APCDE 2011

Qualitative and Quantitative Assessment of Perfusion

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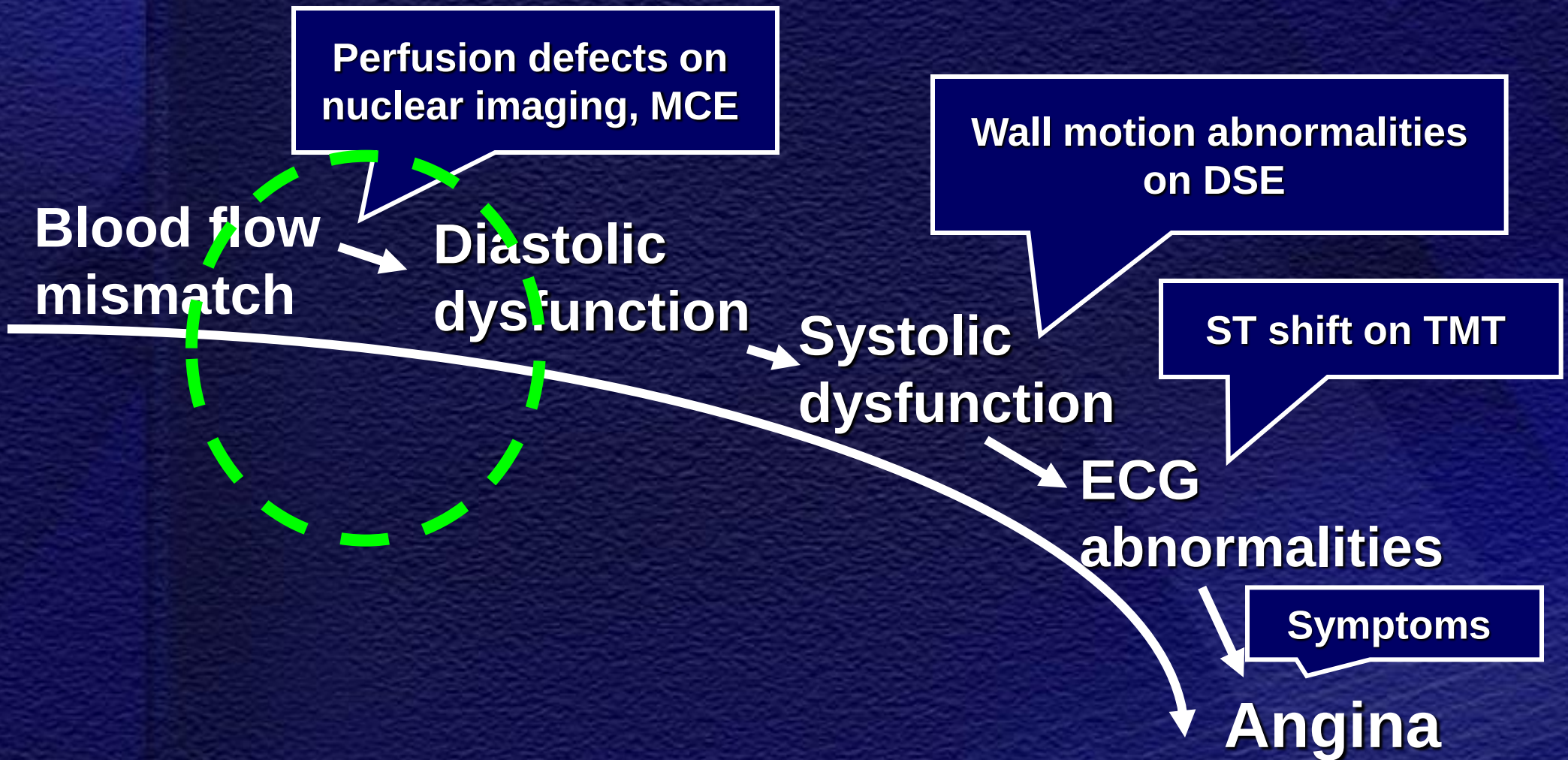
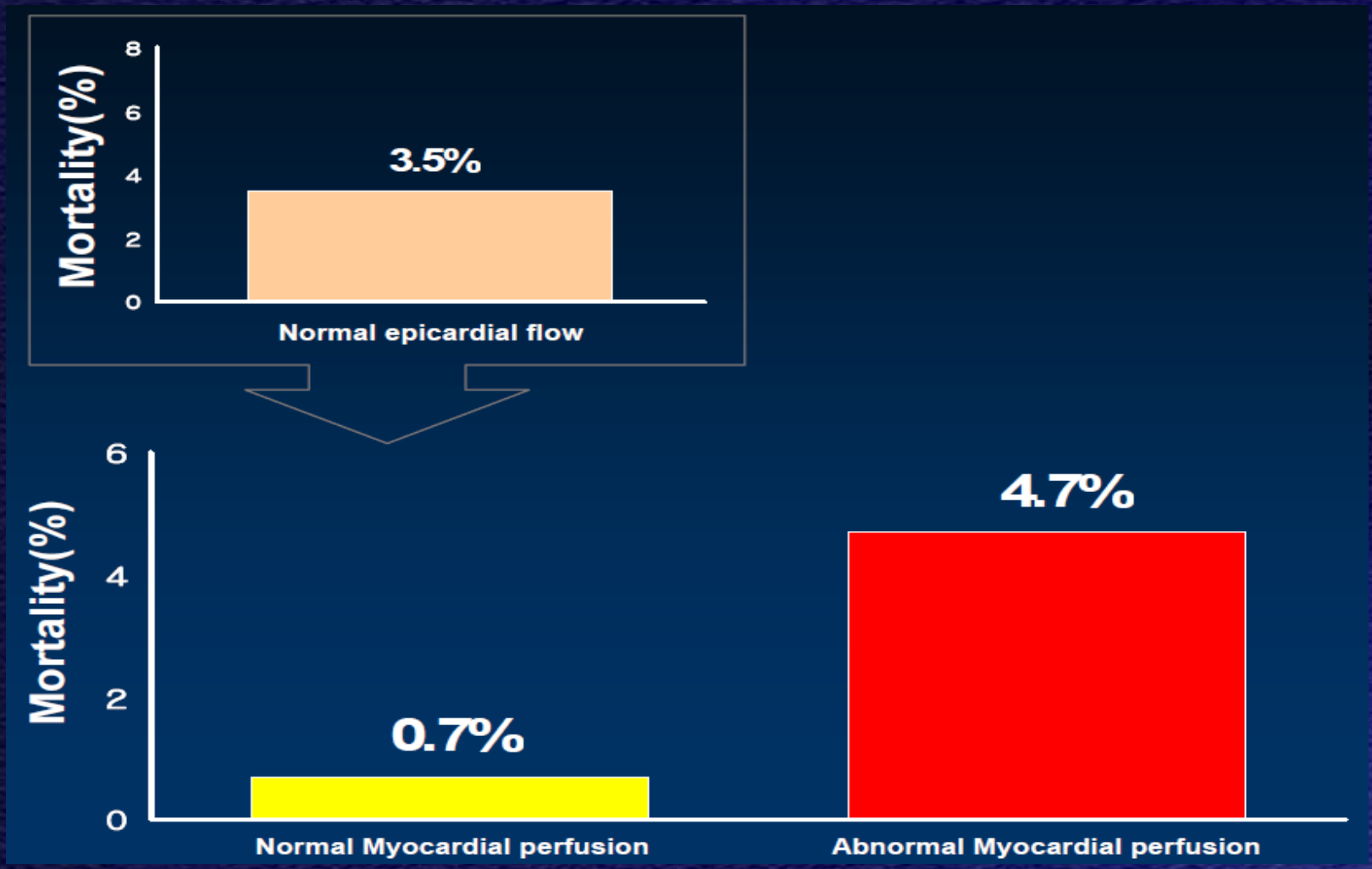
ISCHEMIC CASCADE



Perfusion

- The occurrence of myocardial perfusion deficits is a very sensitive indicator of ischemia in the presence of significant coronary artery stenoses.

