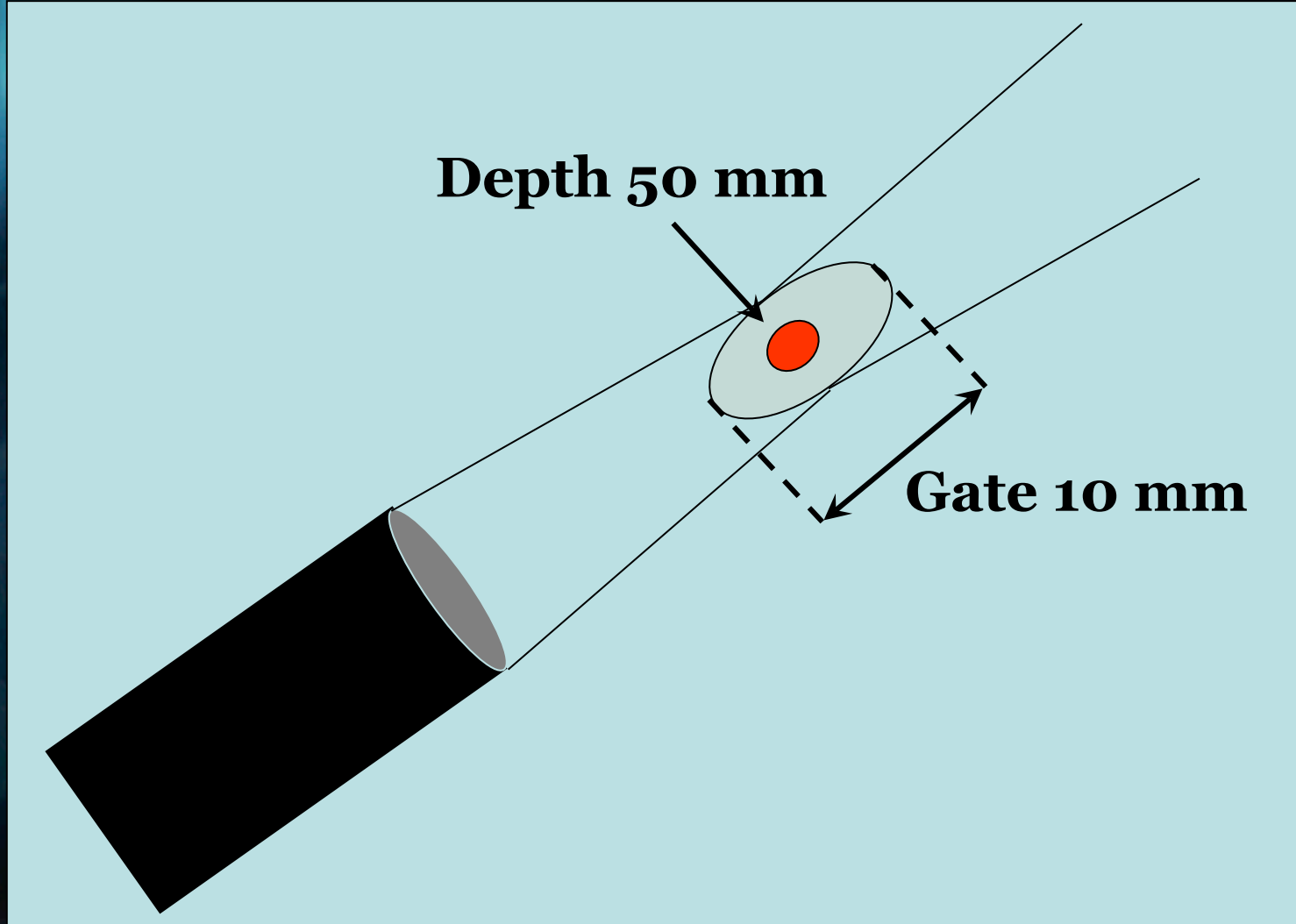




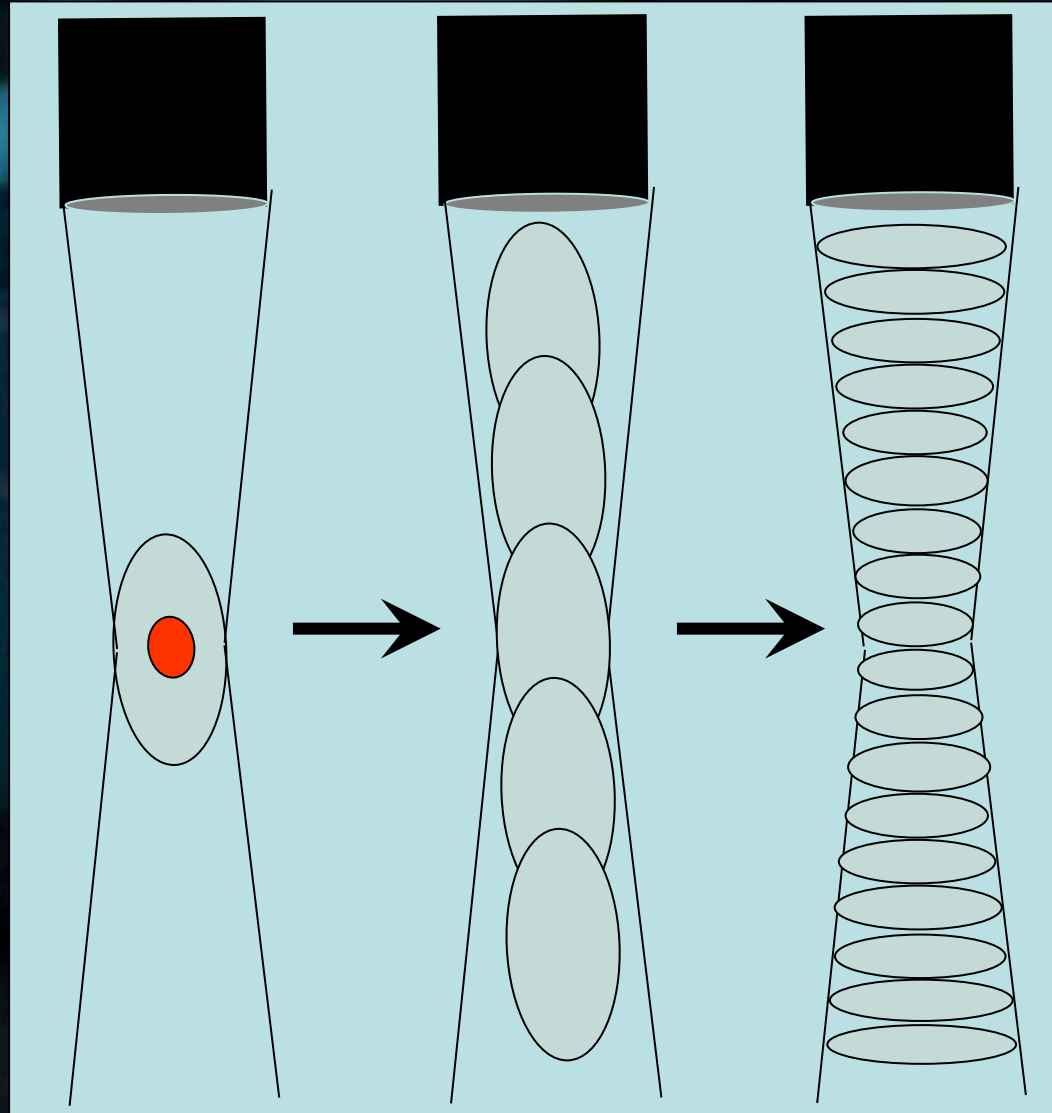
1989



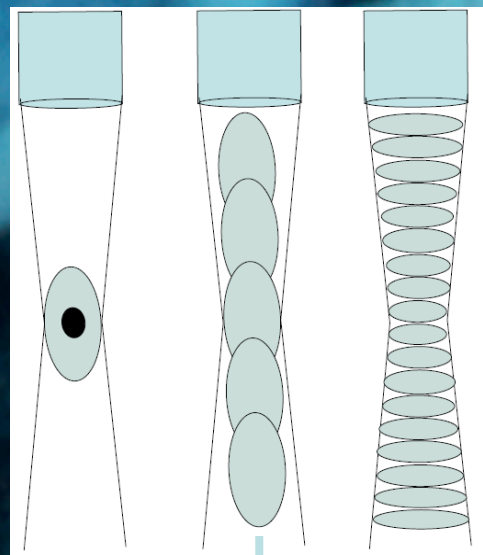
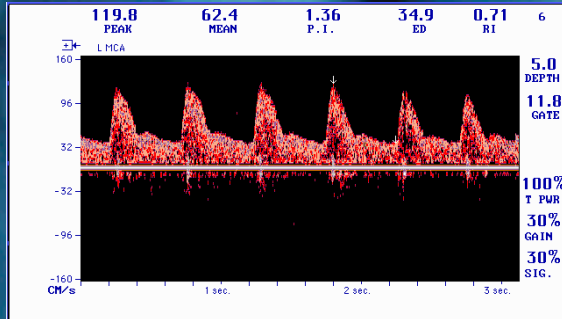
Transcranial Doppler



