

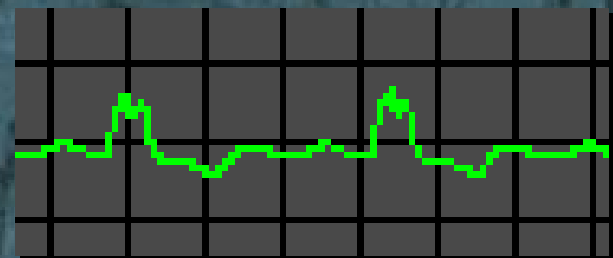
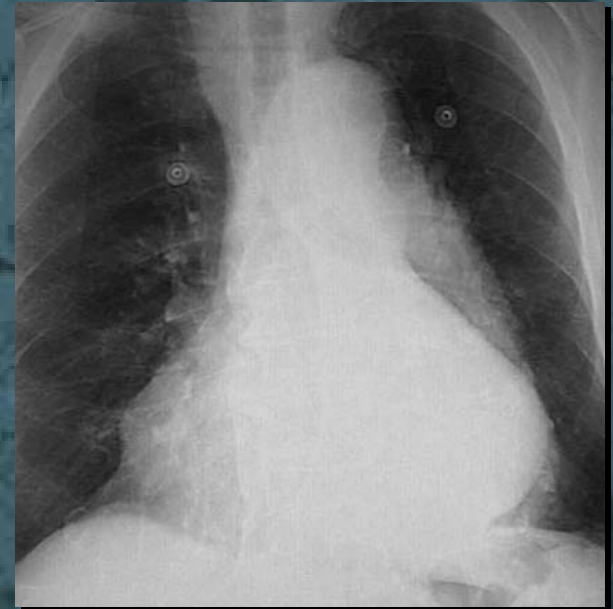
***Element 35.00***

**Gorcsan**

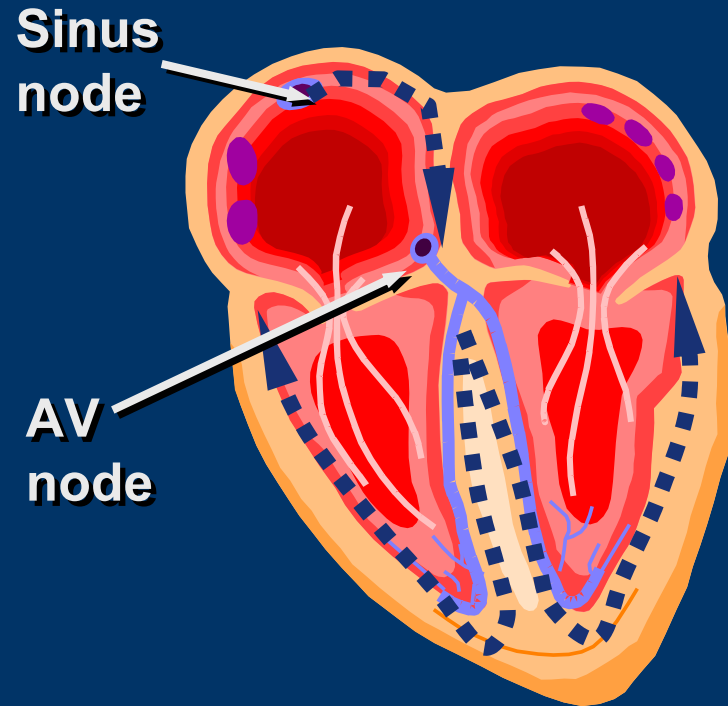


# Heart Failure and Abnormal Electrical Activation

- 500,000 new cases in USA/yr
- # 1 hosp admission diagnosis
- 25-30% LBBB  
*(abnormal electrical activation)*