Perfusion and Mortality



Gibson, Circulation 2000

Assessment of Myocardial Perfusion

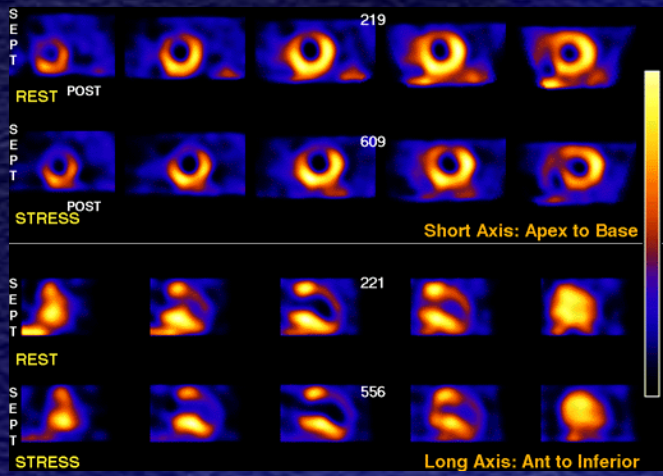
PET Scan

MRI

CT scan

Nuclear Scan

Contrast Echo



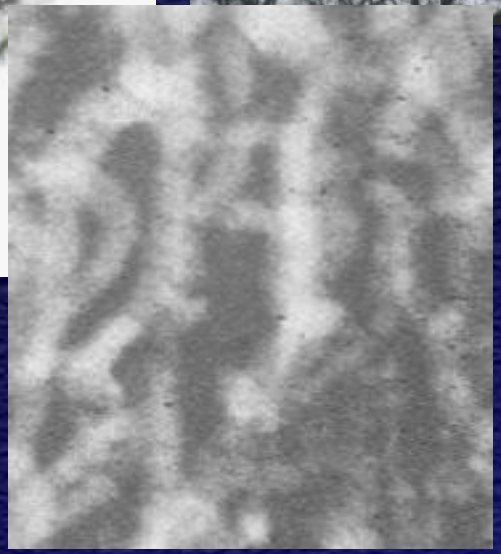
Problems in Echo
Myocardial Perfusion Imaging

Conventional Two Dimensional Echo

- **Blood in the microvasculature**
  - **Weak backscatter**
  - **Low velocity**

- **Bright myocardial echogenecity**

Coronary Circulation



Methods to Enhance Echo from Blood in the Microvasculature

- Contrast Agents Imaging
- Technologies and Techniques

Contrast Echocardiography

Increased echogenicity by microbubbles within the cardiac chambers or vascular structure

Contrast Echocardiography

- Many benefits including:
  - Safety
  - High specificity, sensitivity, negative predictive value,
  - Good visualization despite cardiac motion
  - Echo equipment is widely available
  - Quick
  - Non-invasive
  - Radiation-free
  - Portable
  - Inexpensive

Contrast Echocardiogarphy

- Improved EBD (Regional/Global function)
- Delineation of LV hypertrophy
- Rescue of un-interpretable studies (e.g. ICU)
- Improved stress echocardiography
- Doppler signal enhancement (AS/PV)
- Definition of structural abnormalities (Thrombus, Pseudoaneurysm)
- Myocardial perfusion

Application of Myocardial Contrast Echocardiography

- to assess risk area and infarct size
- to evaluate the presence of collaterals
- to evaluate viable myocardium after acute infarction
- to delineate reperfusion reflow zones
- to predict prognosis and functional discovery after revascularization

Imaging modalities for assessment of myocardial perfusion

	MI	Real-time imaging	Residual myocardial tissue signals	Need for background subtraction	Endocardial border delineation
Harmonic B-mode	0.6	No	Yes	Yes	Poor
Power Doppler	> 1.0	No	Few*	No	Good
Pulse inversion	0.3	No	Yes	Yes	Moderate
Power pulse inversion	< 0.15	Yes	No	No	Good
Power modulation	< 0.15	Yes	No	No	Good
Coherent imaging	< 0.15	Yes	No	No	Good

MI = mechanical index; * = wall motion artifacts can be minimized with proper machine settings

Journal of Clinical and Basic Cardiology 2002

About the Ideal Microbubble

- About 3 μm in diameter (Smaller than RBC)
- Contain gases of low diffusibility and solubility
- Nontoxic/easily eliminated
- Administered intravenously
- Passes easily through microcirculation
- Physically stable
- Acoustically responsive
  - Stable harmonics
  - Capable of rapid disruption
- Reliable and linear relationship

MCE tecnique

- Myocardial perfusion can be assessed with continuous infusion of microbubbles.
- When the microbubbles have reached steady-state concentrations, a high mechanical index pulse is used to destroy the bubbles in the imaging plane.
- The subsequent replenishment of microbubbles is related to myocardial perfusion.

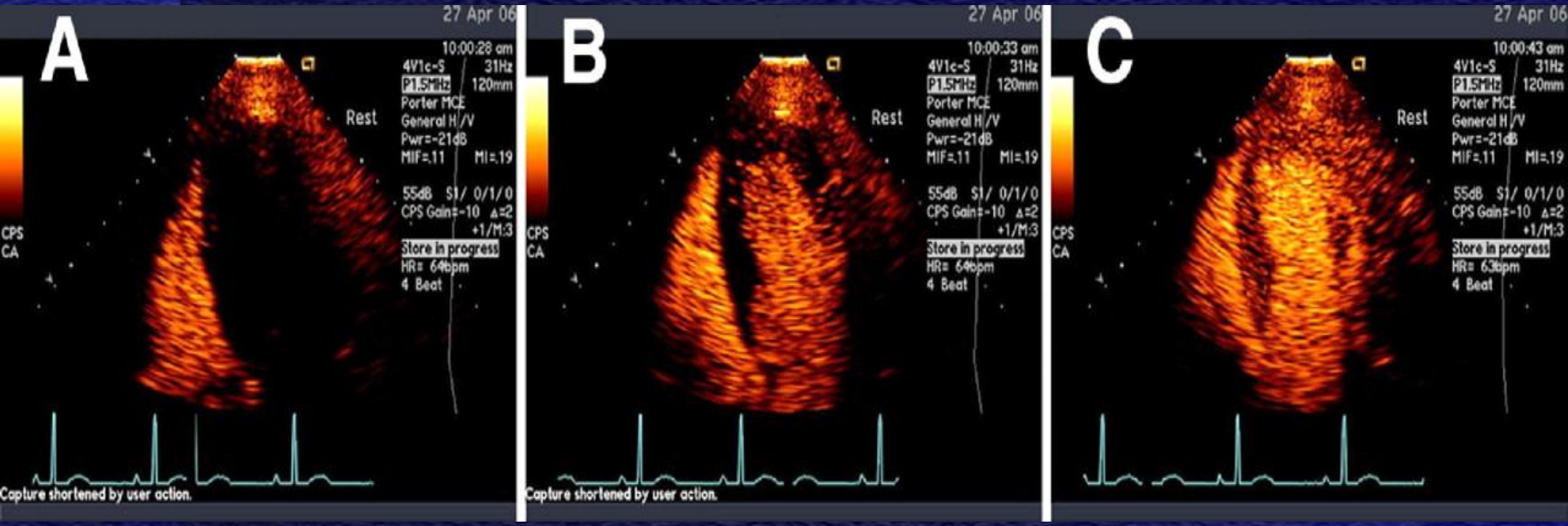
MCE tecnique

- Areas that are hypoperfused will have a slower return of microbubbles, whereas areas that are well perfused will have a more rapid return of microbubbles.
- After the high mechanical index pulse, images can be obtained in a gated intermittent mode with high mechanical index pulses or in a real-time mode with low mechanical index pulses.

Analysis of Perfusion

- **Qualitative analysis**
  - For routine clinical use
  - by visual comparison of the contrast enhancement in different myocardial regions
  - looking for abnormalities in the rate or amount of contrast replenishment after a high MI pulse.