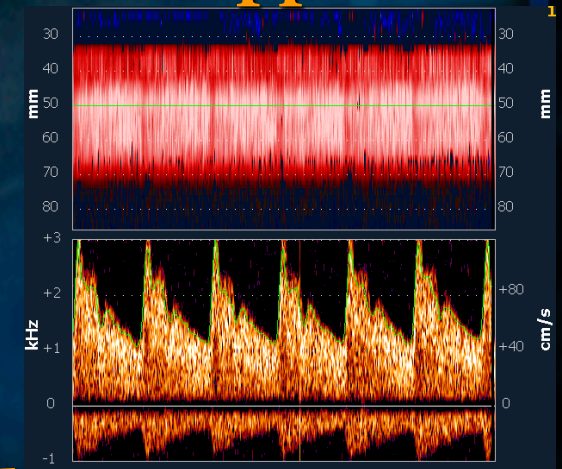
Single Channel Multi-Depth Sampling



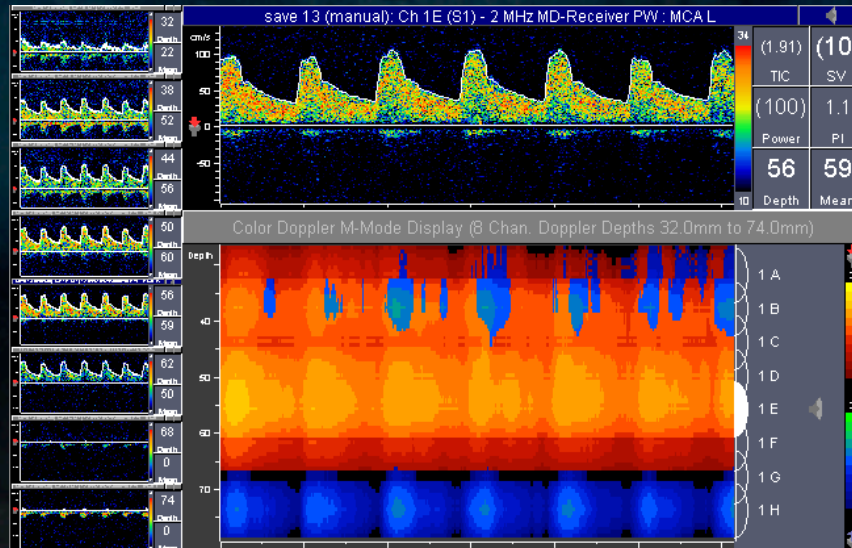
Single gate TCD



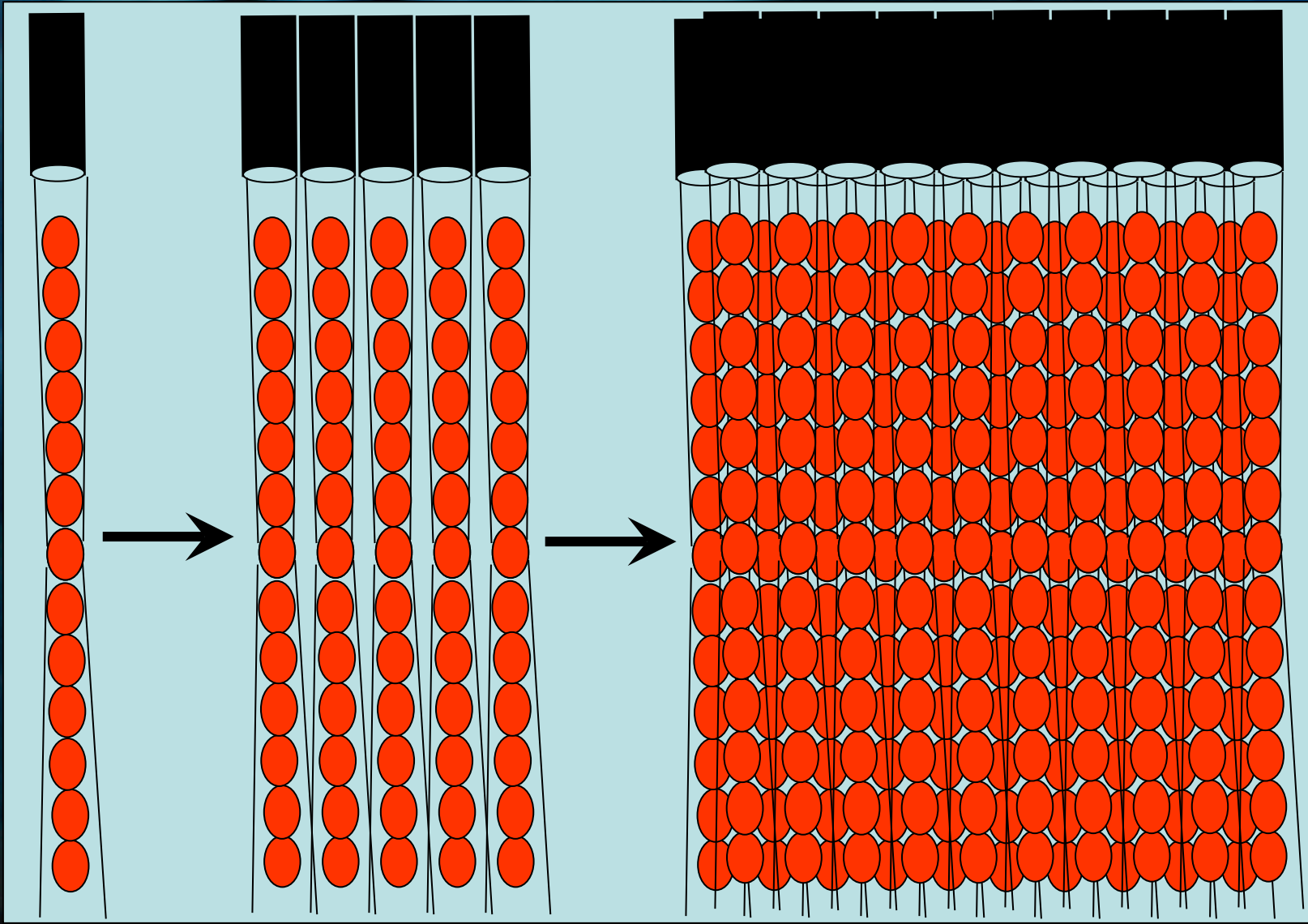
Power Motion Doppler



Multi-gate Spectral Doppler

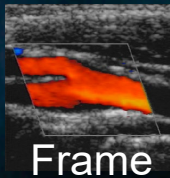
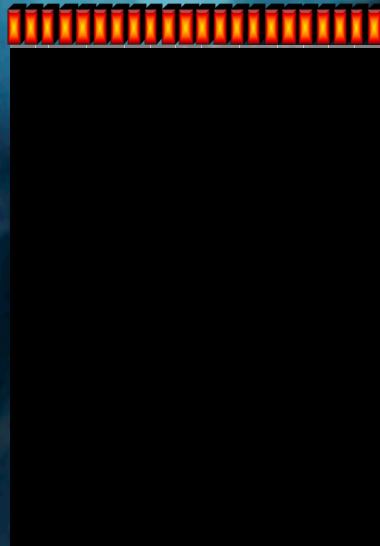


Multi-Transducer Linear Array

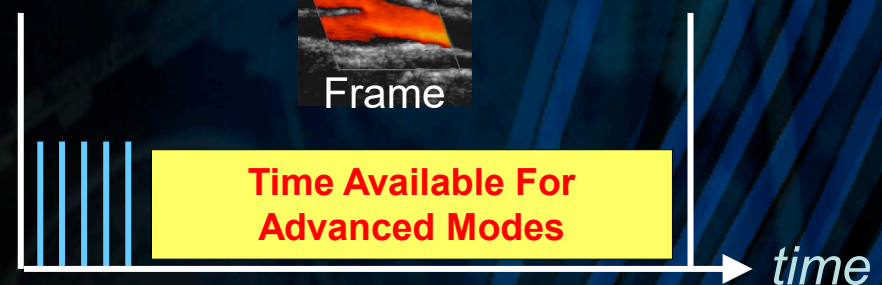
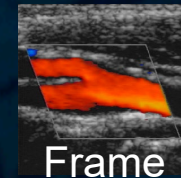