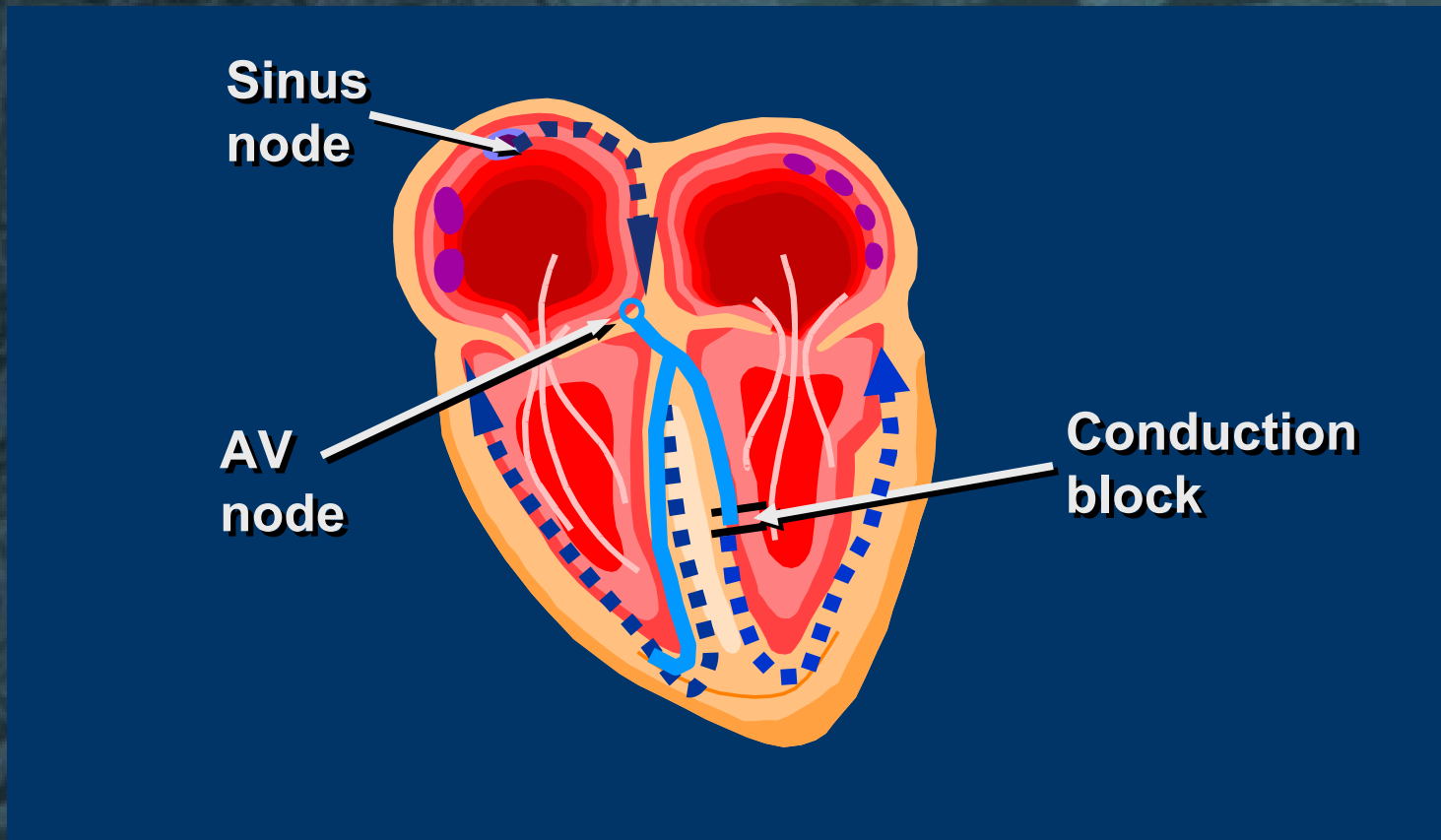


# Normal Electrical Activation



*Kass D: Heart Failure Society of America 2000*

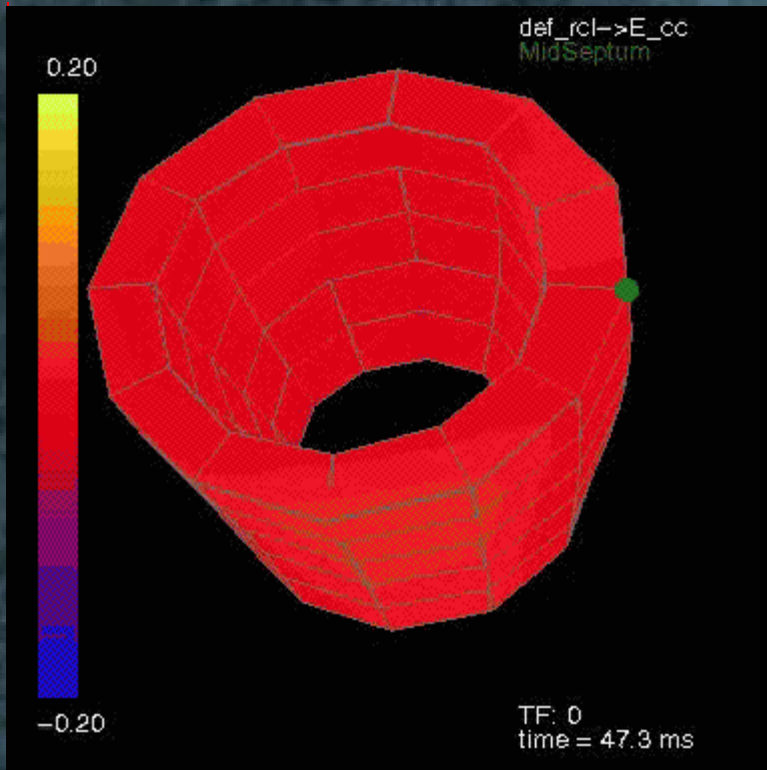
# Left Bundle Branch Block



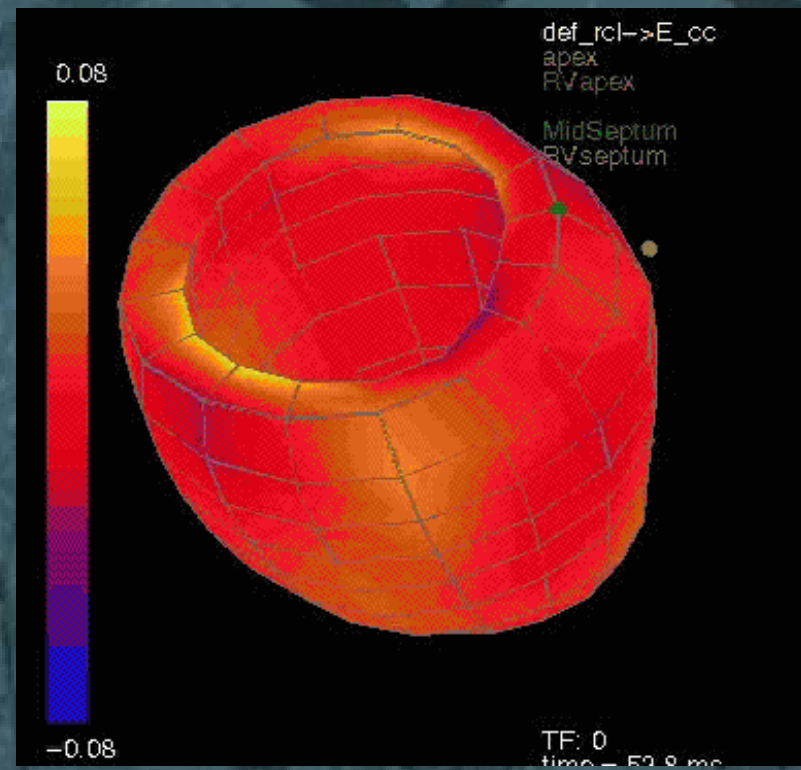
*Kass D: Heart Failure Society of America 2000*