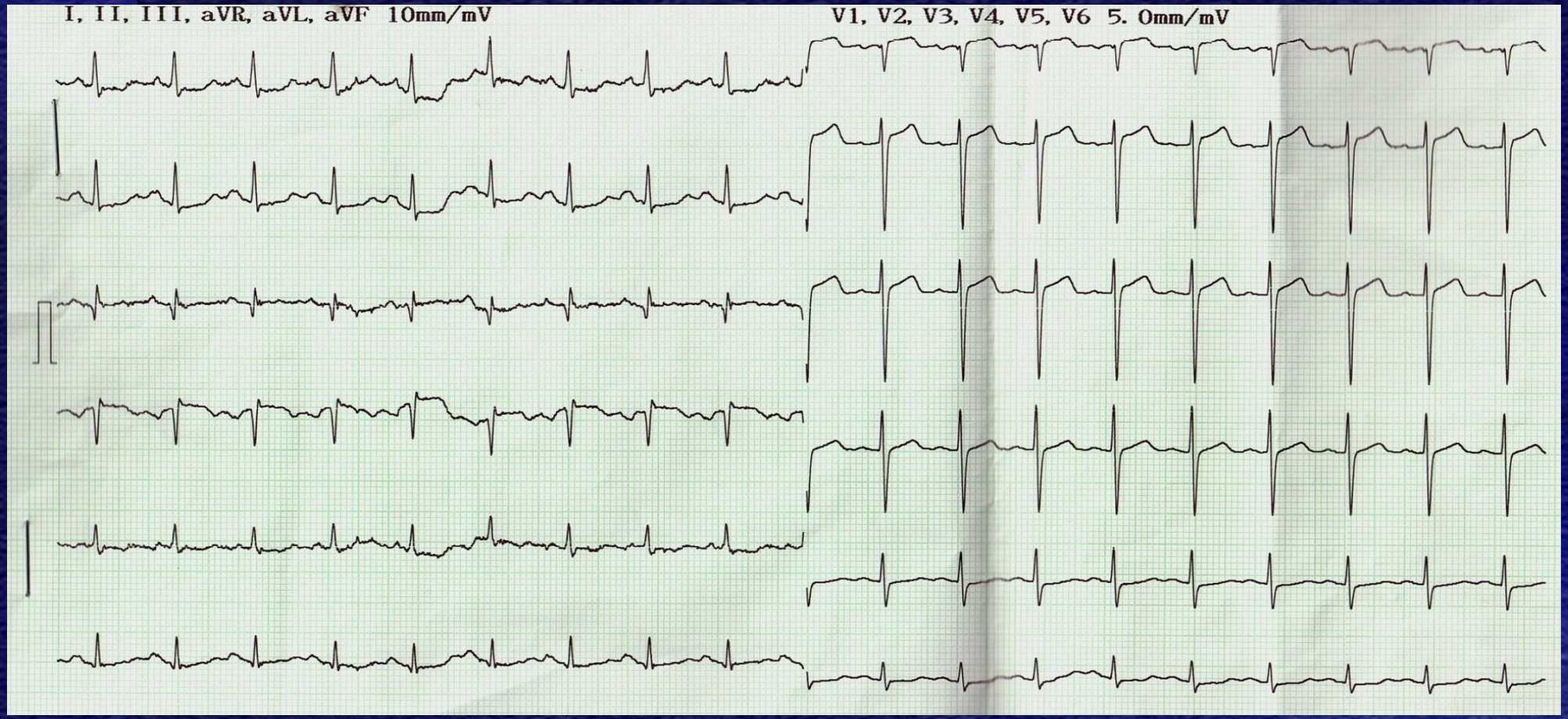
Background Subtraction



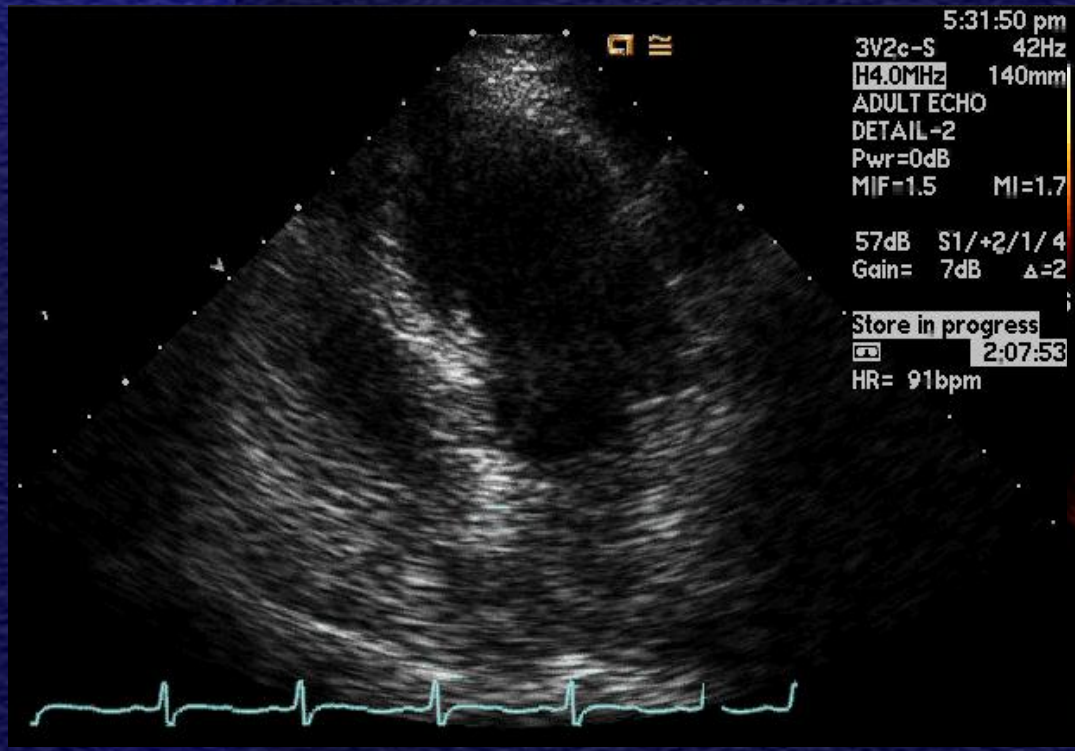
Images are achieved with low–mechanical index pulse sequence schemes designed to assess myocardial perfusion. No signals from the myocardium before contrast administration **(A)**, but excellent LVO **(B)** and eventual myocardial contrast **(C)** after venous infusion of contrast.

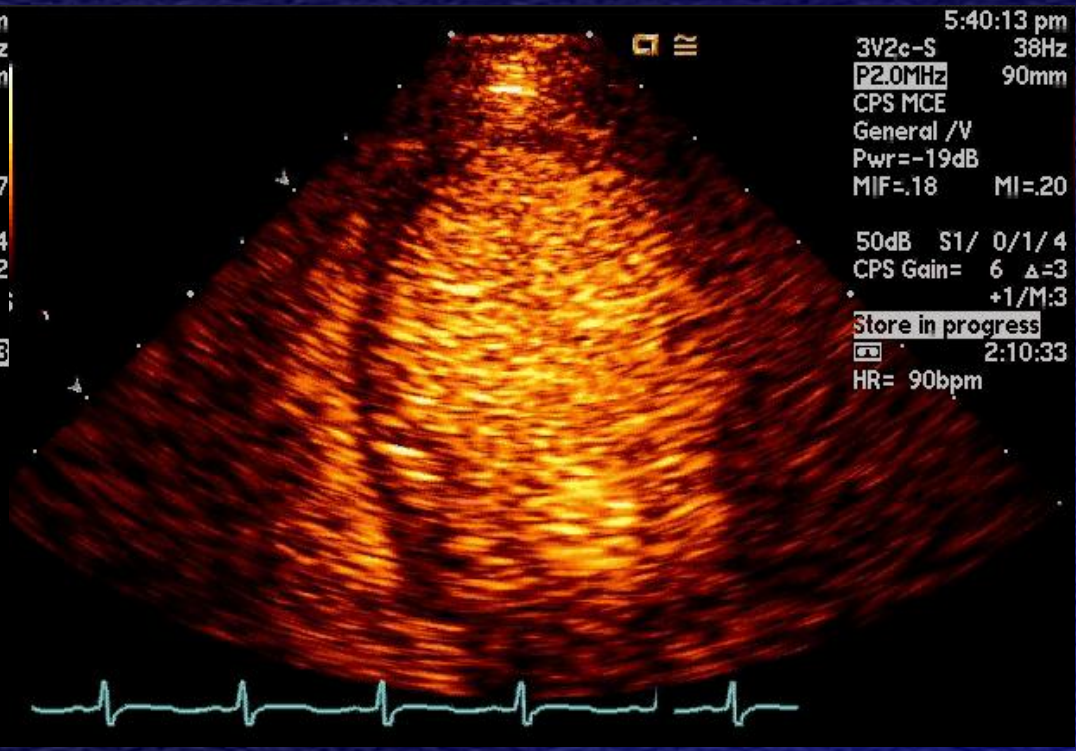
Porter, T. R. et al. J Am Coll Cardiol Img 2010;3:176-187