Conventional vs ZS Acquisition

Conventional



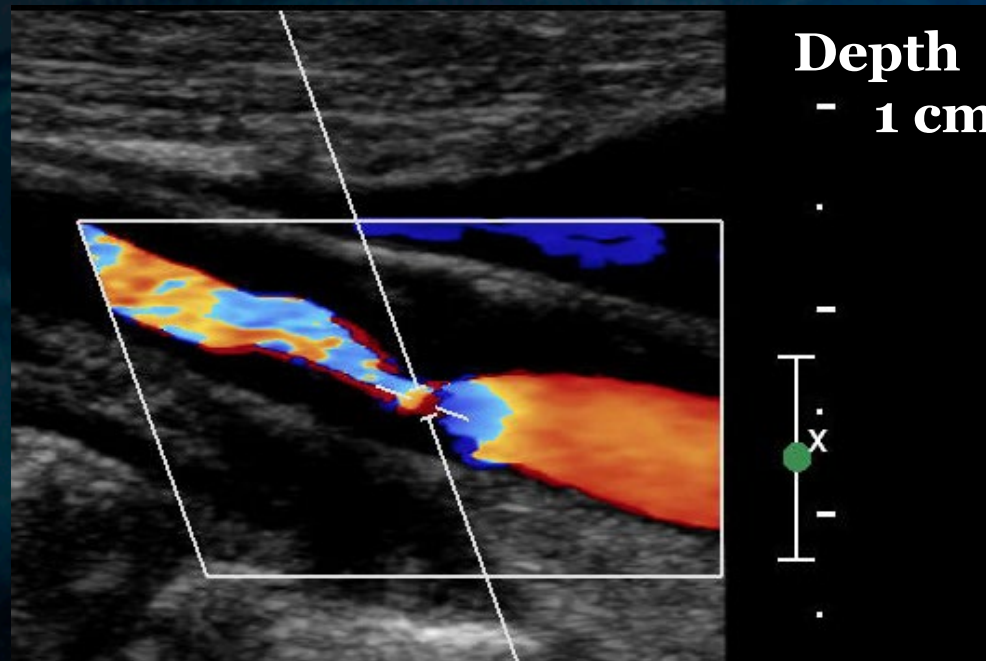
Zone Sonography™



Key Elements of Duplex Imaging

Gray image = B-mode

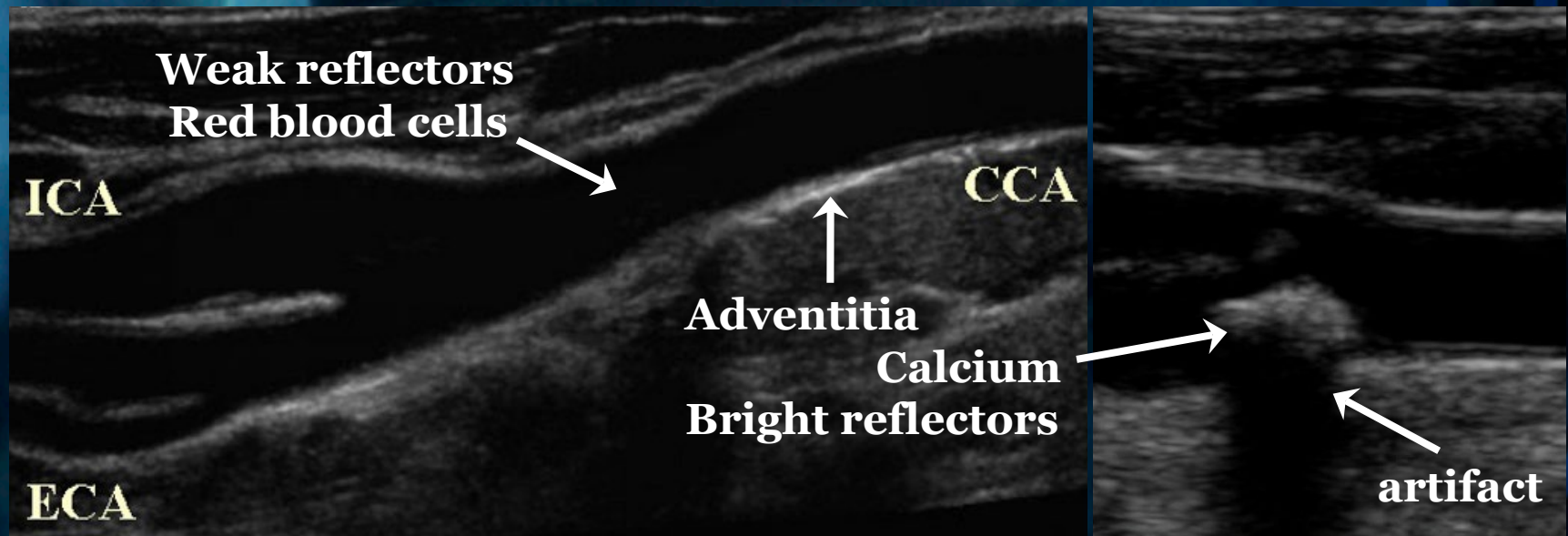
Color flow = Doppler



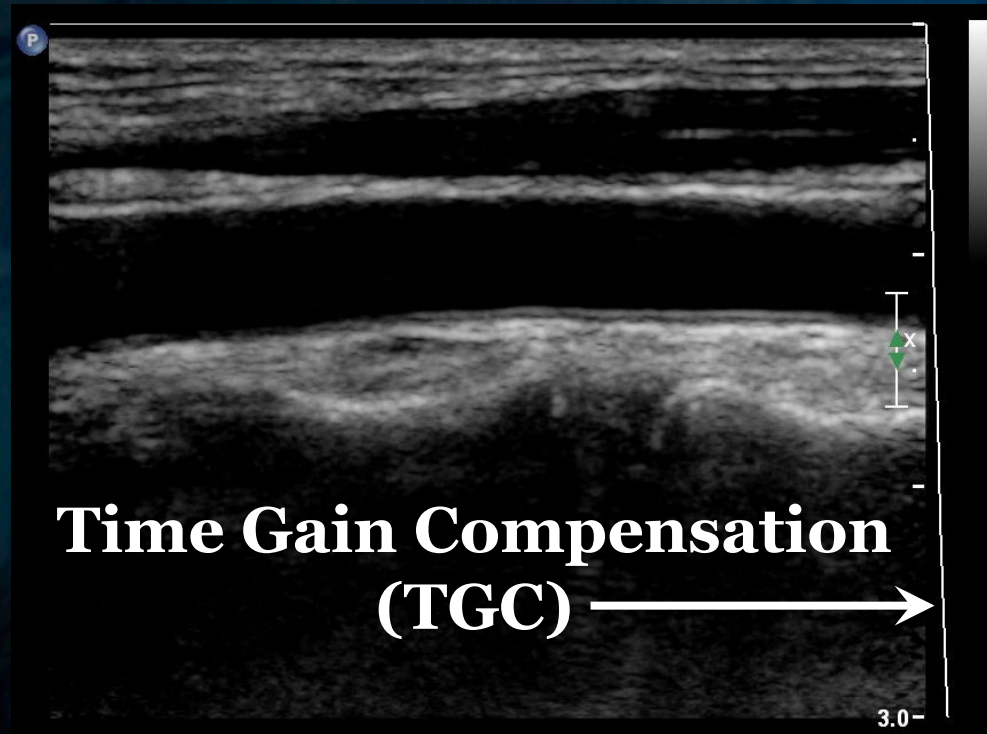
B-mode – brightness of returned echoes

Doppler – frequency shift from moving blood

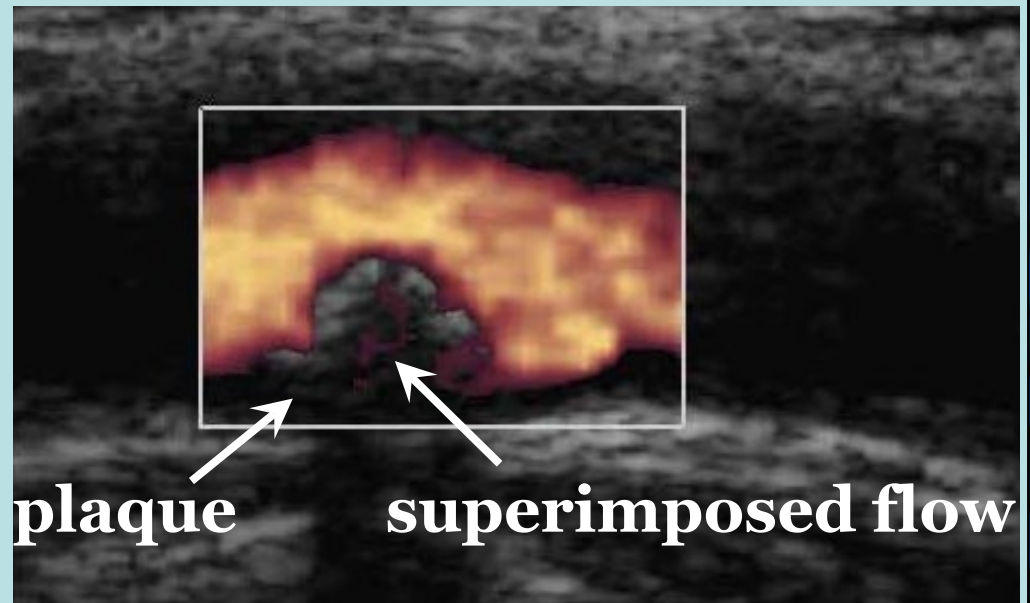
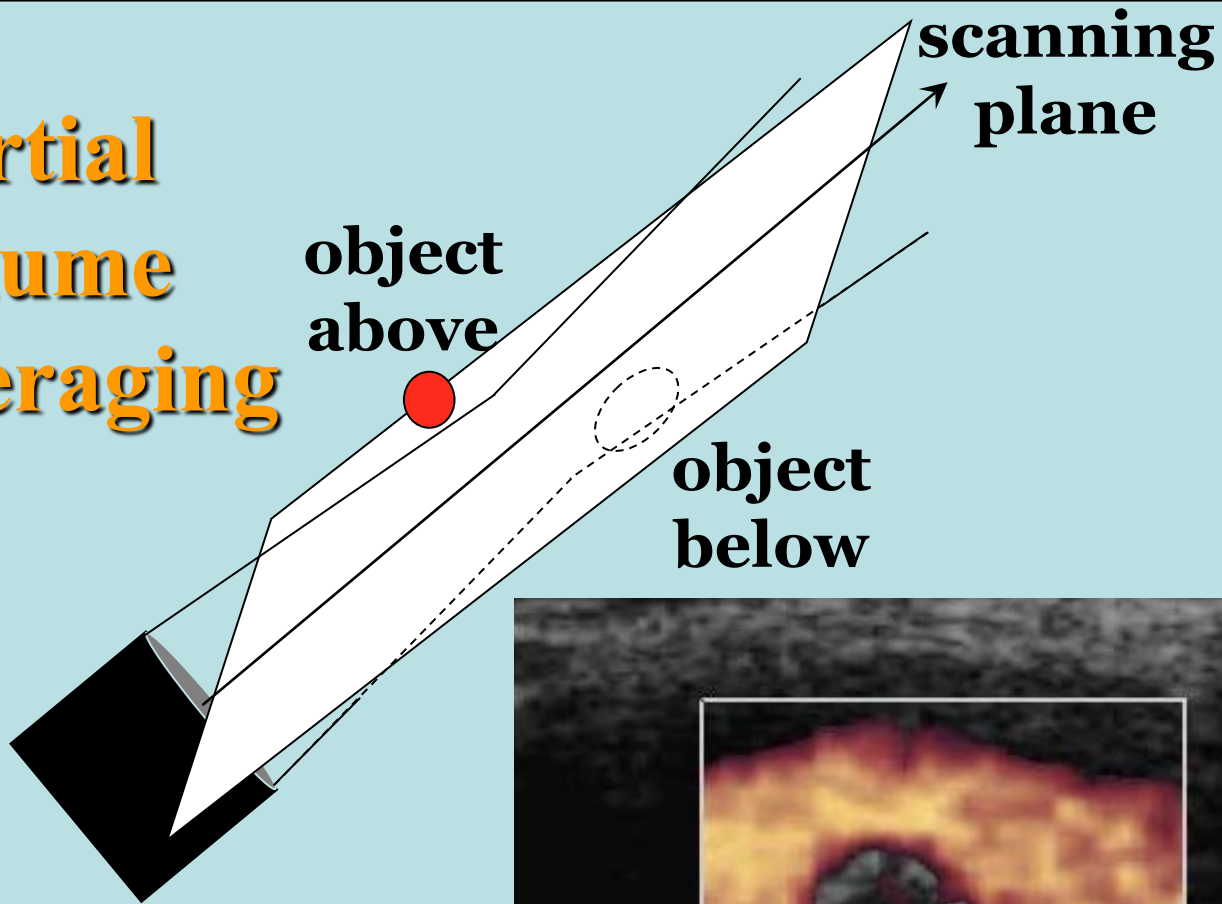
Brightness (B-mode) Ultrasound