# Dyssynchrony with LBBB

## Strain patterns with tagged Cine MRI



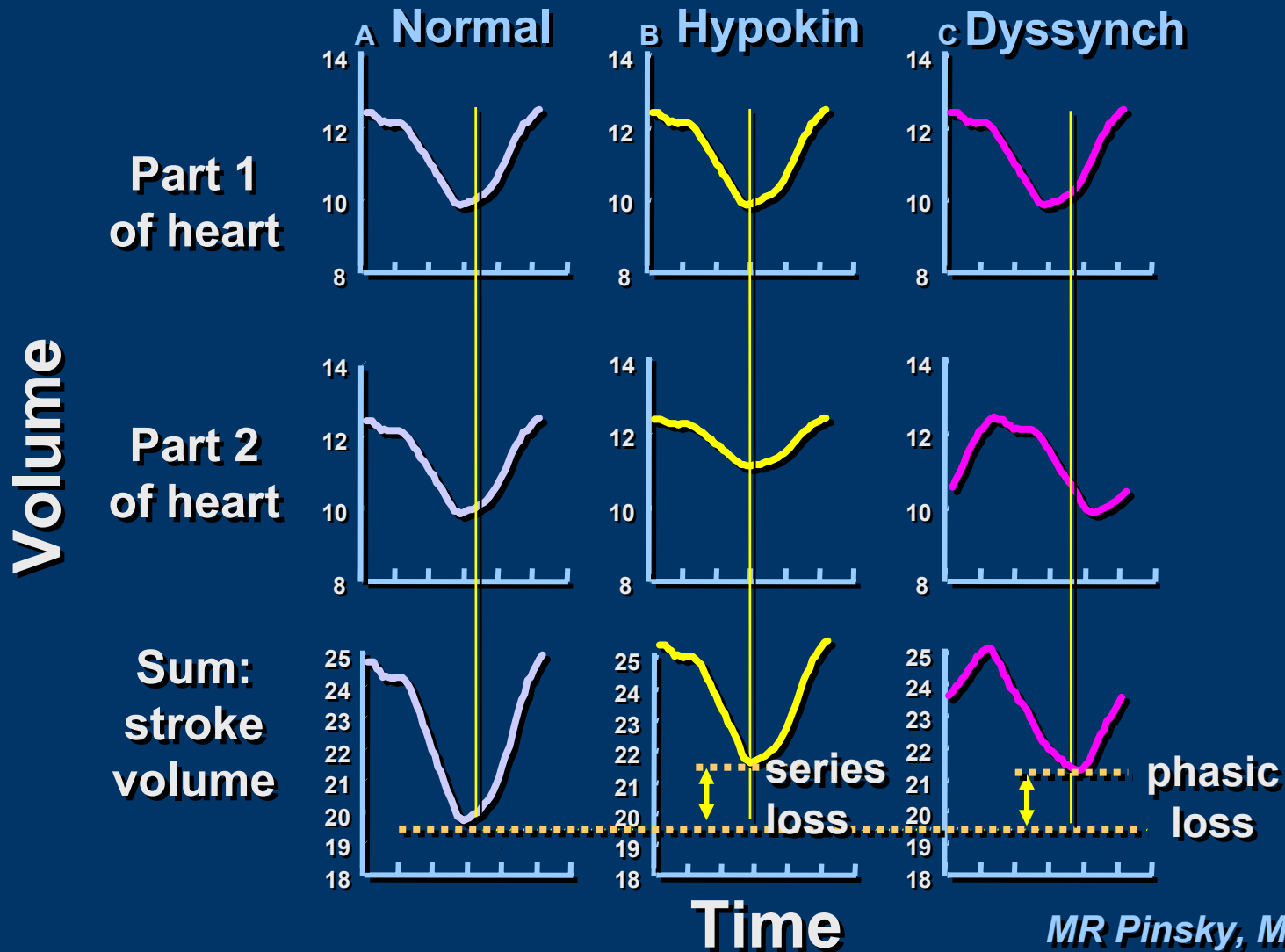
**Normal**



**Cardiomyopathy: LBBB**

*Curry ...Kass et al. Circulation 2000*

# Summation of Regional LV Function

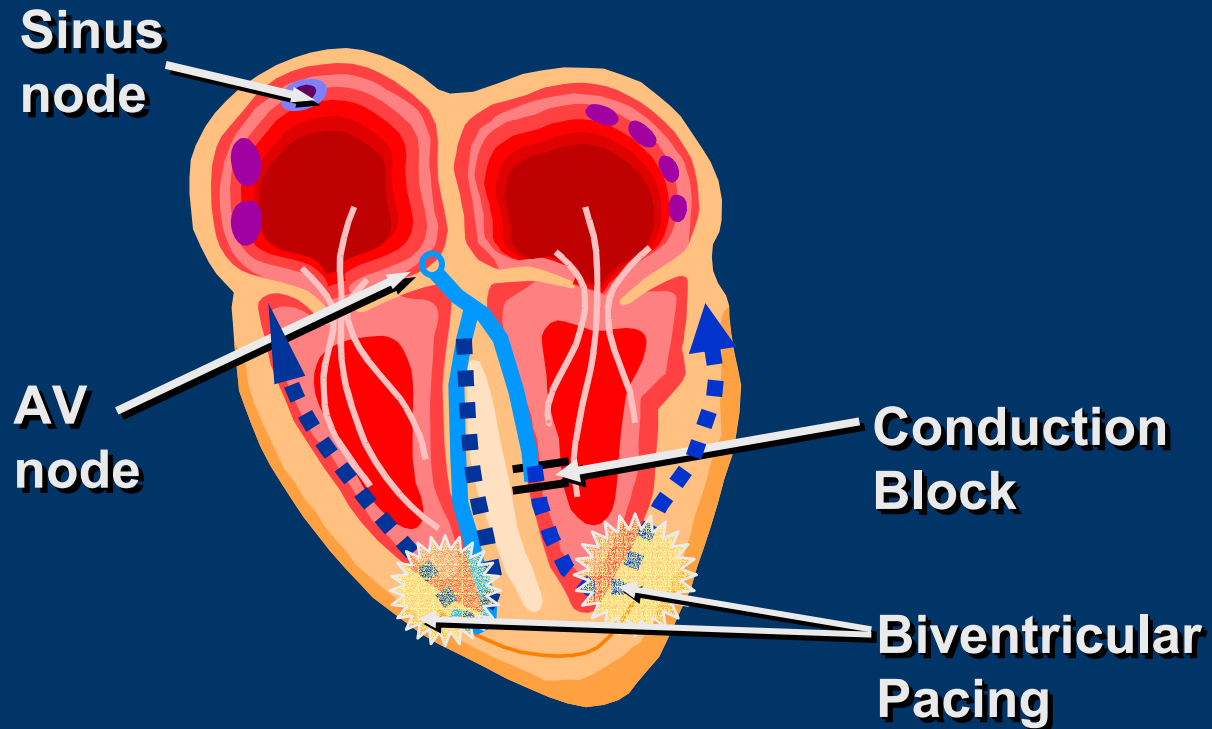


**LV Dyssynchrony is a  
Mechanical Problem:  
Timing of LV segments**

*Septum vs posterior -  
lateral wall*

# Resynchronization

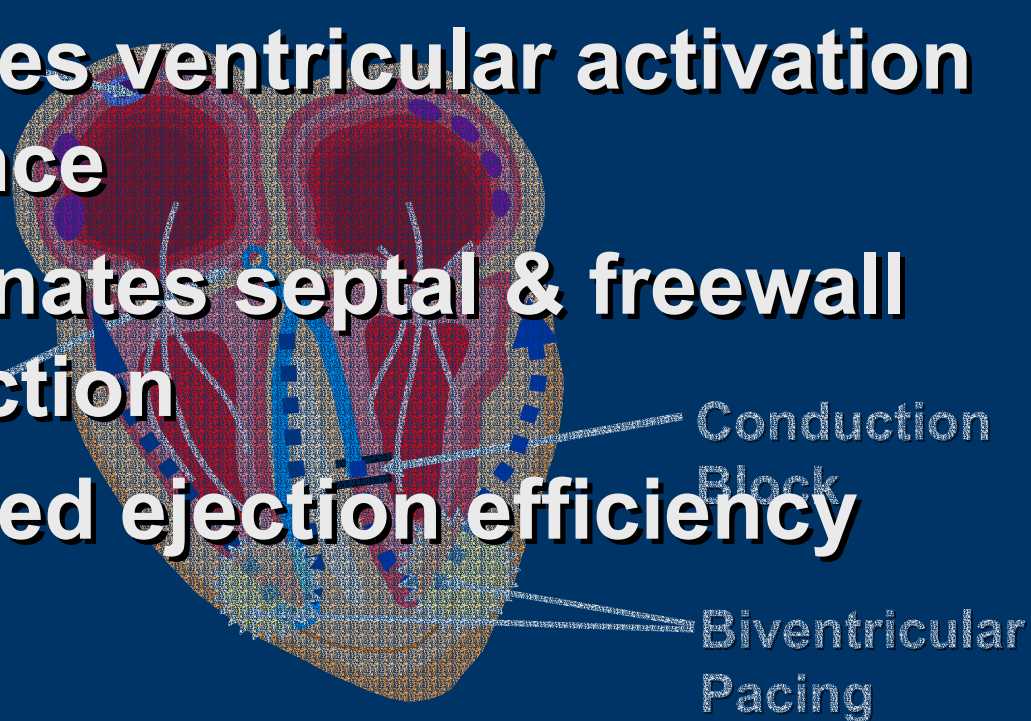
## *Biventricular pacing therapy*



# Resynchronization

## *Biventricular pacing therapy*

- Improves ventricular activation sequence
- Coordinates septal & freewall contraction
- Improved ejection efficiency



# **Flourosopic View**

## ***Transvenous left ventricular pacing lead***

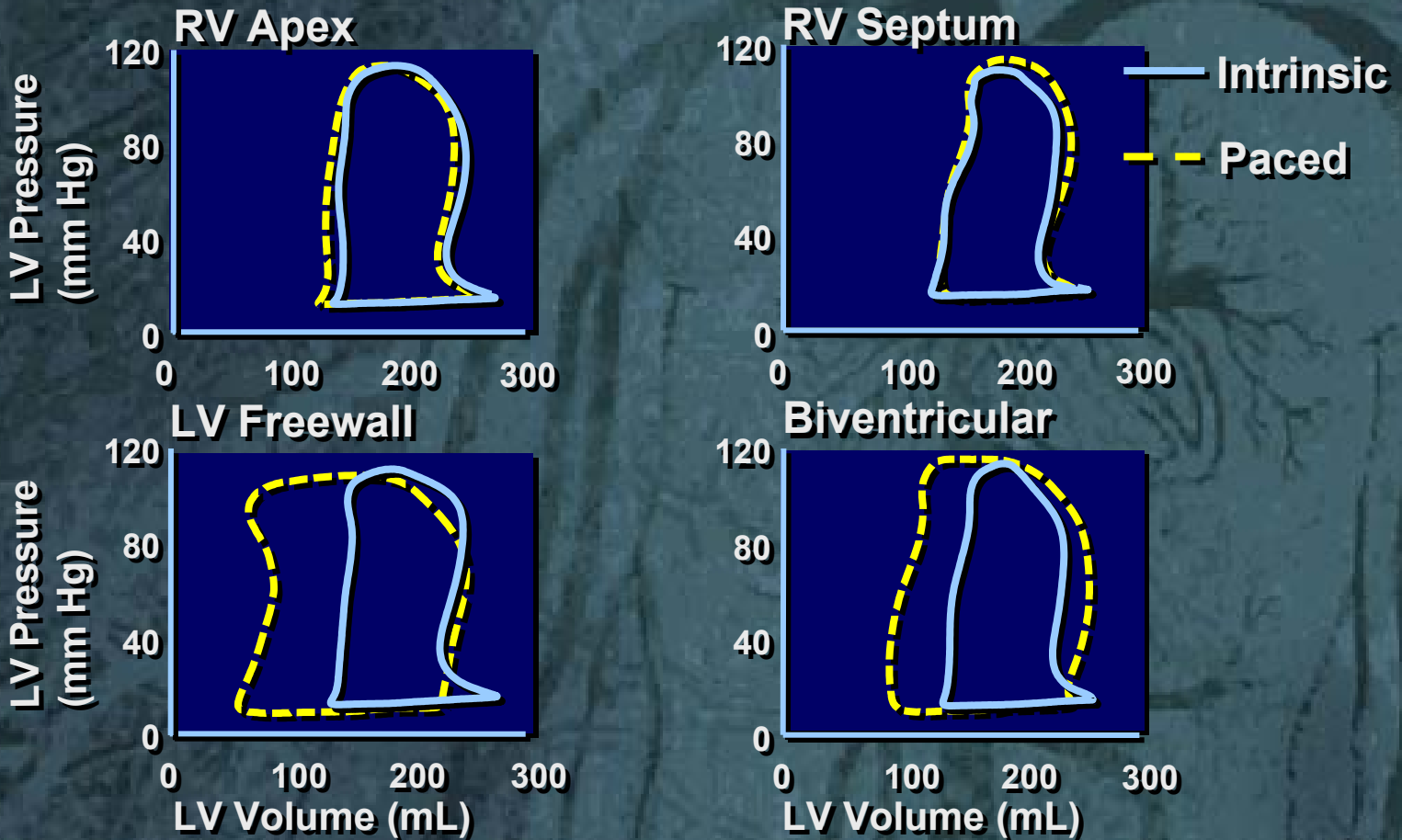


**Coronary sinus venogram**



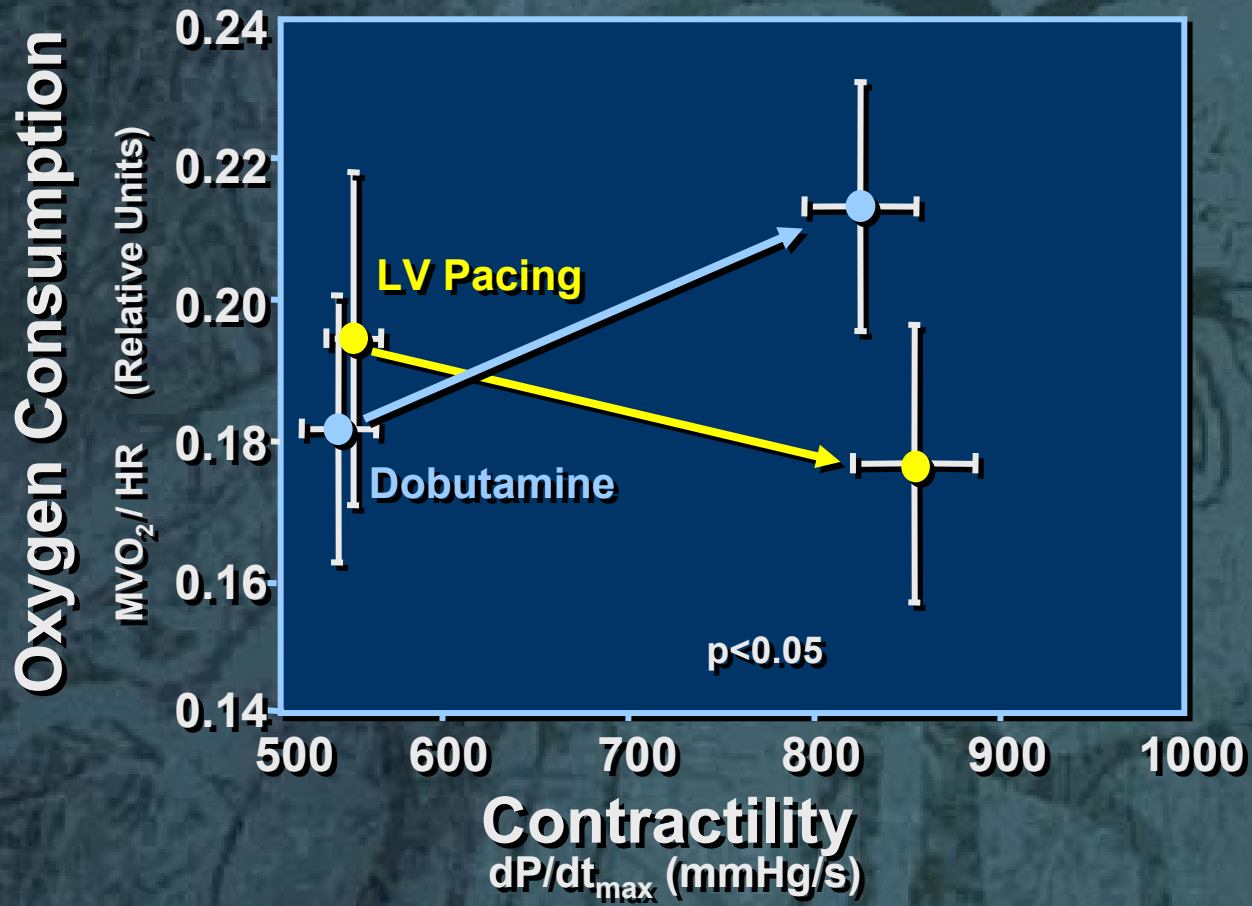
**LV lead in  
posterolateral coronary vein**