Case (77/F) chest pain

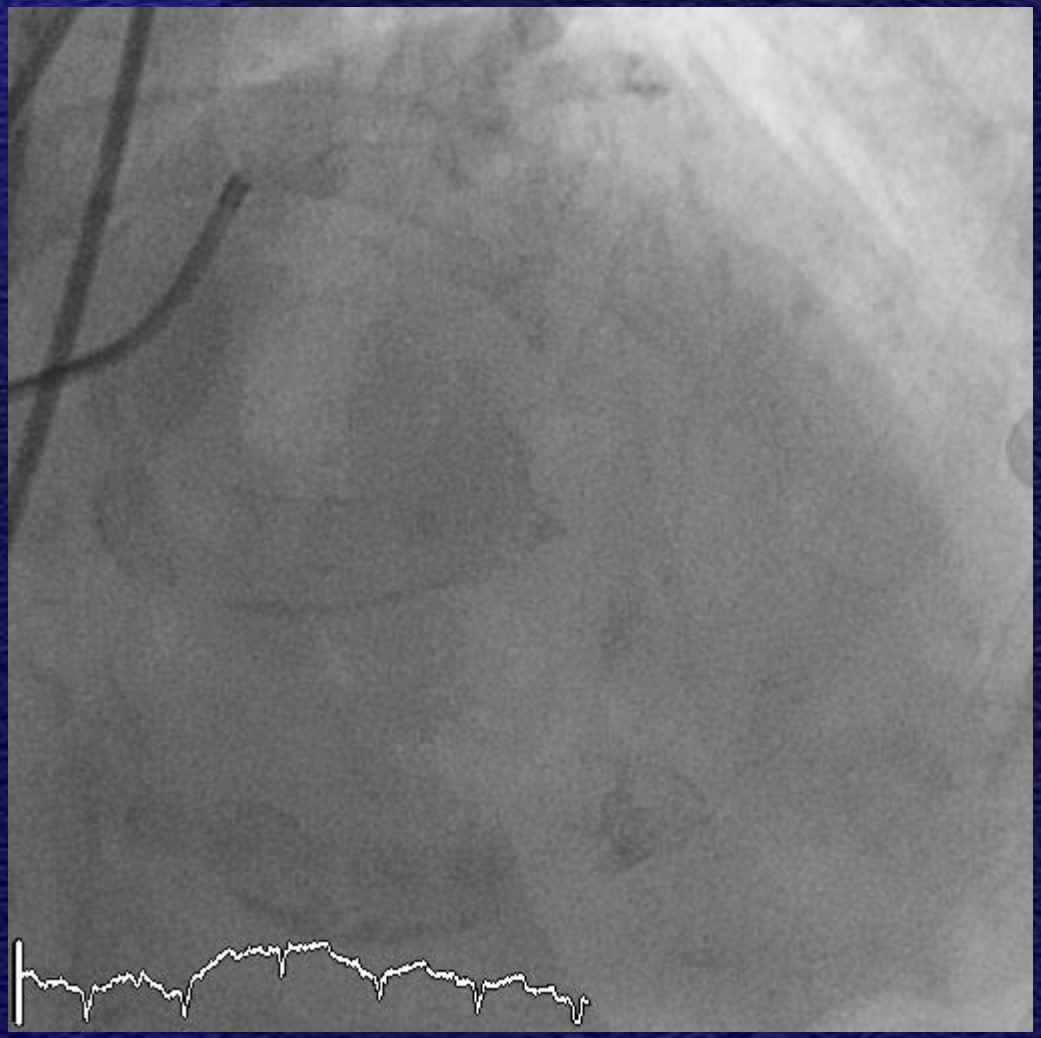


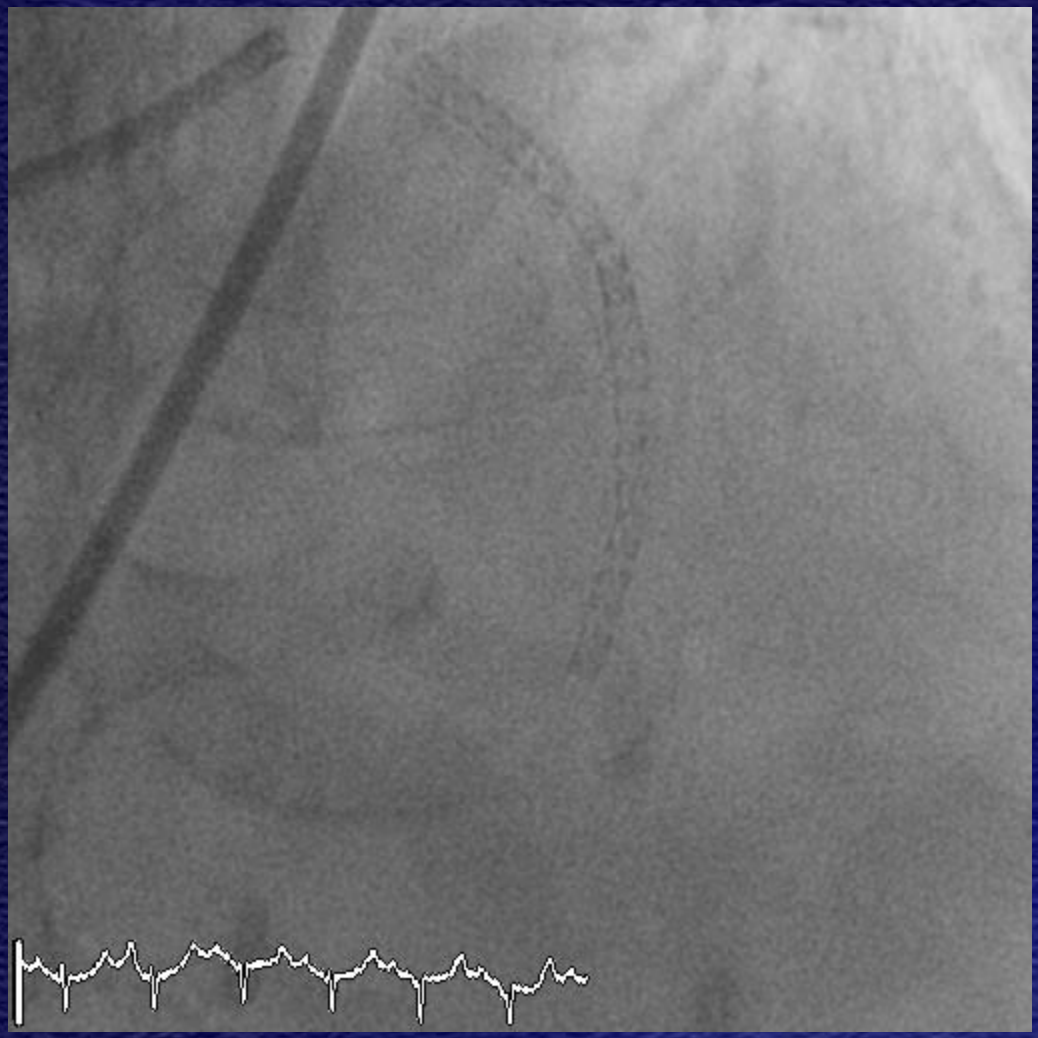
Case (77/F) chest pain



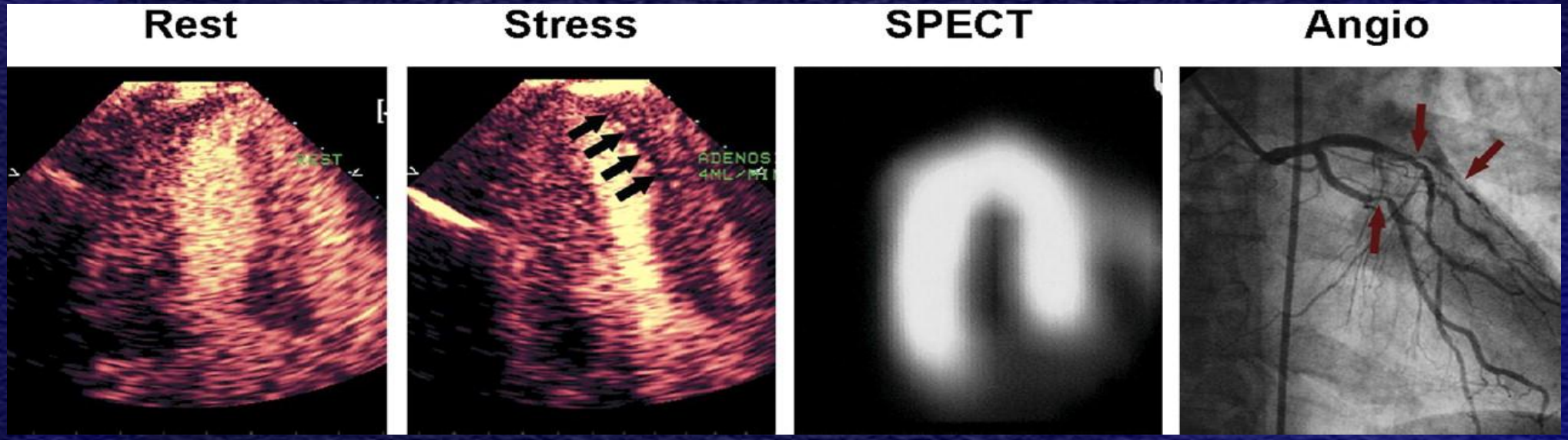


Case (77/F) chest pain





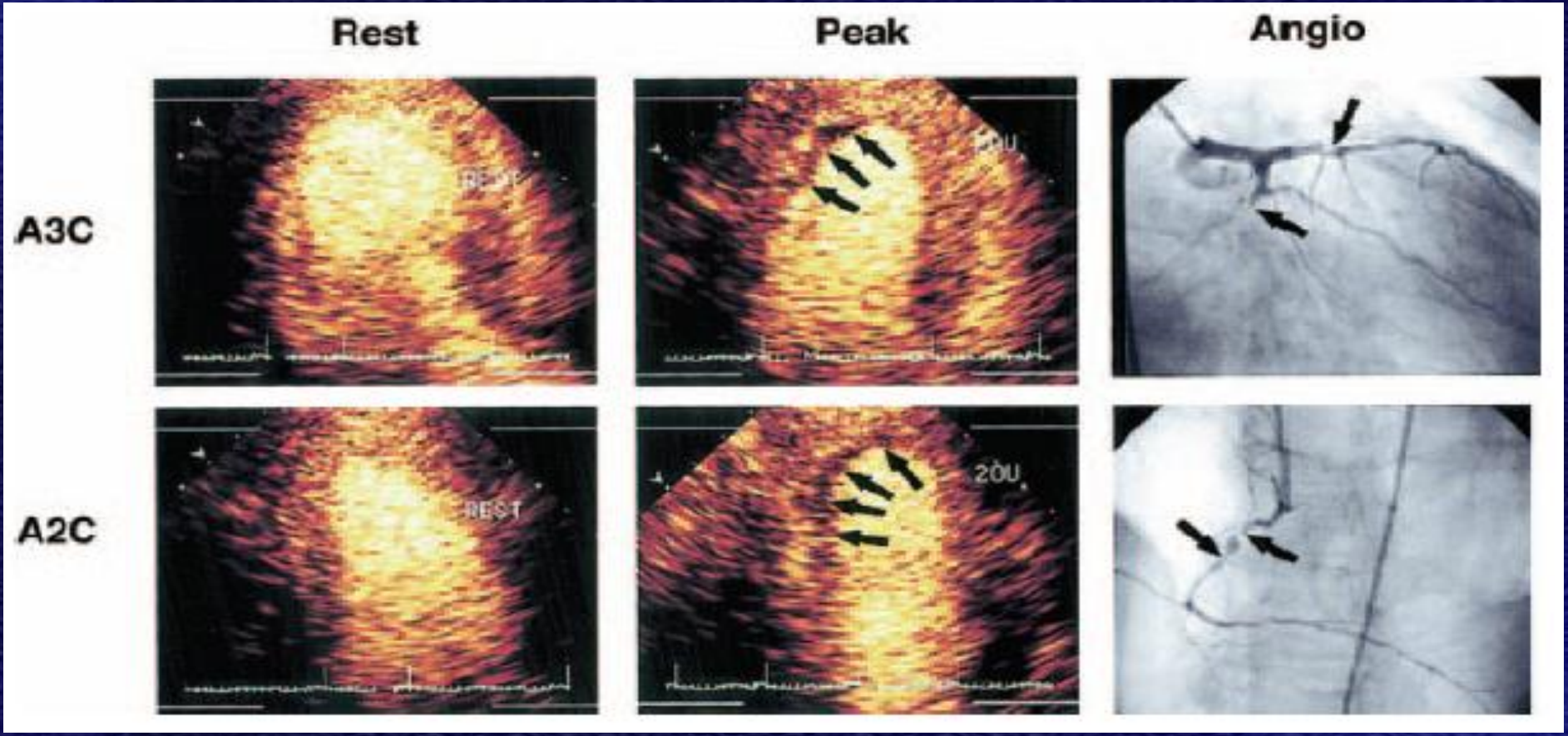
An Example of a subendocardial Perfusion Defect



The defect is evident in the anteroseptal and apical segments of the left ventricle during the replenishment phase of contrast after a high–MI impulse during adenosine stress imaging.