Key Elements of Duplex Imaging

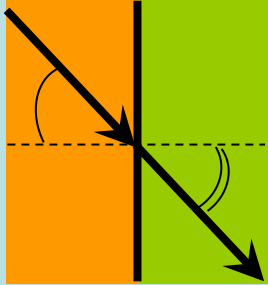


Partial volume averaging

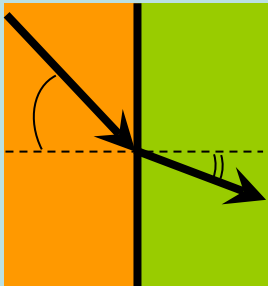


Refraction

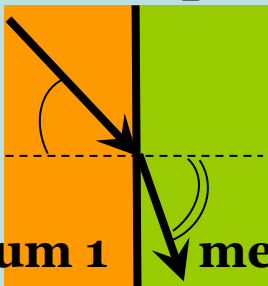
speed 1 = speed 2



speed 1 > speed 2

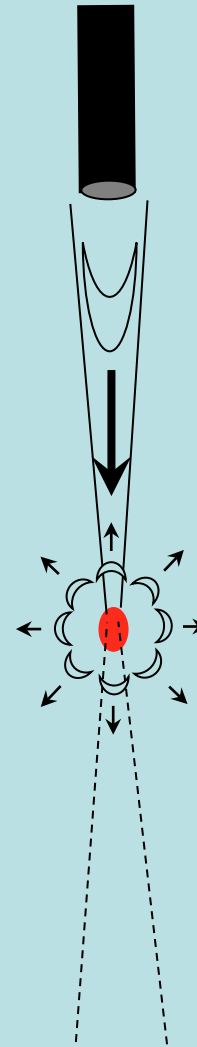


speed 1 < speed 2



medium 1 medium 2

Rayleigh Scattering



wavelength and
emitted pulse
amplitude

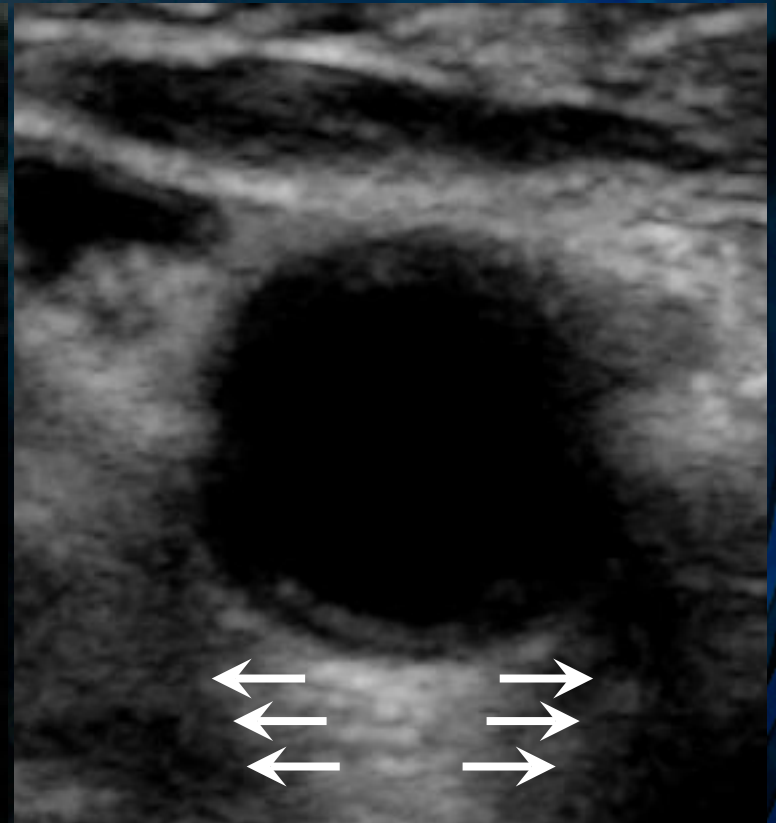
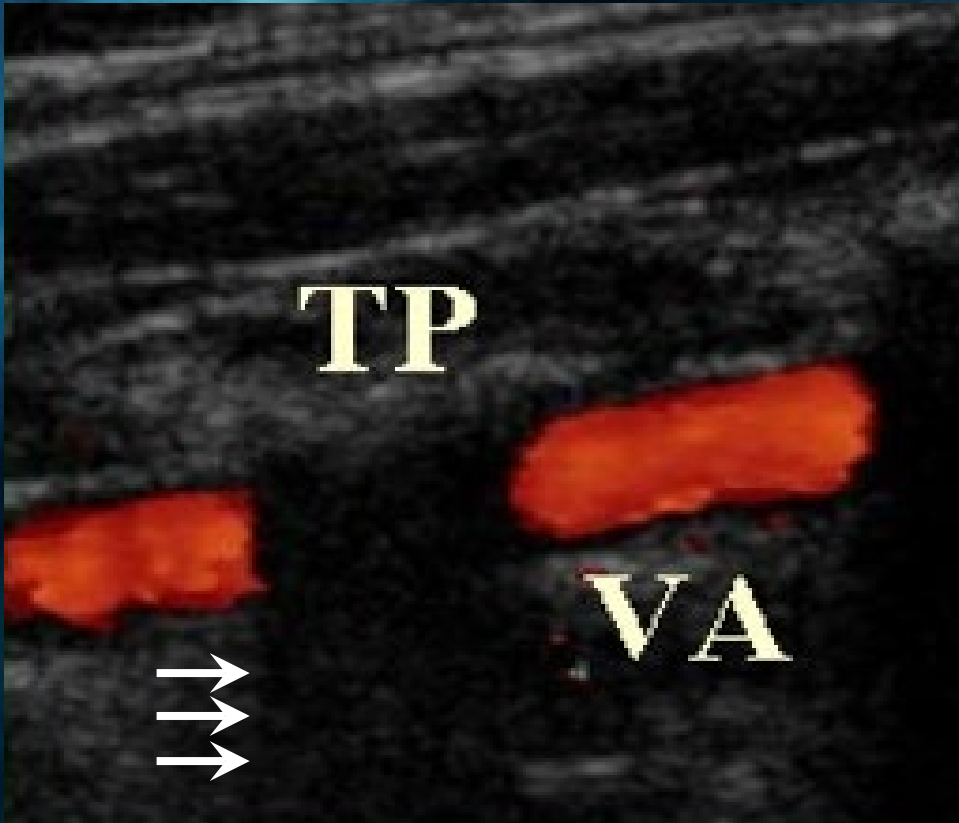