# Pacing Response: CHF-LBBB Pts Pressure-Volume Loops



*Kass D, et al. Circulation. 1999;99:1567-1573.*

# CRT Enhances Cardiac Mechano-Energetic Efficiency



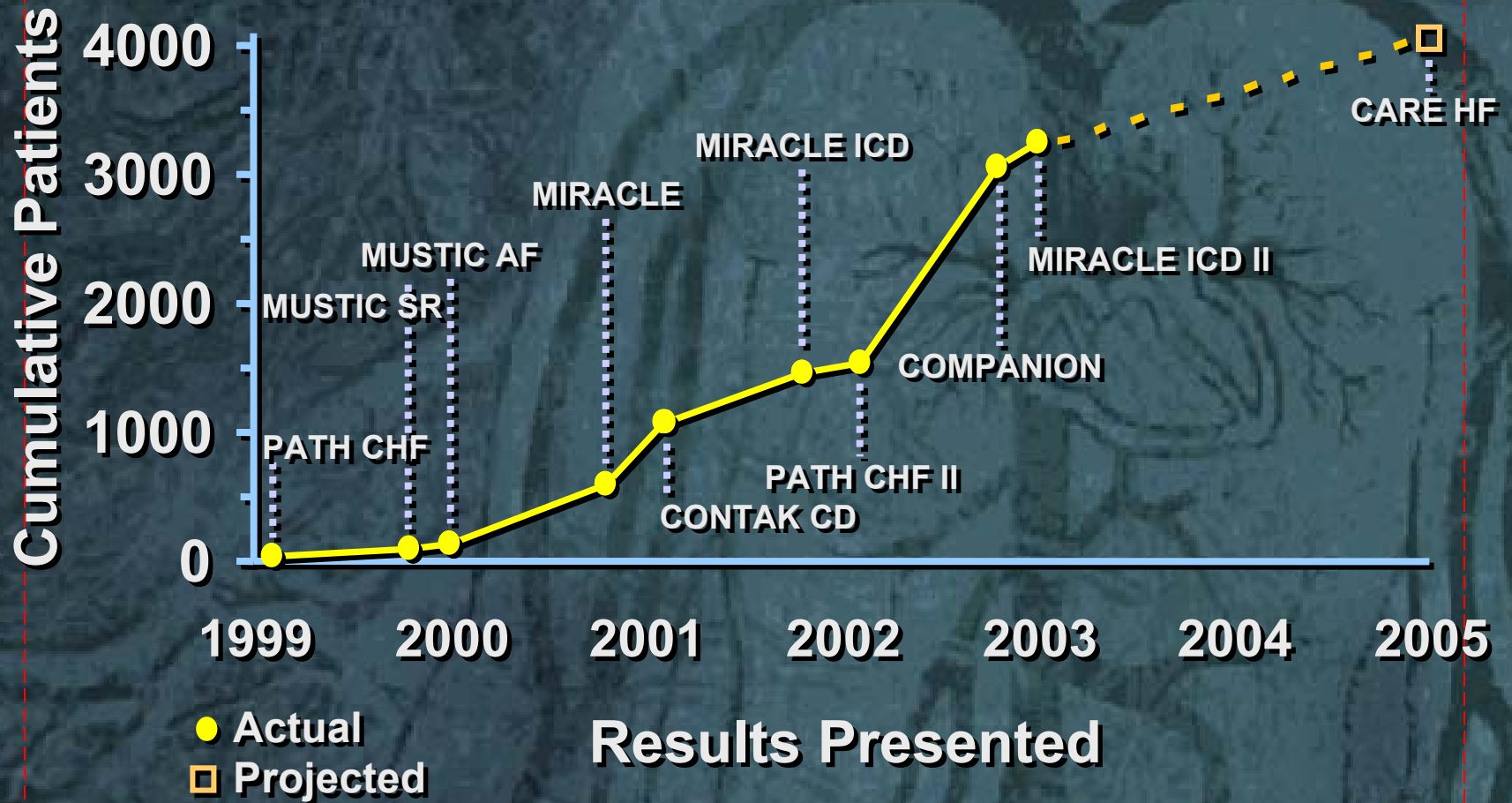
Nelson et al. *Circulation*. 2000; 102:3053-3059

# Cardiac Resynchronization Therapy: *Weight of Evidence*

- > 4000 pts randomized controlled trials
- Consistent improvement: quality of life, functional status, and exercise capacity
- Strong evidence for reverse remodeling
  - ↓ *LV volumes and dimensions*
  - ↑ *LV ejection fraction*
  - ↓ *Mitral regurgitation*
- Reduction in heart failure (CRT) and all-cause morbidity and mortality (CRT-D)

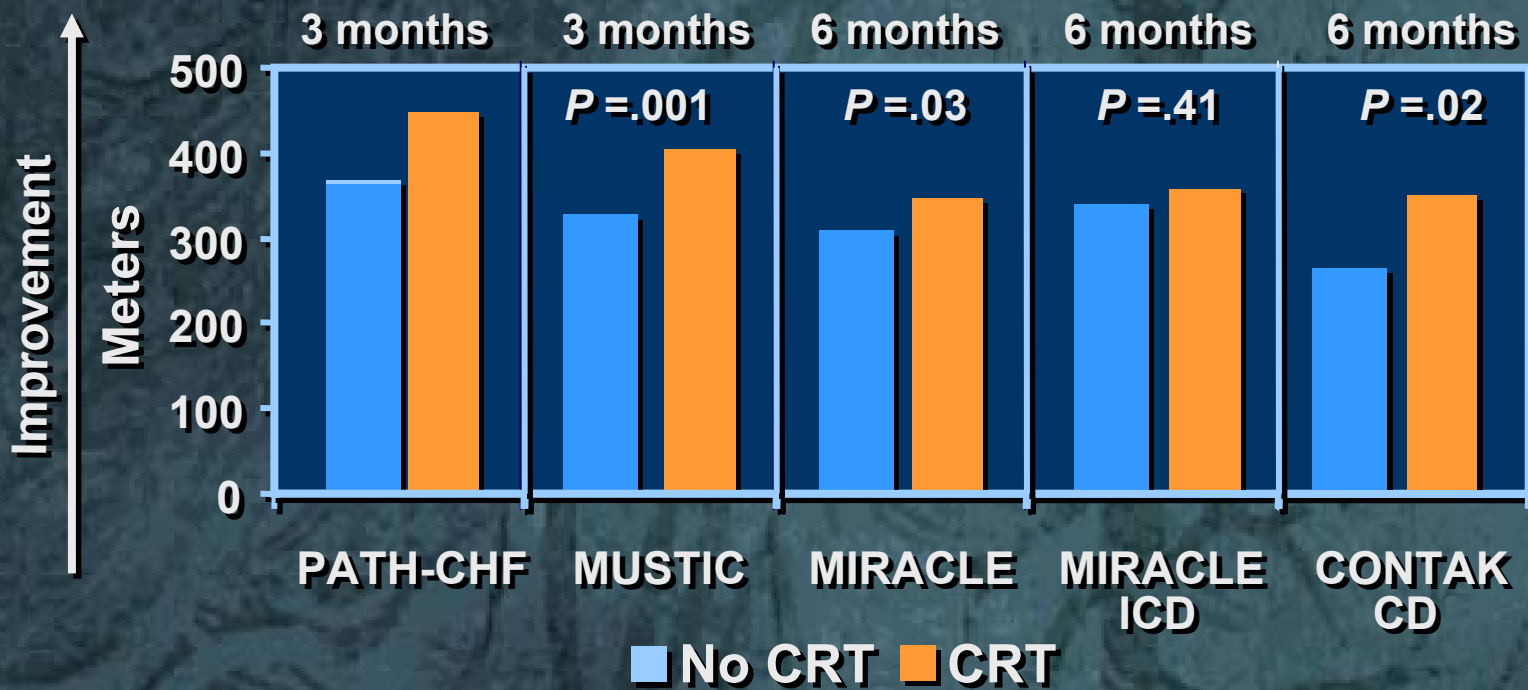
*Abraham WT and Hayes DL, Circulation 2003; 108:2596-2603*

# Cumulative Enrollment Cardiac Resynch Randomized Trials



Abraham WT

# Resynchronization Therapy Improves 6-Minute Walking Distance



Mean improvement in meters walked ~ 50+ meters

# Resynchronization Therapy Improves NYHA Functional Class

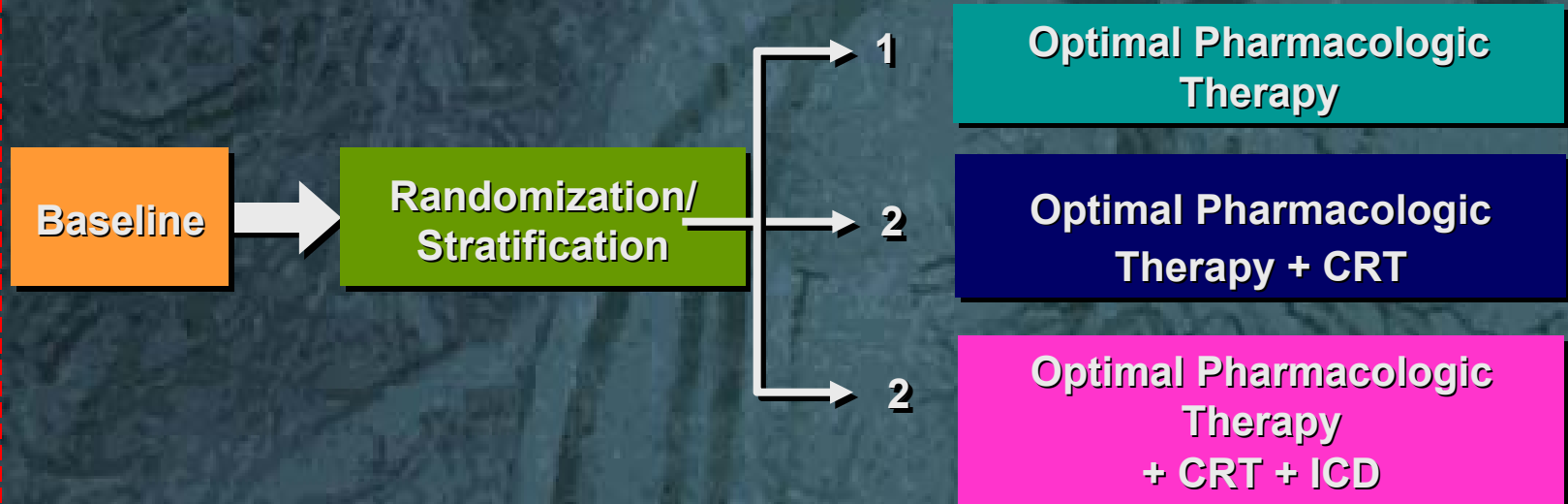


# COMPANION Trial

- Randomized 1,520 pts
- NYHA Class III or IV,  $EF \leq 35\%$ ,  
 $QRS \geq 120$  ms
- Equal distribution of B-blocker  $\geq 3$   
mos
- Diuretic ACEi/ARB, spironolactone