Porter, T. R. et al. J Am Coll Cardiol Img 2010;3:176-187

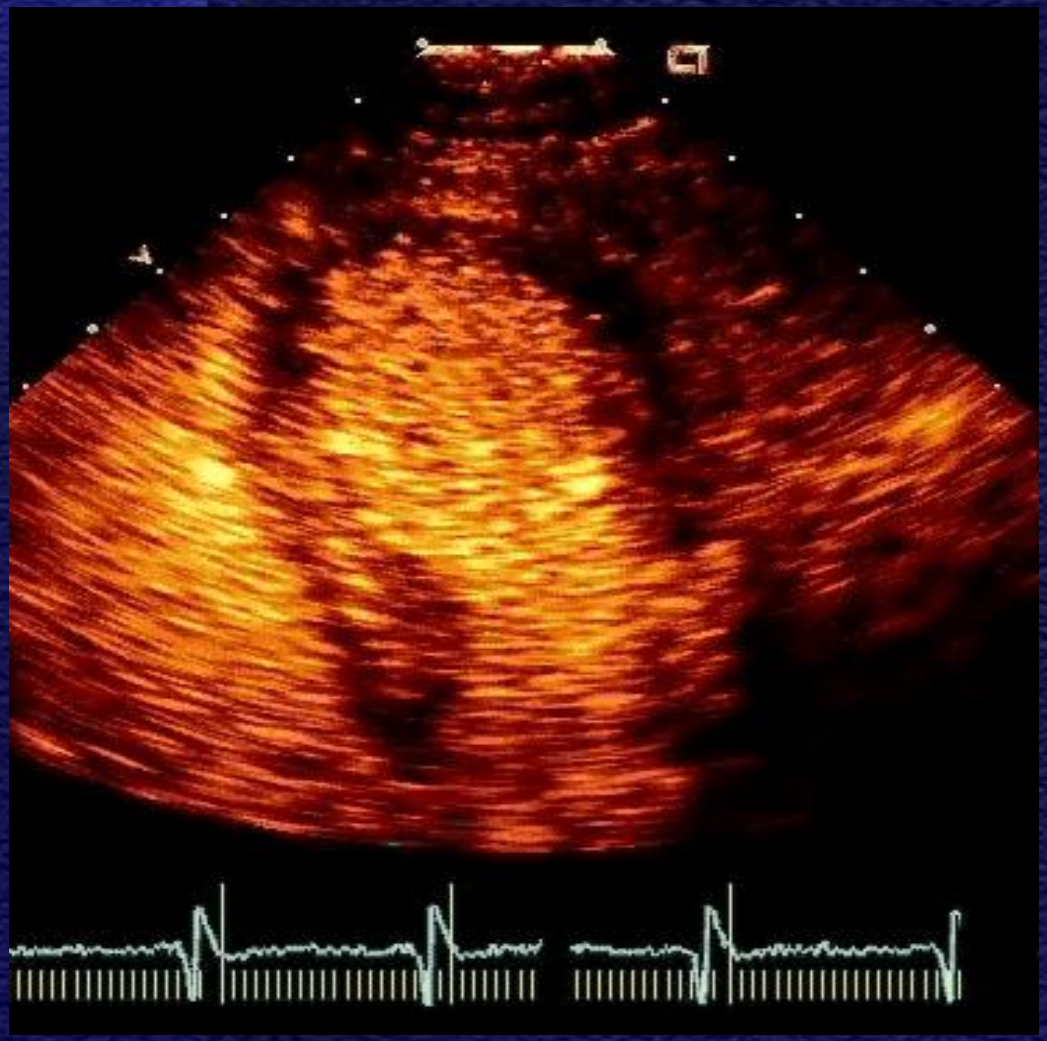
Dobutamine Stress MCE



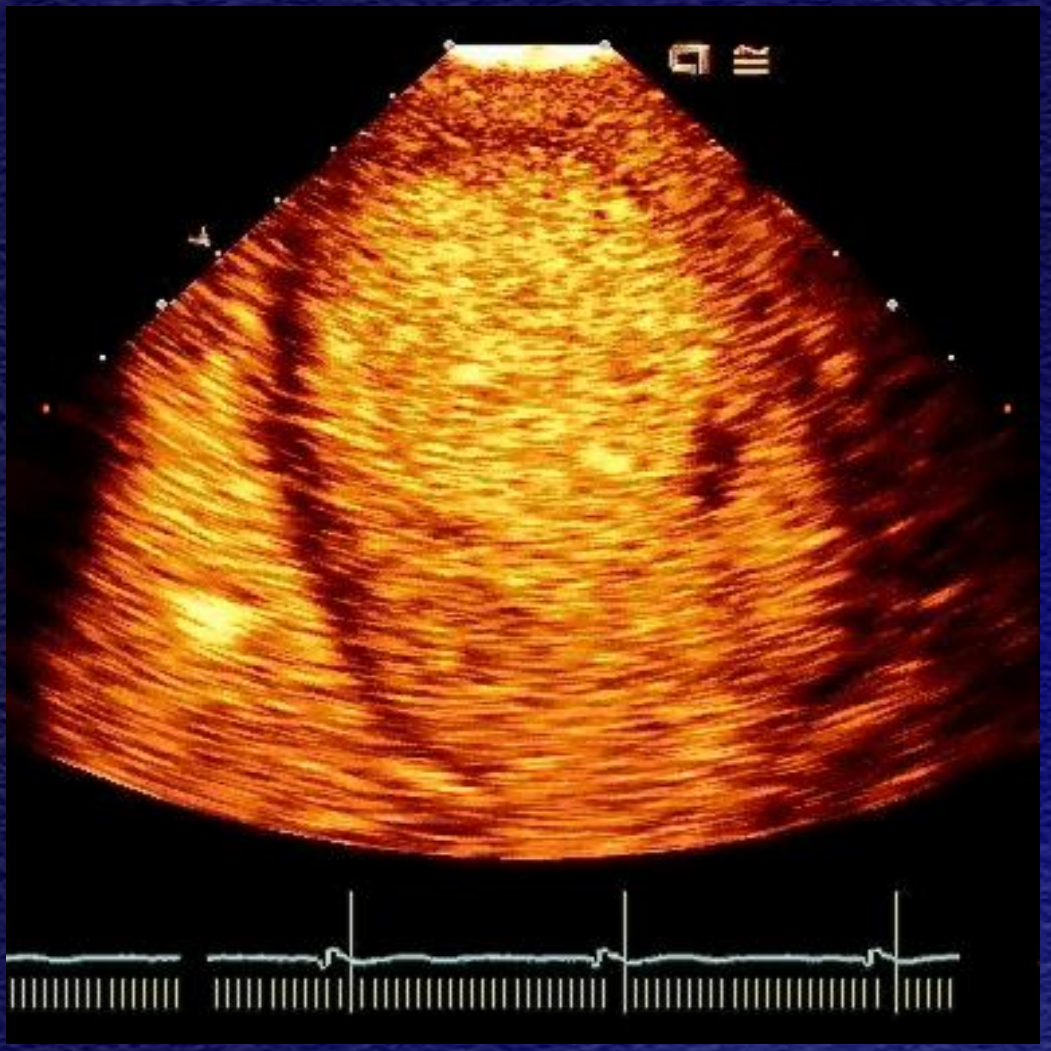
Inducible ischemia in the post/apical and inf/apical regions that correalte to the significant stenosis of LCX and RCA in CAG.

PA wt al. JACC 2066;48:11

AMI



SCMP



Analysis of Perfusion

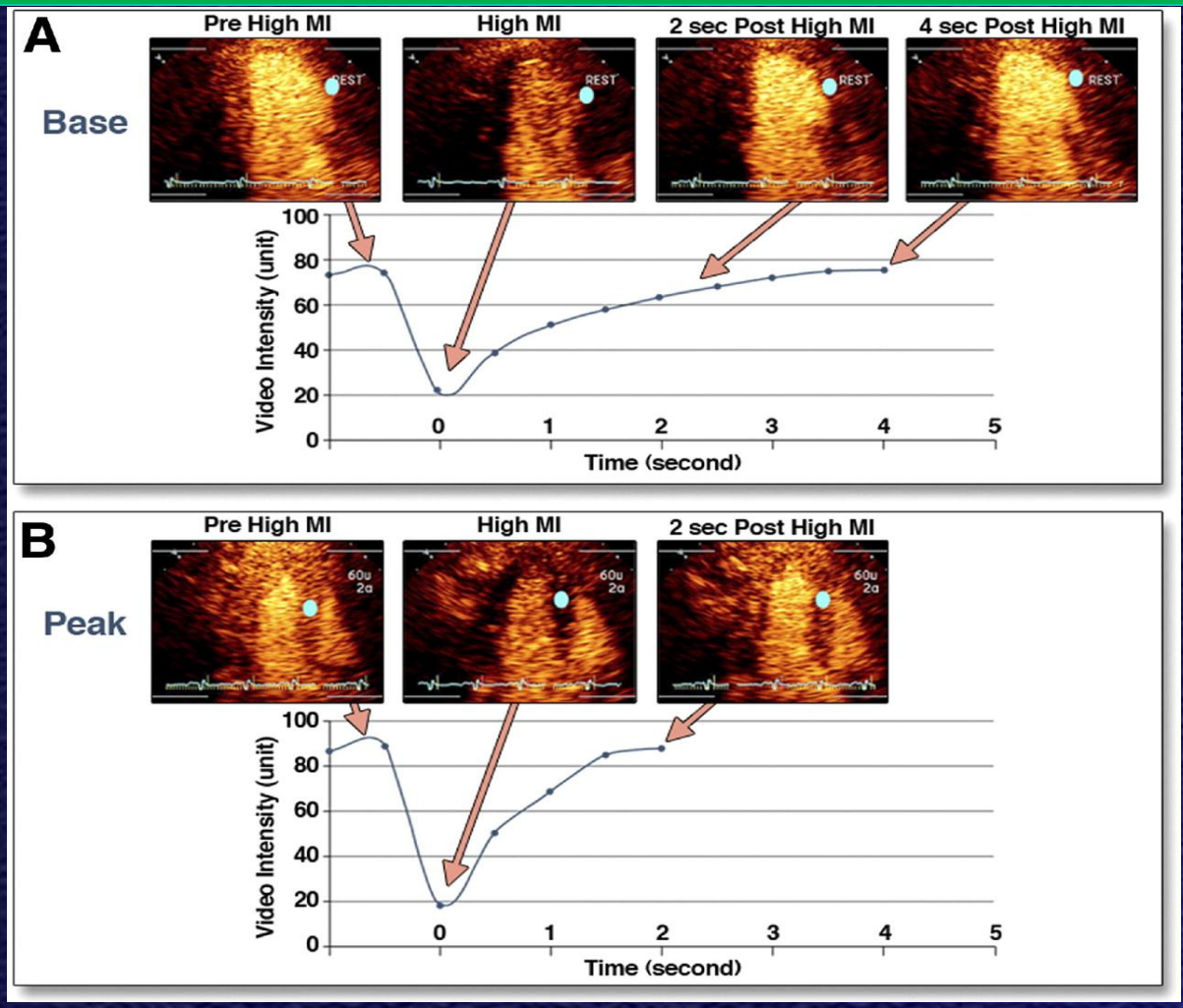
- **Quantitative**

- involves fitting parameters to the time intensity curves of microbubble replenishment.

- The reappearance rate of microbubbles is related to myocardial blood flow velocity, and the plateau value is related to the microvascular cross-sectional area.

- Absolute myocardial blood flow can also be determined with myocardial blood volume, which can be assessed as the ratio of the signal intensity of the myocardium to LV.

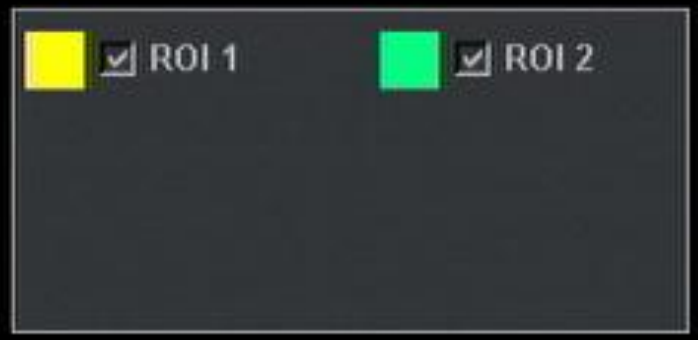
Normal Myocardial Replenishment



With real-time perfusion image, the myocardial replenishment is after a high–mechanical index (MI) impulse.