red blood cell

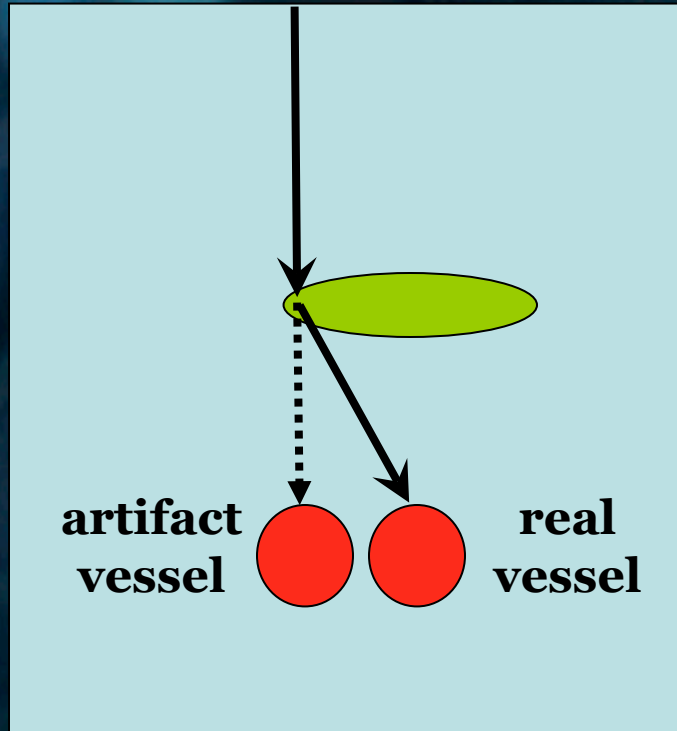


reflected echo
amplitude and
direction

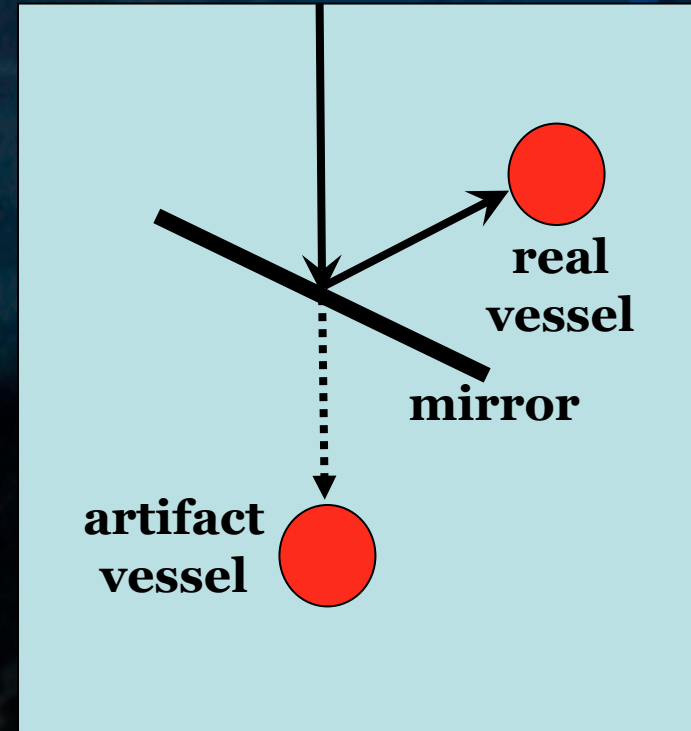
Shadowing Artifact

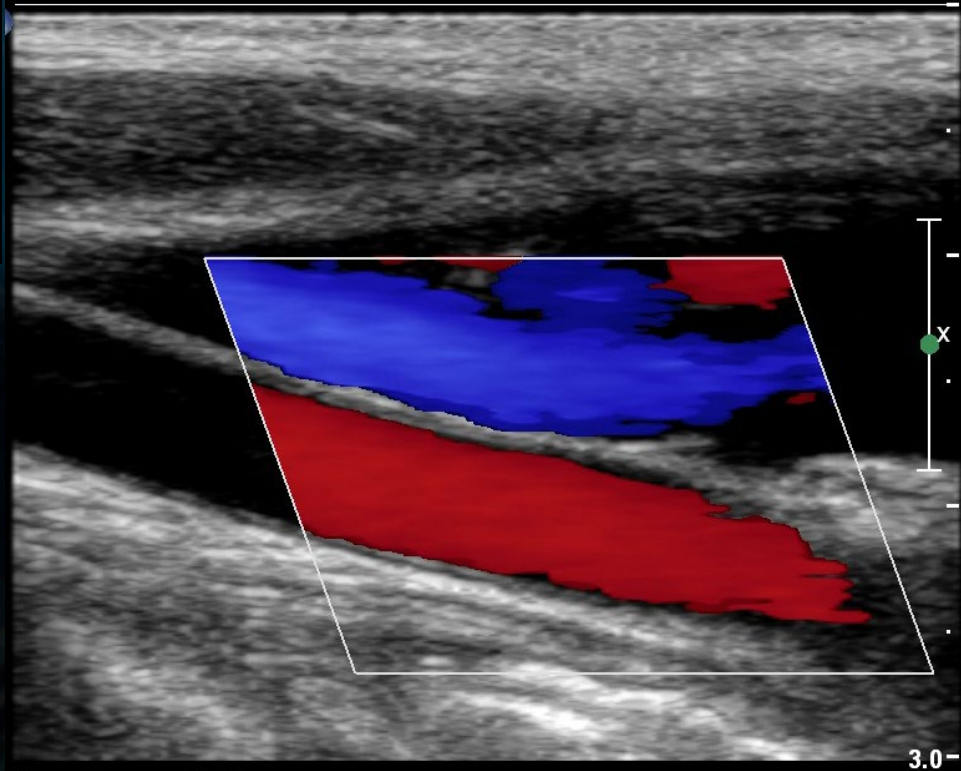
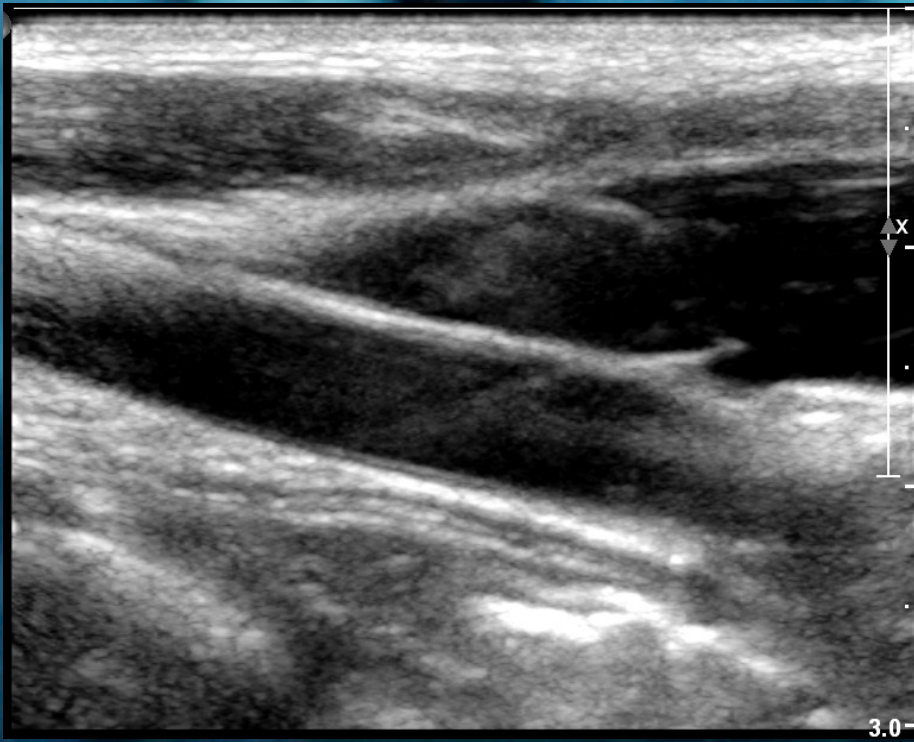