*Bristow MR & Feldman AM, et al. NEJM, May 2004*

# COMPANION Trial

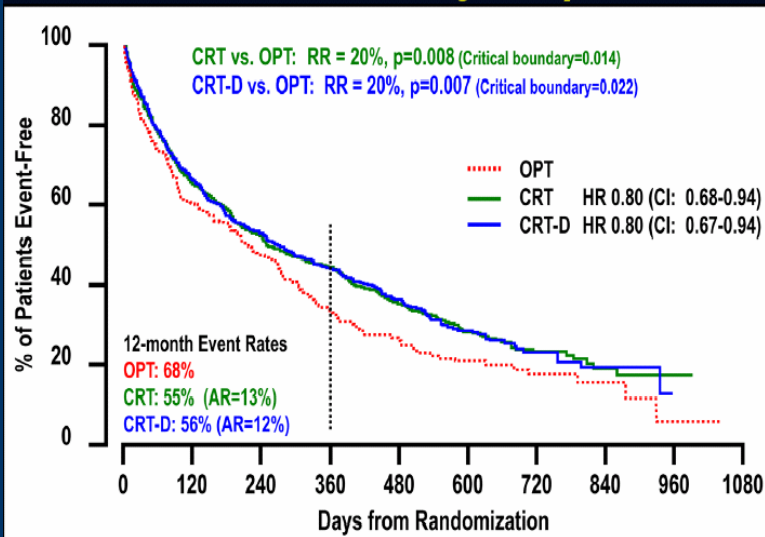


**CRT = cardiac resynchronization therapy**  
**ICD = implantable cardioverter-defibrillator**

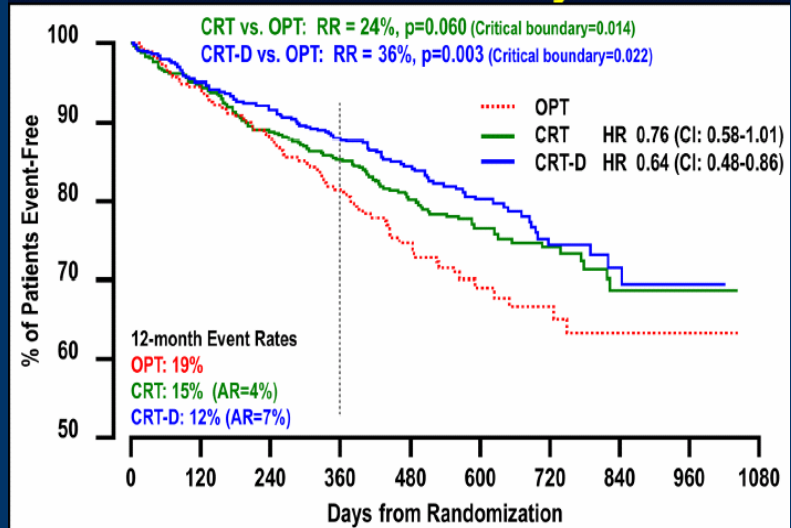
*Bristow MR & Feldman AM, et al. NEJM, May 2004*

# All Cause Mortality or All Cause Hospitalization

## COMPANION: Primary Endpoint



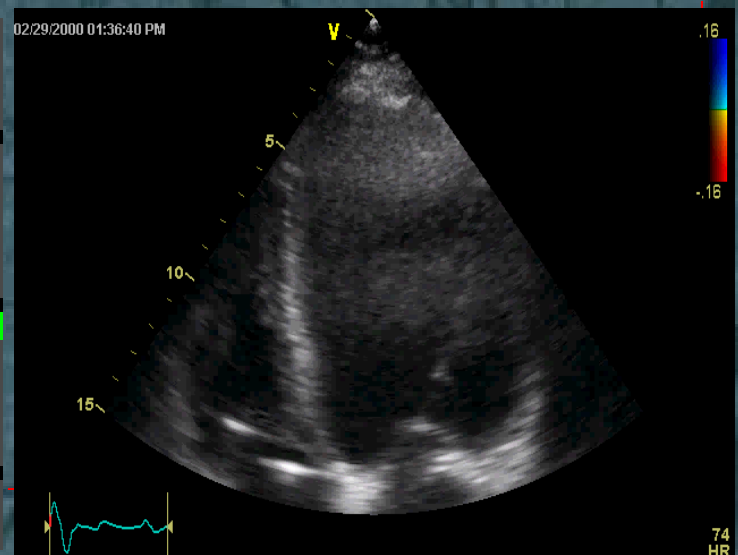
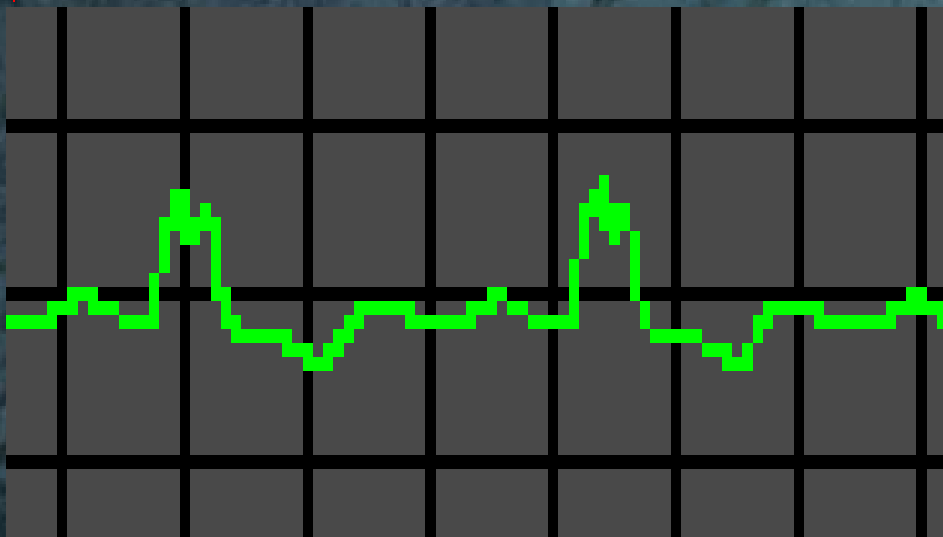
## COMPANION: Secondary Endpoint of All-Cause Mortality



*Bristow MR, ...Feldman AM, et al. N Eng J Med May 2004*

# Candidates for CRT

- Heart failure:  
*NYHA Functional Class III or IV*
- QRS  $\geq$  120 msec
- EF  $\leq$  35%