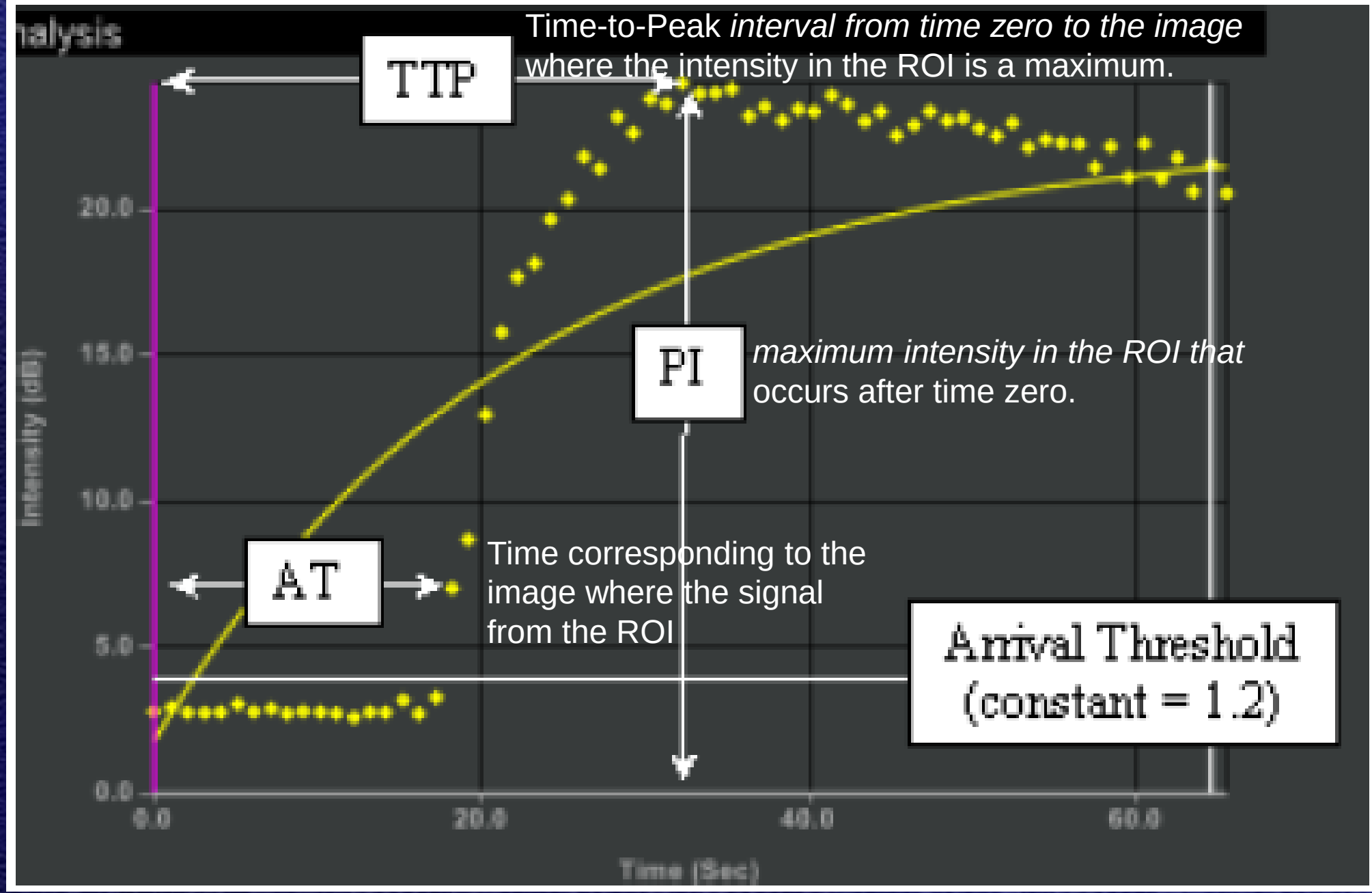
Porter, T. R. et al. J Am Coll Cardiol Img 2010;3:176-187