Refraction artifact

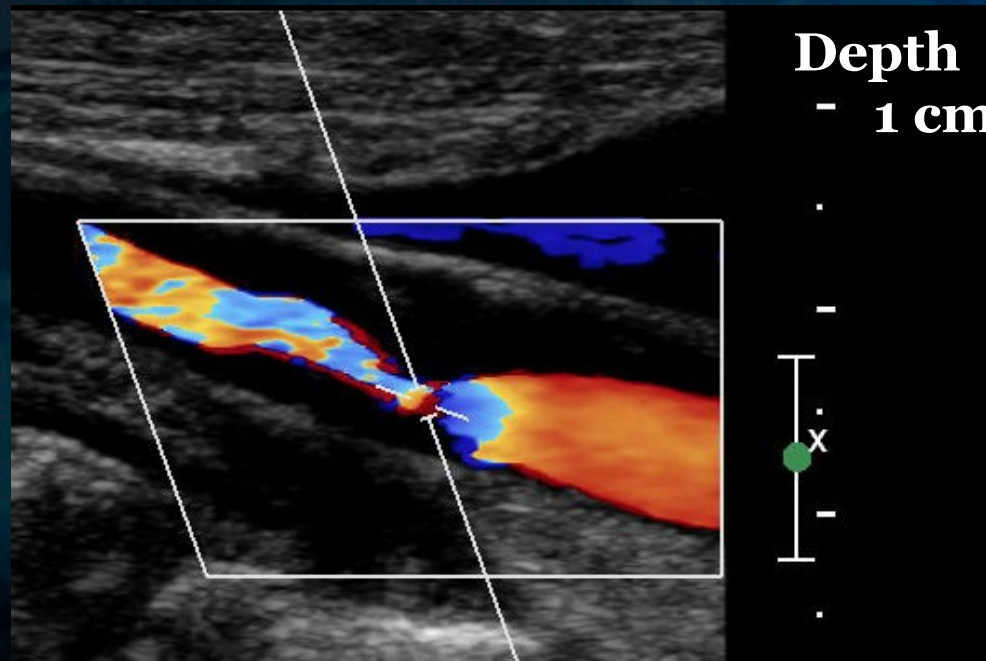


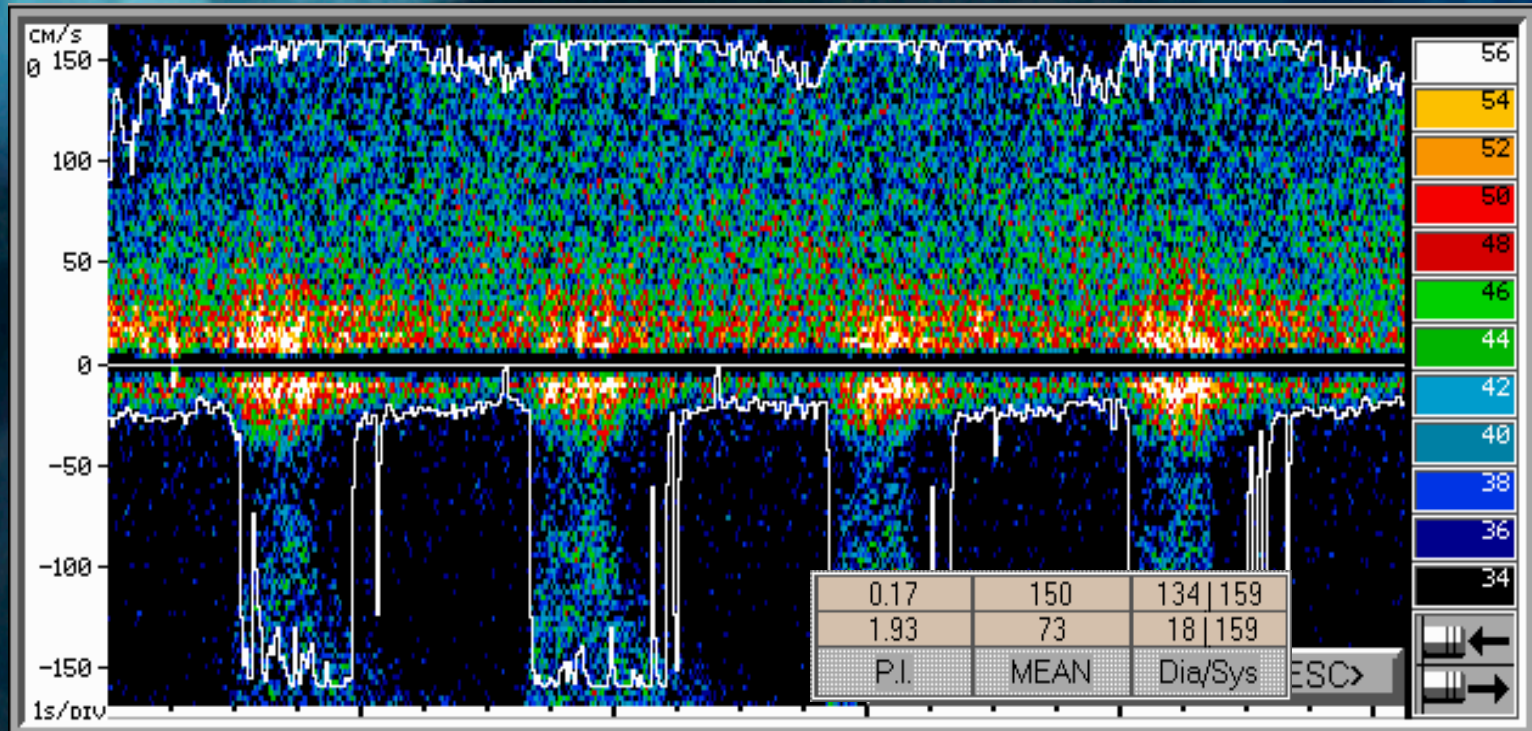
Mirror artifact





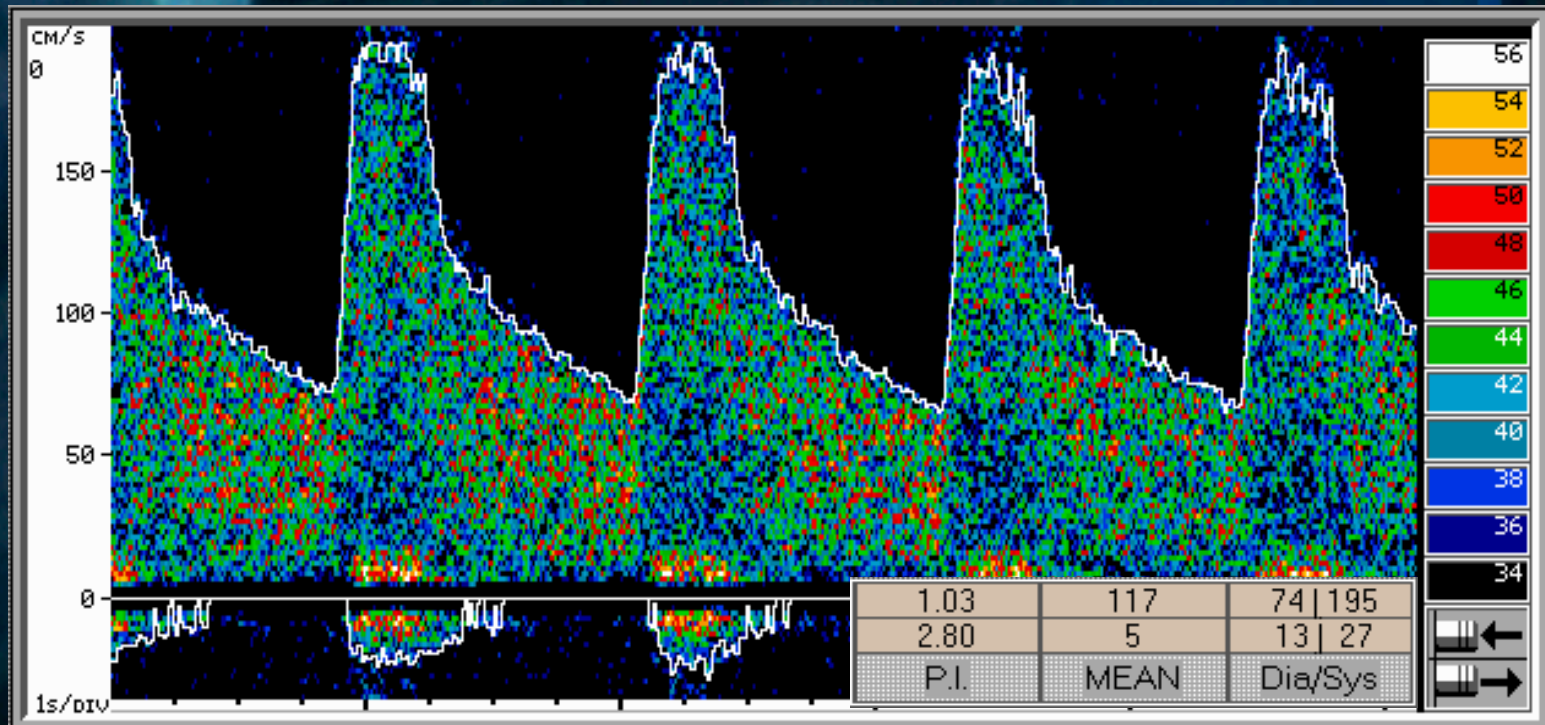
Which Artifact Does this Image Show?