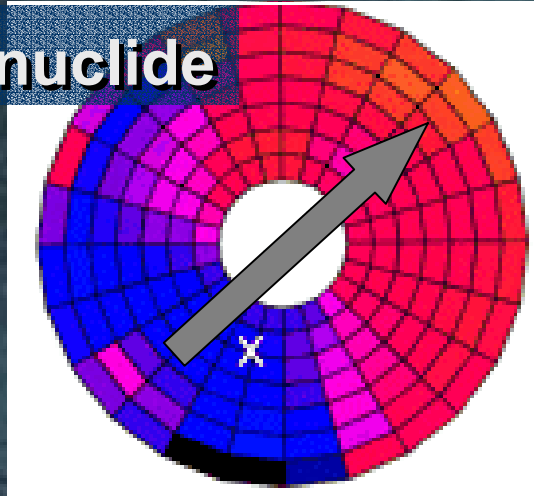


# Why Echo for Dyssynchrony?

Temporal resolution  
- *timing*

Spatial resolution  
- *segments*

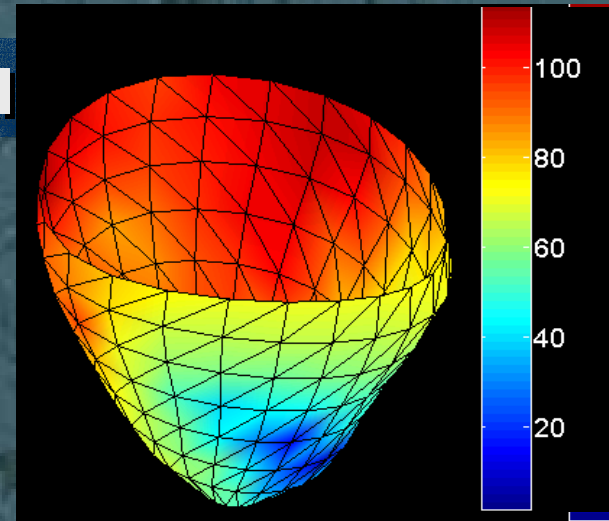
Radionuclide



*Wymen*

Echo-Doppler better

MRI



*Kass*

No studies post-pacer  
Limited clinical availability

# Echo-Doppler to Quantify the Favorable Effects of CRT



**ACUTE**

*Immediate*

- Reduction in MR
- Acute hemodynamic effects



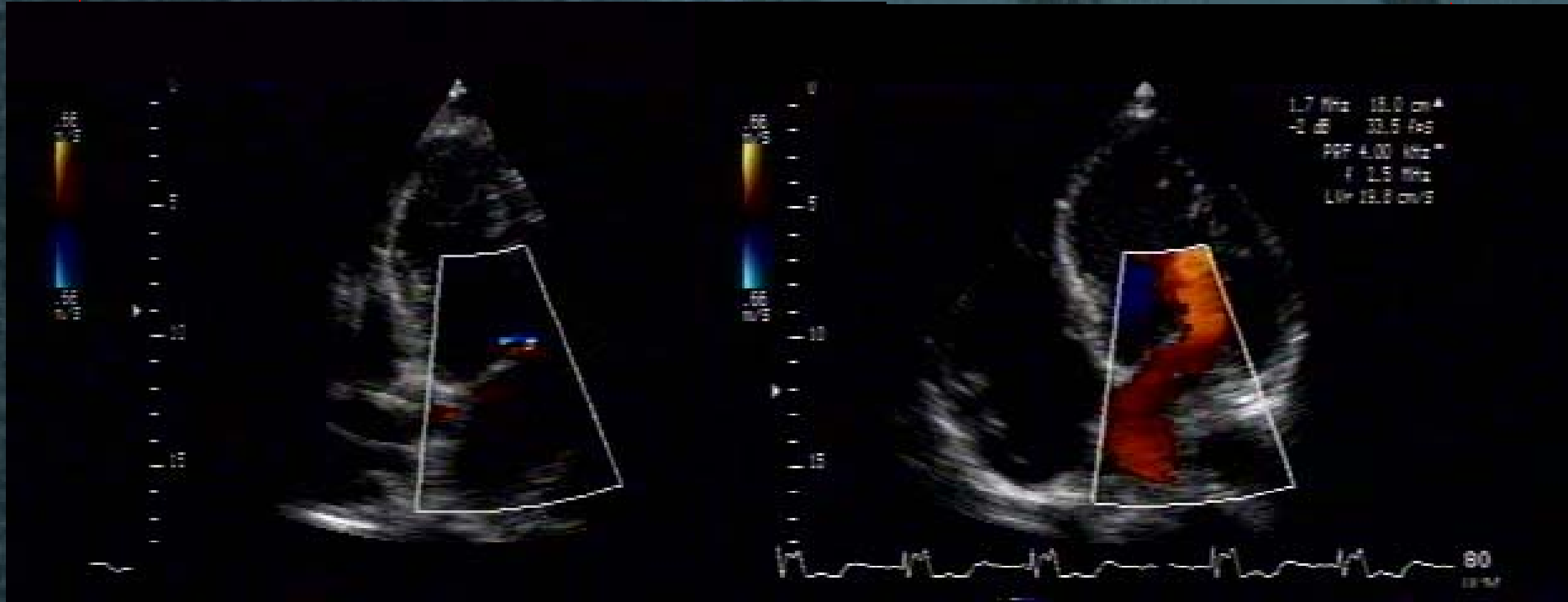
**LATE**

*3-6 months*

- Decrease in LV size
- Increase in LVEF
- Improvements in LV synchrony

*Reverse remodeling*

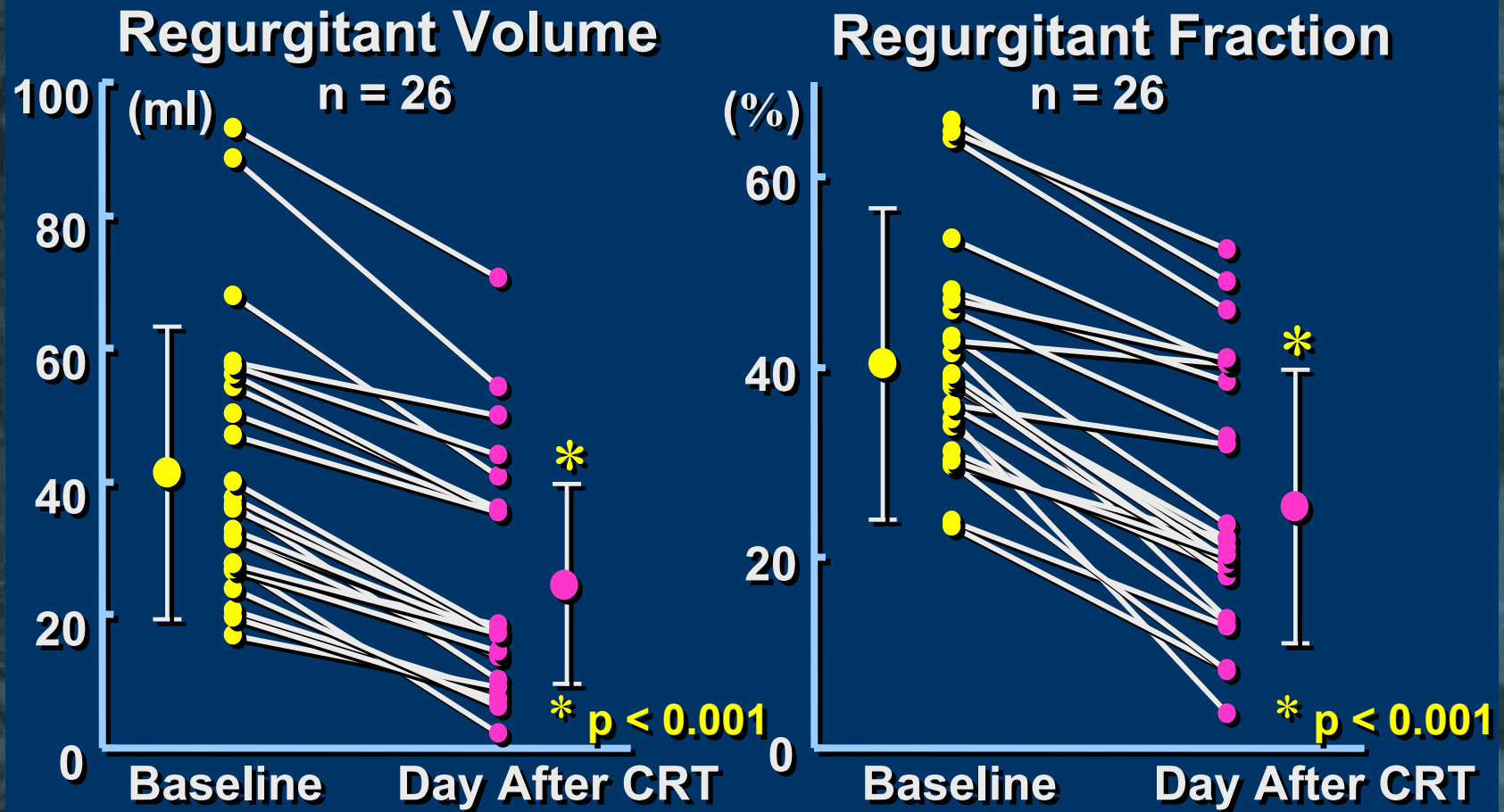
# Acute Reduction in Mitral Regurgitation with Bi-vent Pacing



**Baseline**

**1 day after BiV pacing**

# Acute Reduction In Mitral Regurgitation After CRT



Kanzaki H...Gorcsan et al. J Am Coll Cardiol 2004; Oct 19

# **Strain Imaging**

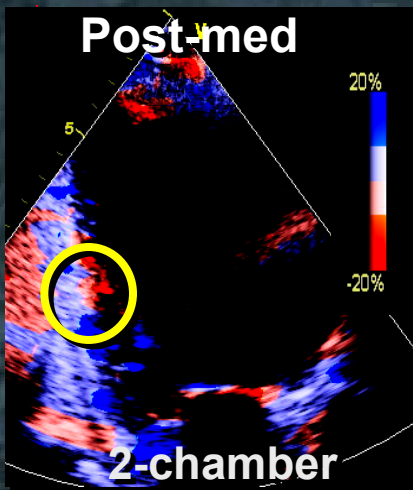
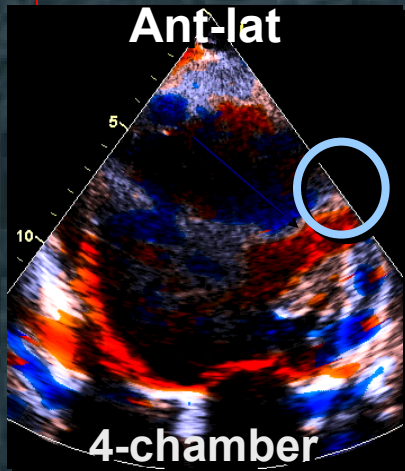
## ***Isolates longitudinal shortening***



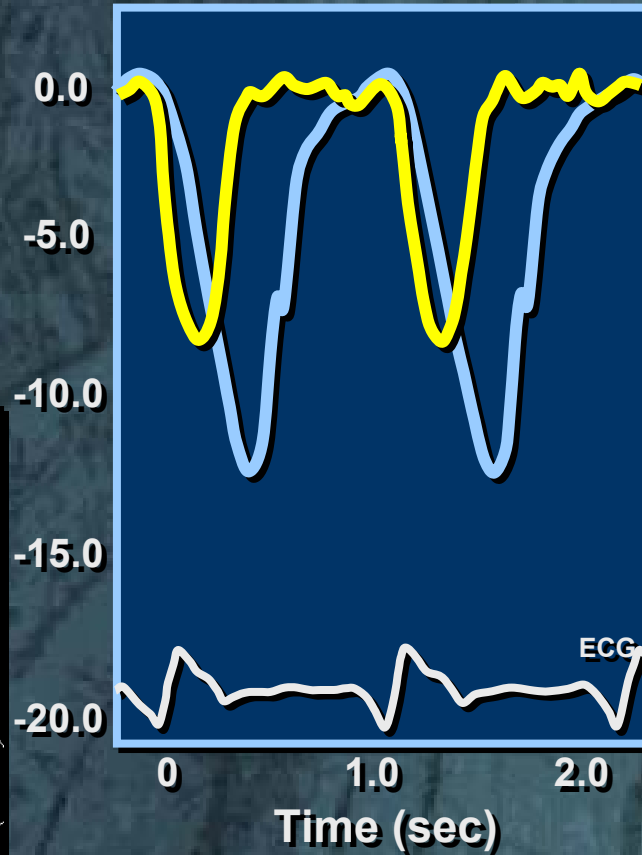
**Strain = Change in length / original length**