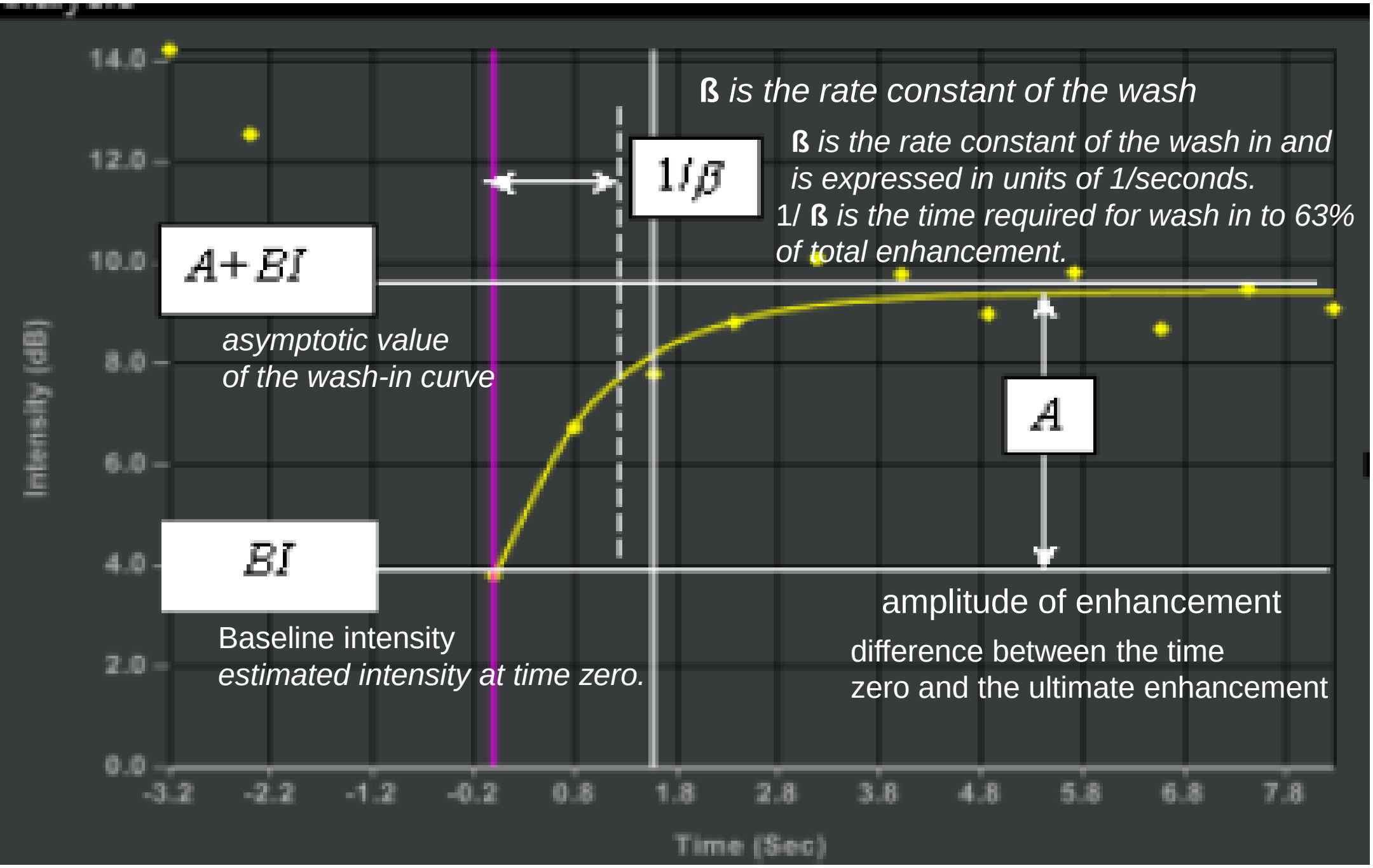
Data Summary

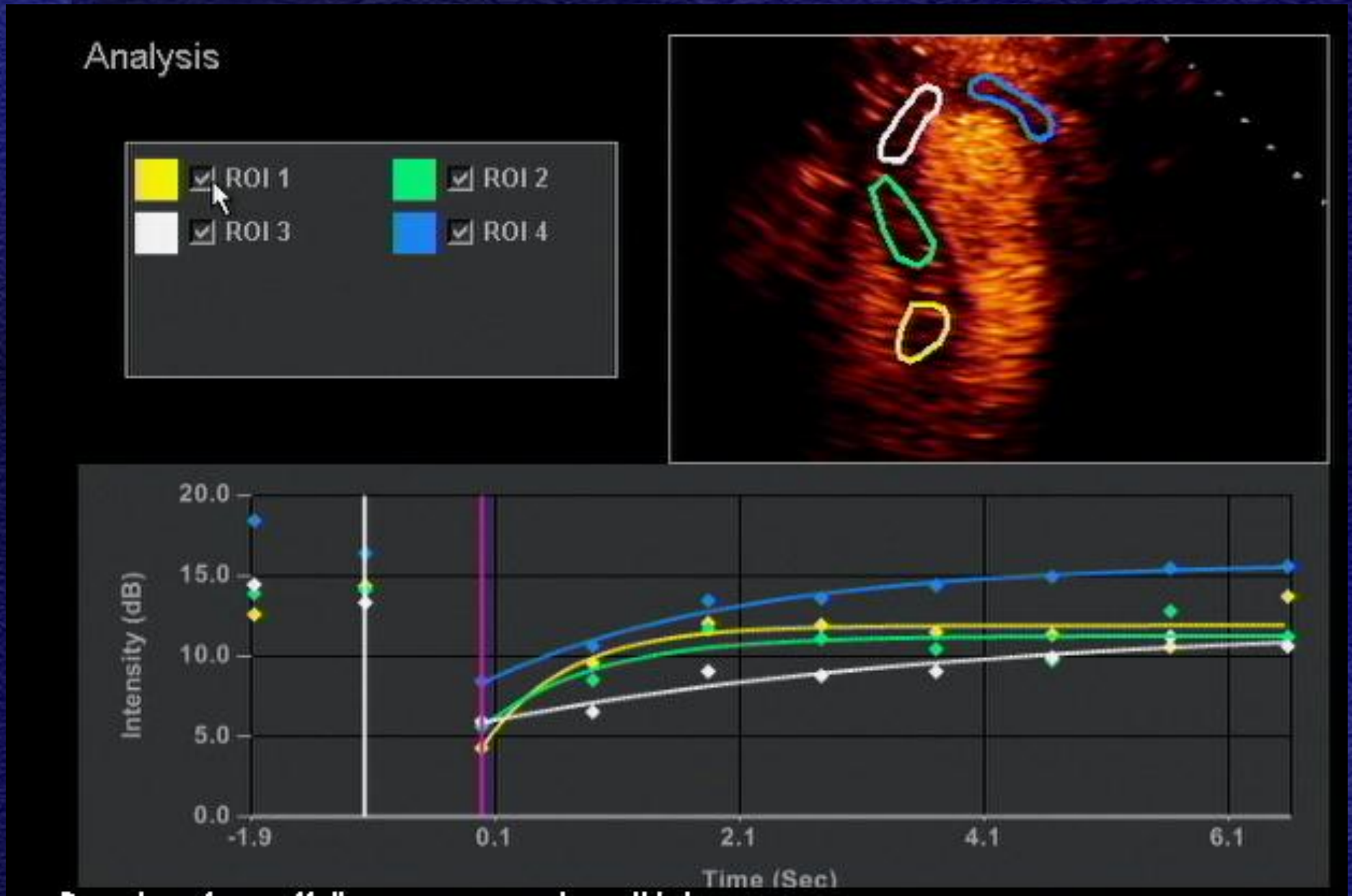


ROI	BI	A	β	GOF	AT	TTP	PI
1	7.12	11.07	0.63	0.97	0.79	7.43	12.33
2	5.70	5.58	1.08	0.99	0.79	5.72	5.85

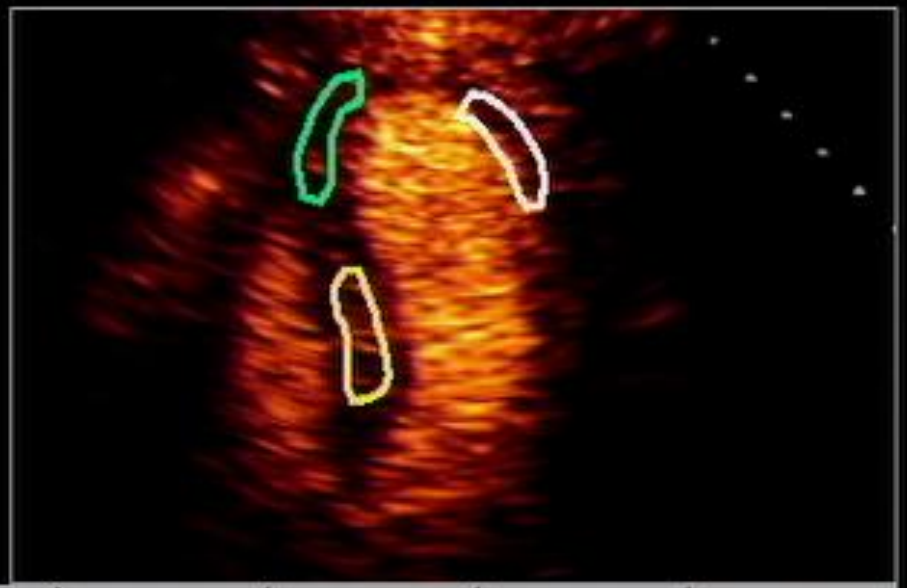
GOF is a measure of how well the function fits the measured data


Time-to-Peak *interval from time zero to the image* where the intensity in the ROI is a maximum.
TTP
PI
maximum intensity in the ROI that occurs after time zero.
AT
Time corresponding to the image where the signal from the ROI
Arrival Threshold (constant = 1.2)
20.0
15.0
10.0
5.0
0.0
Intensity (dB)
0.0
20.0
40.0
60.0
Time (Sec)


ß is the rate constant of the wash
ß is the rate constant of the wash in and is expressed in units of 1/seconds.
1/ ß is the time required for wash in to 63% of total enhancement.
1/β
A+BI
asymptotic value of the wash-in curve
A
BI
Baseline intensity
estimated intensity at time zero.
amplitude of enhancement
difference between the time zero and the ultimate enhancement
Intensity (dB)
Time (Sec)
14.0
12.0
10.0
8.0
6.0
4.0
2.0
0.0
-3.2
-2.2
-1.2
-0.2
0.8
1.8
2.8
3.8
4.8
5.8
6.8
7.8


Analysis
ROI 1
ROI 2
ROI 3
ROI 4
20.0
15.0
10.0
5.0
0.0
Intensity (dB)
-1.9
0.1
2.1
4.1
6.1
Time (Sec)

Data Summary



ROI	BI	A	β	GOF	AT	TTP	PI
1	8.42	7.22	0.88	0.97	2.86	5.67	7.75
2	6.03	6.35	0.73	0.91	2.86	3.80	6.67
3	4.82	12.21	0.91	0.98	1.92	3.80	13.05

Curve fitting with exponential value

- Parameters BI, A and are used to minimize error between measured data and function

$$BI + A(1 - e^{-\beta \cdot t})$$

- This curve is based on destruction-re-flow technique using a continuous infusion.
- A nonlinear, least-square, curve fit using an interior trust region method is performed to quickly and accurately identify the parameters based on the data.

Coleman TF, Li Y, "An Interior, Trust Region Approach for Nonlinear Minimization Subject to Bounds", SIAM Journal on Optimization 6:418-445 (1996).

Log Compression vs. Antilog Data

- Antilog data more mathematically justifiable.
- Log compression reduces effect of very bright pixels in ROI.
- Log compression compresses changes seen in time intensity curve.
- Less Noisy
- More rapid approach to final value

Advantage of MCE Perfusion

- MCE has an advantage over SPECT, PET, and CT perfusion imaging because it does not involve ionizing radiation.
- Compared with SPECT, MCE has improved spatial resolution, detection of subendocardial ischemia.
- MCE also has the ability to perform absolute quantification of myocardial blood flow.
- Imaging can be performed during pharmacological stress with inotropes or vasodilators or with exercise.

Limitation of MCE Perfusion

- Suboptimal images as the result of respiratory motion, body habitus, or lung disease.
- Attenuation from the microbubbles may result in artifacts in the basal segments of LV. It can limit image quality and adequate spatial coverage of the ventricle, resulting in increased variability and decreased reproducibility.
- Operator-dependent factors such as maintaining a constant image plane during replenishment of microbubbles.


Thank you very much!