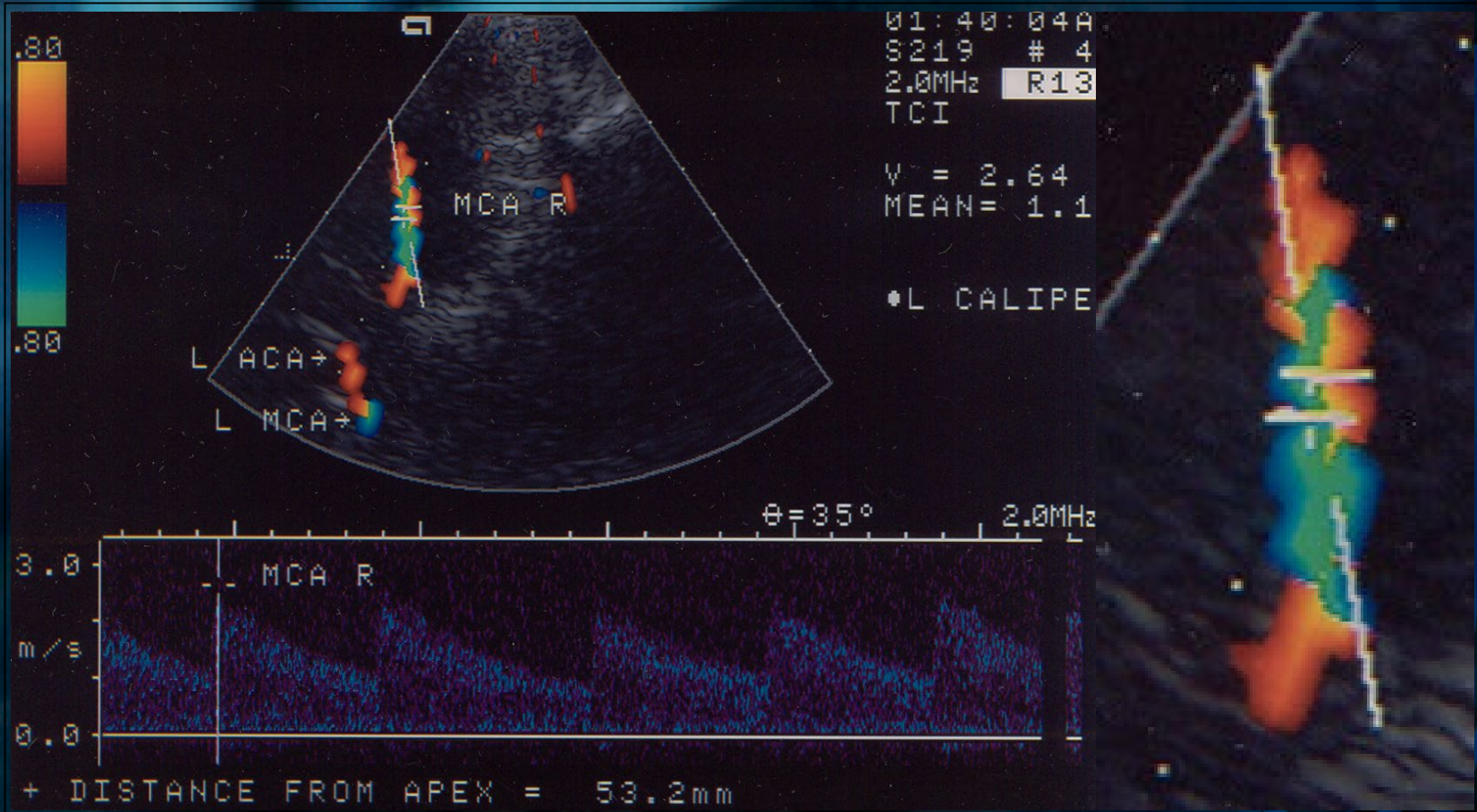




Flow Velocity Increase

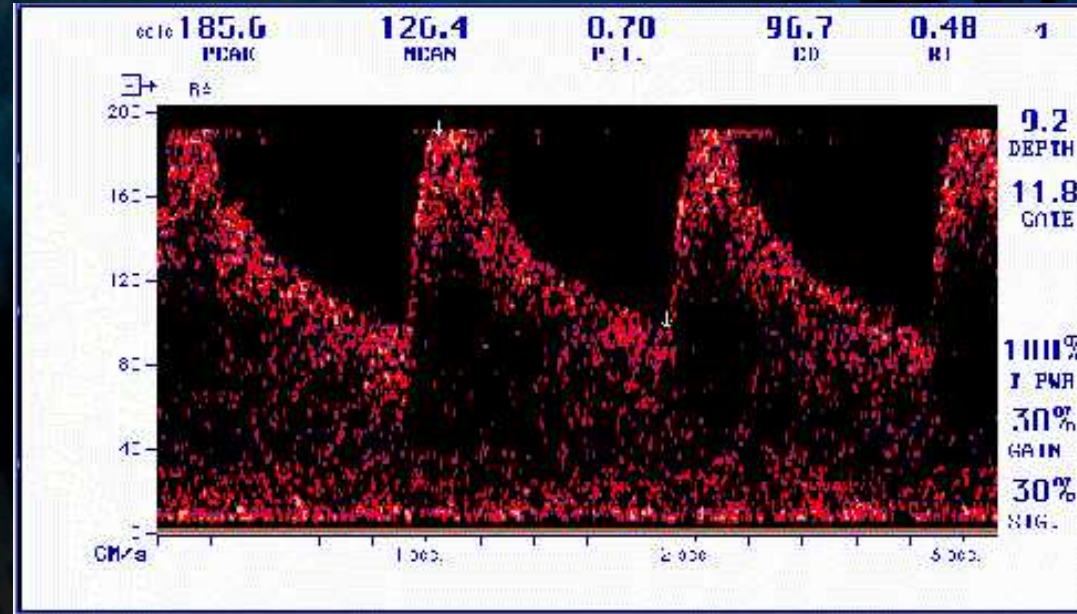
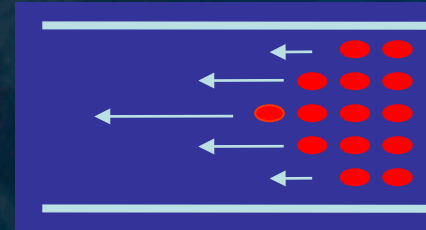
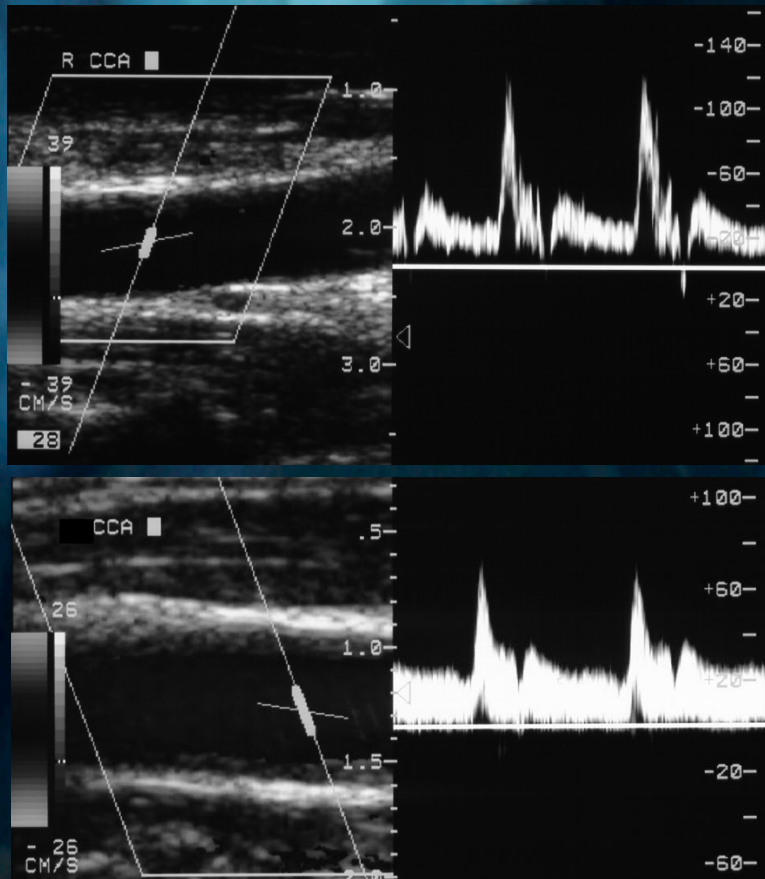
single most valuable predictor of stenosis severity