*Courtesy of Dr. Joerg Schlegel Toshiba*

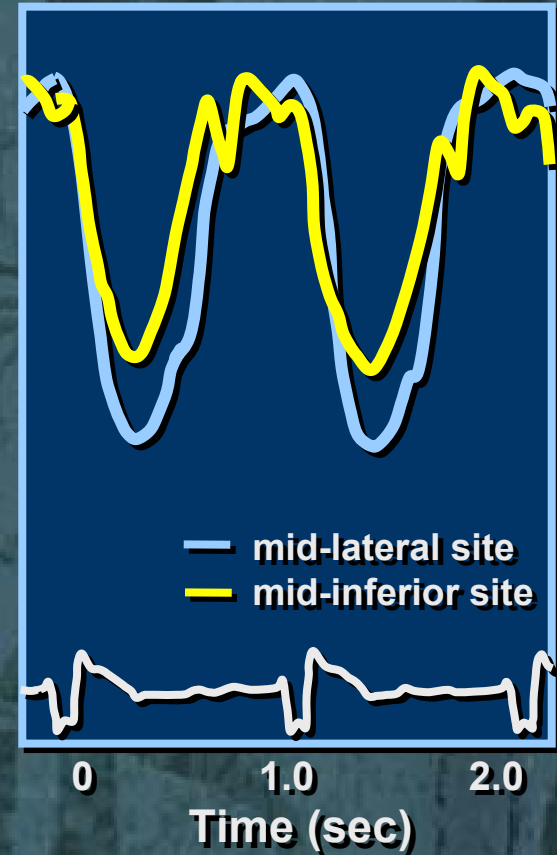
# Papillary Muscle Strain Curves



**Baseline**



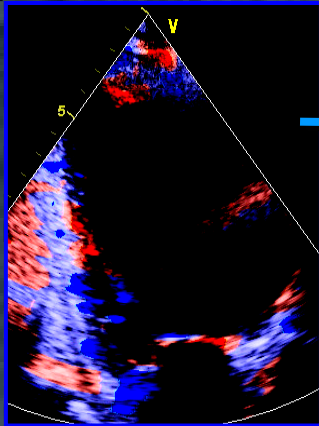
**Immediately After CRT**



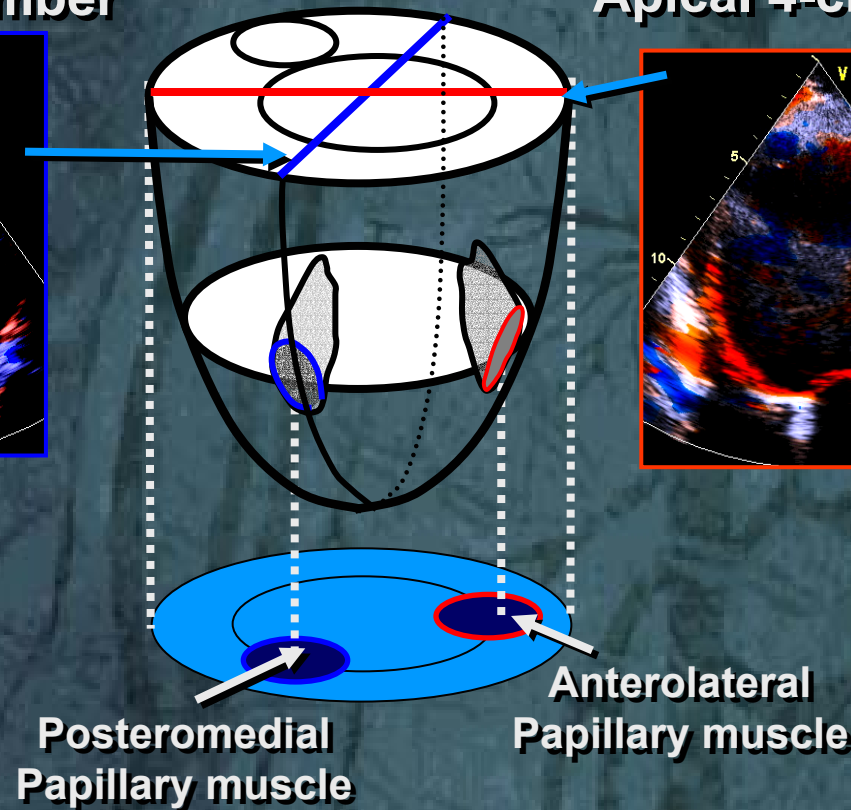
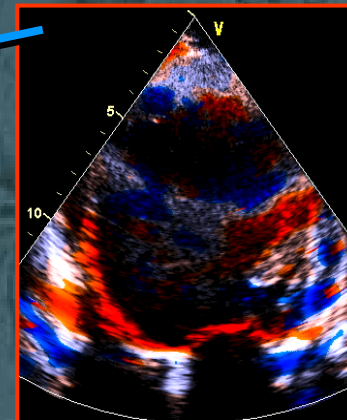
*Kanzaki H & Gorcsan et al. JACC. 2004; Oct 19*