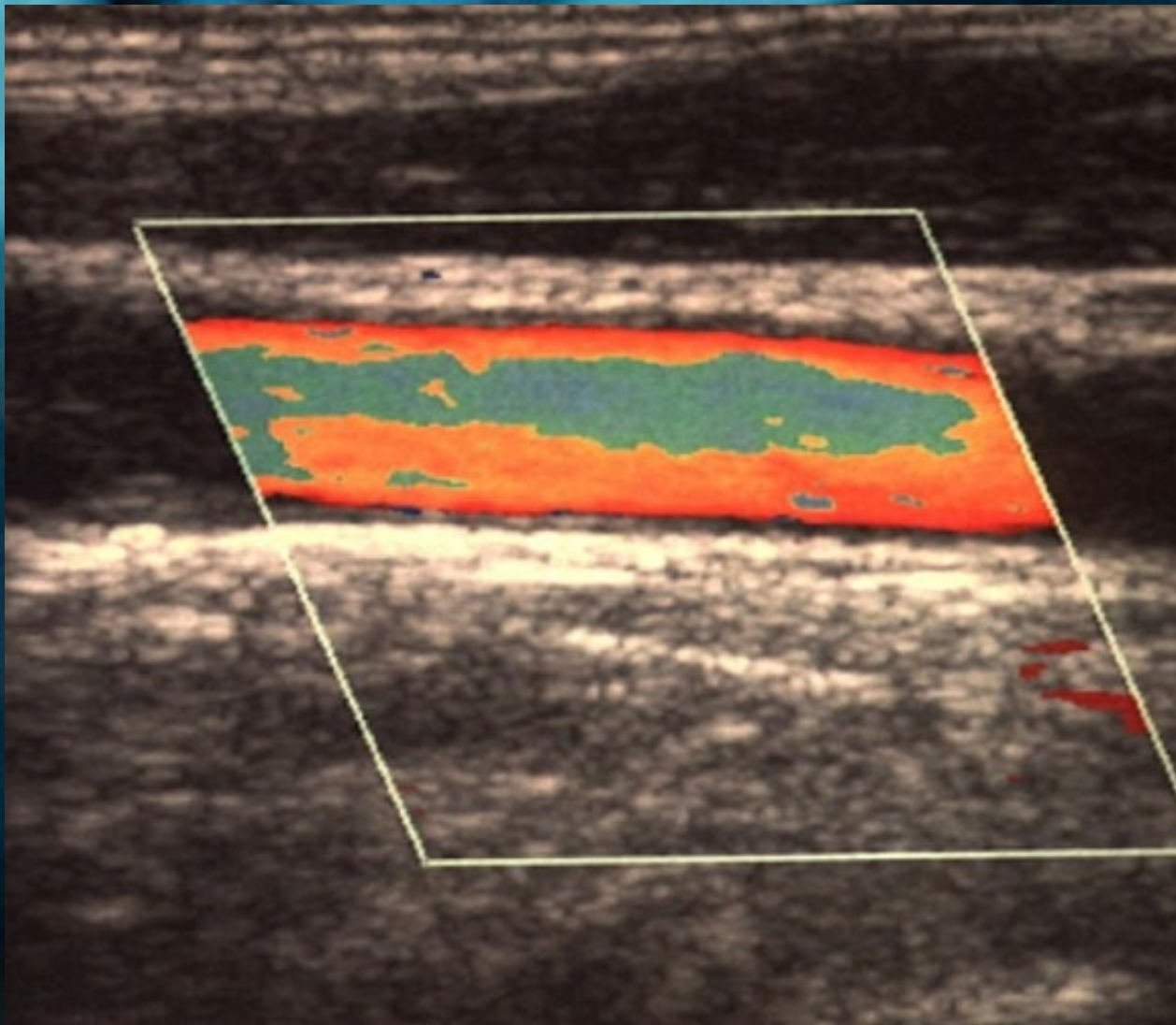


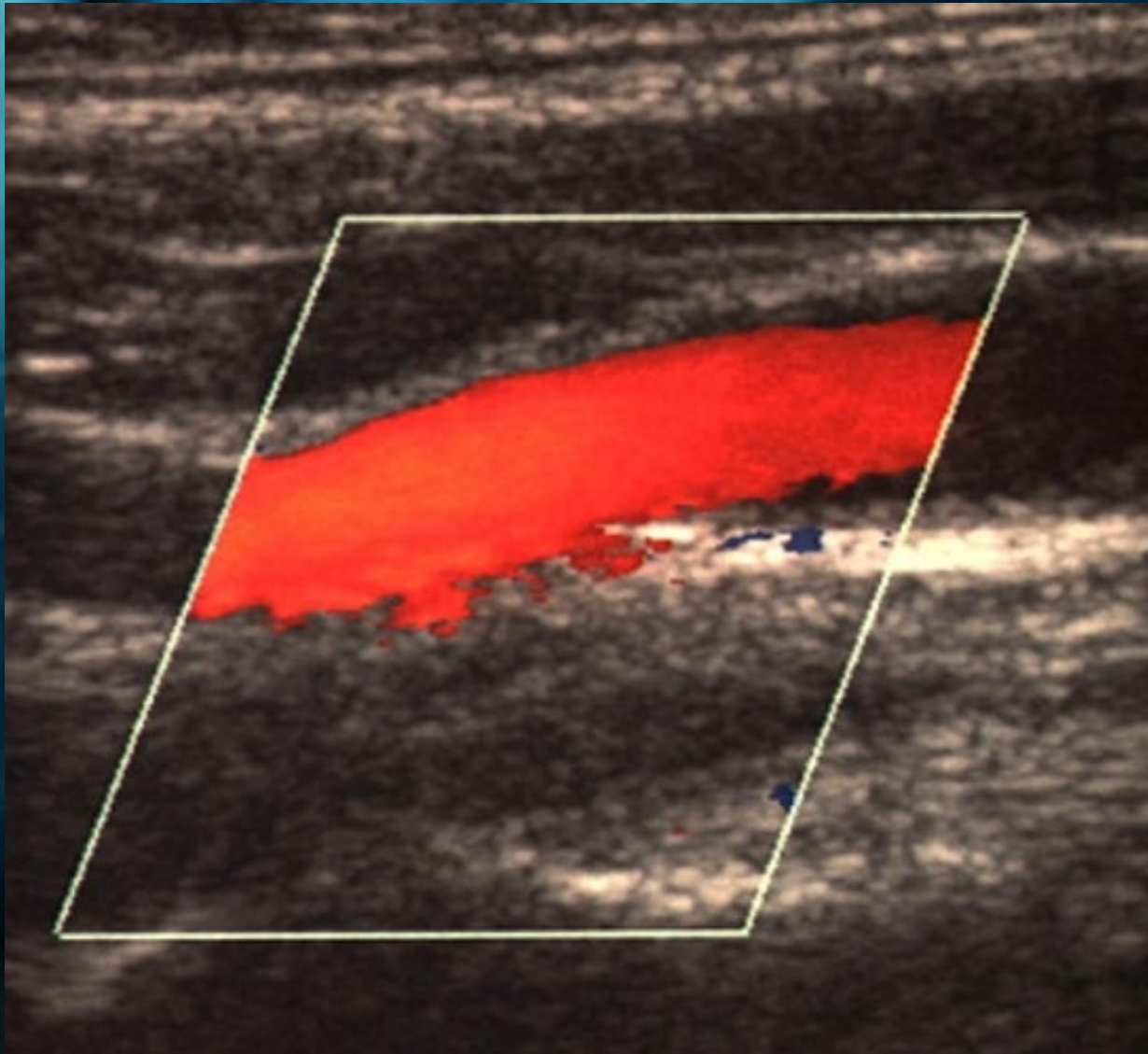


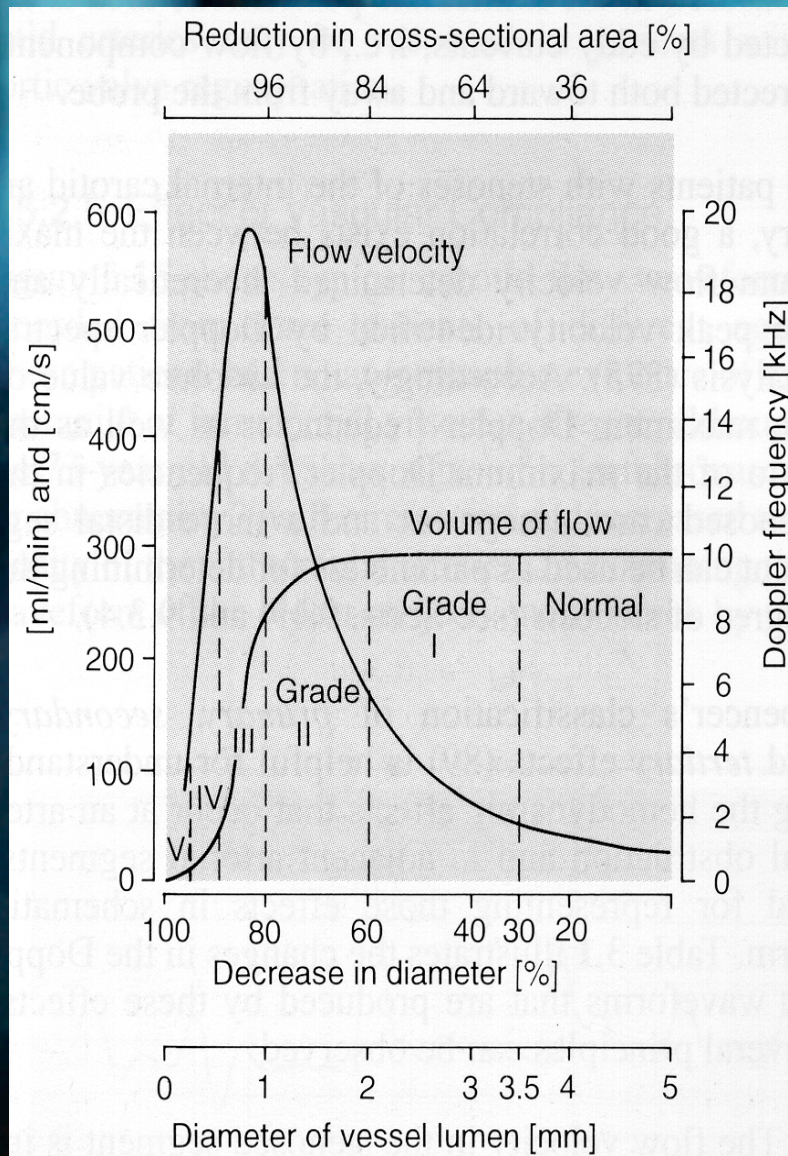
Imaging done by Eva Bartels, MD

Spectral Broadening vs Narrowing









The Spencer's Curve

Spencer & Reid.
Stroke 1978.

Alexandrov AV. The Spencer's curve: clinical implications of a classic hemodynamic model.

J Neuroimaging 2007;17:6-10.