# Mechanical Strain Activation Map “Bulls-eye” projection

Apical 2-chamber



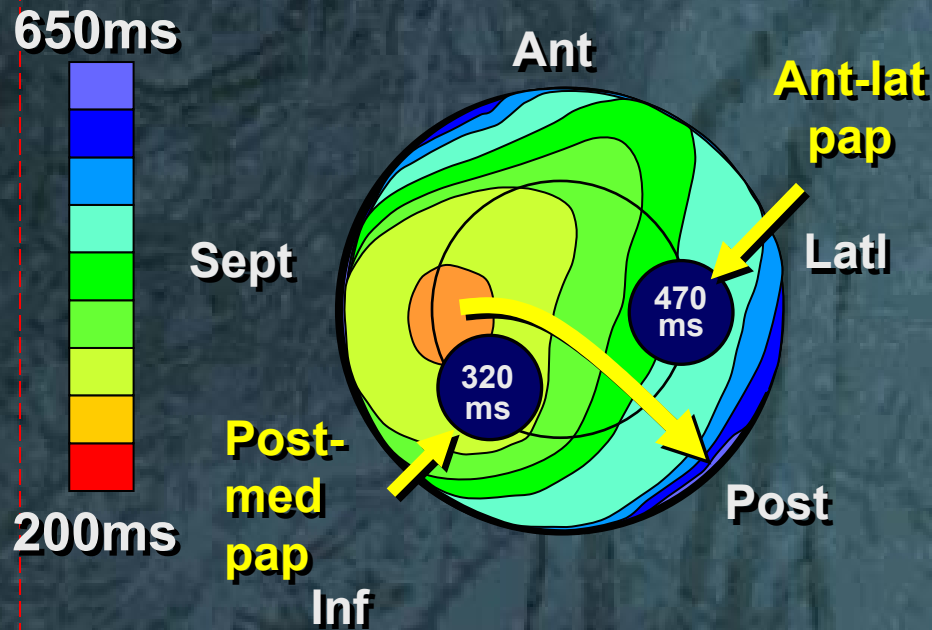
Apical 4-chamber



*Kanzaki H & Gorcsan et al. JACC. 2004; Oct 19*

# Mechanical Strain Activation Map

## *Timing of papillary muscles and MR*



**Baseline: LBBB**  
**Moderate MR**

*Kanzaki H, Gorcsan et al. J Am Coll Cardiol 2004; Oct 19*

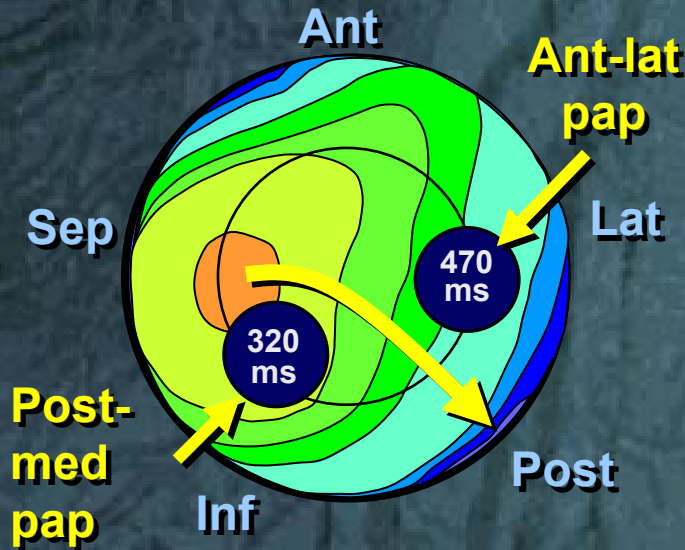
# Mechanical Strain Activation Map

## Timing of papillary muscles and MR

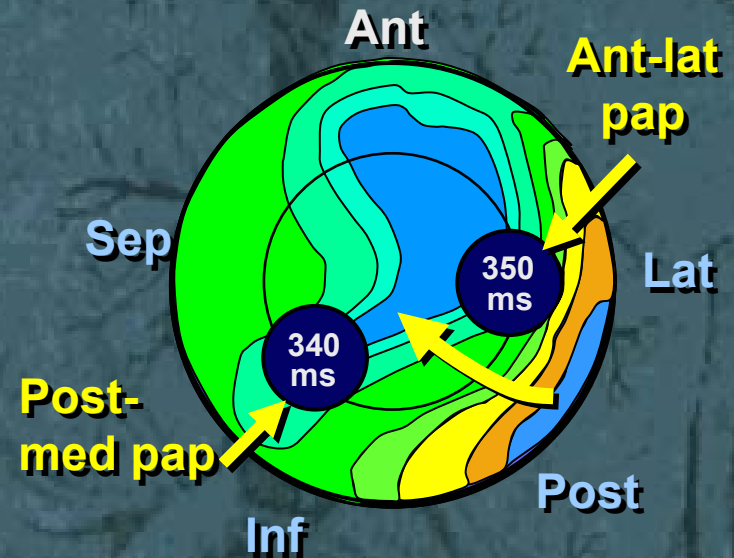
650ms



200ms

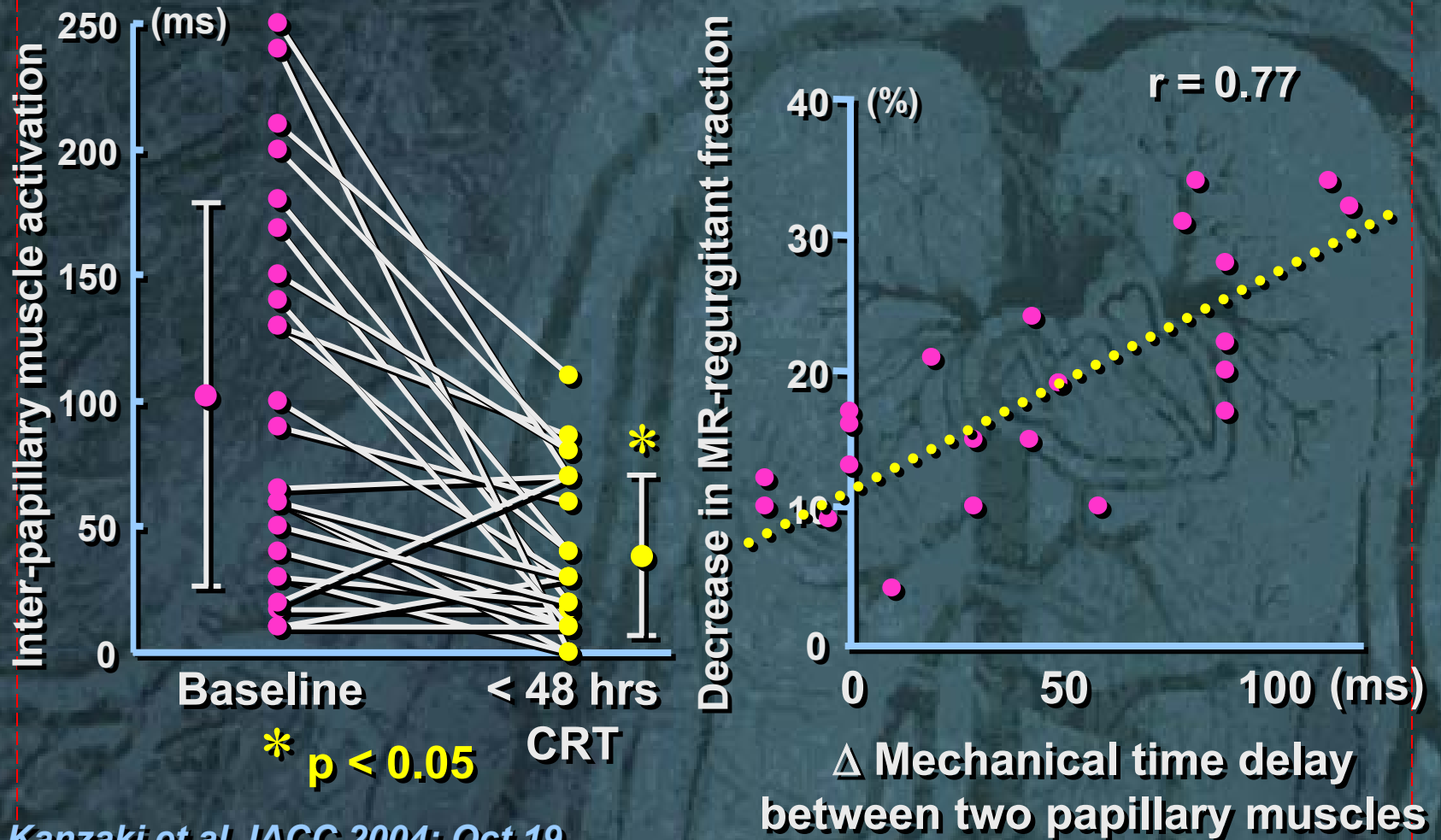


**Baseline: LBBB**  
**Moderate MR**



**Post CRT**  
**Trace MR**

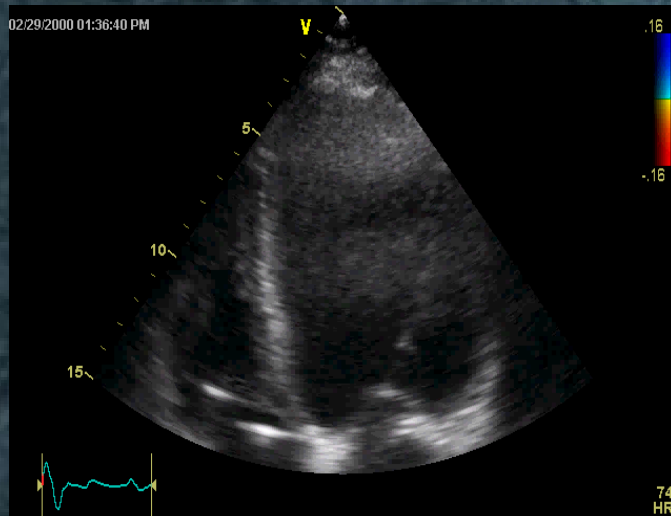
# Decrease in Mitral Regurgitation Papillary muscle dysfunction



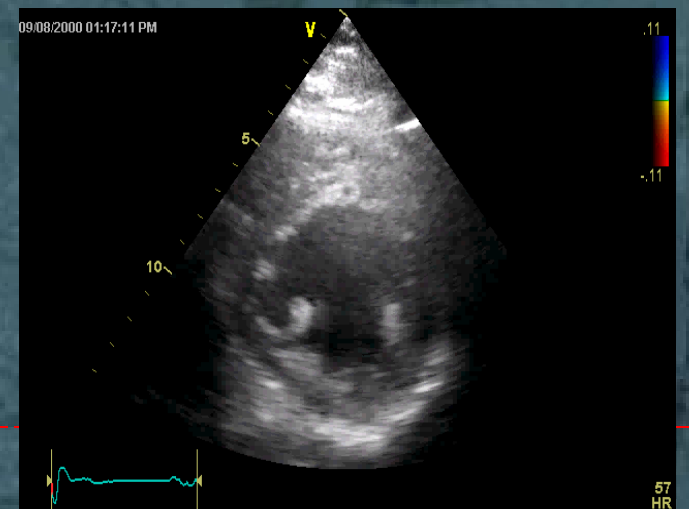
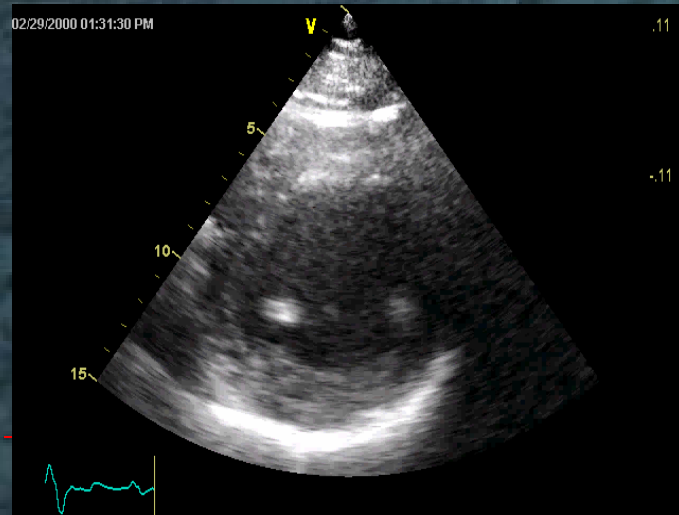
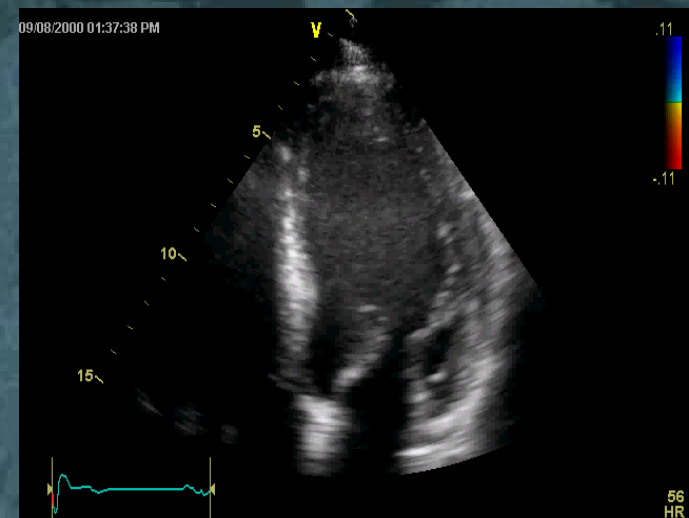
Kanzaki et al. JACC 2004; Oct 19

# Later Effects of CRT on LV Function

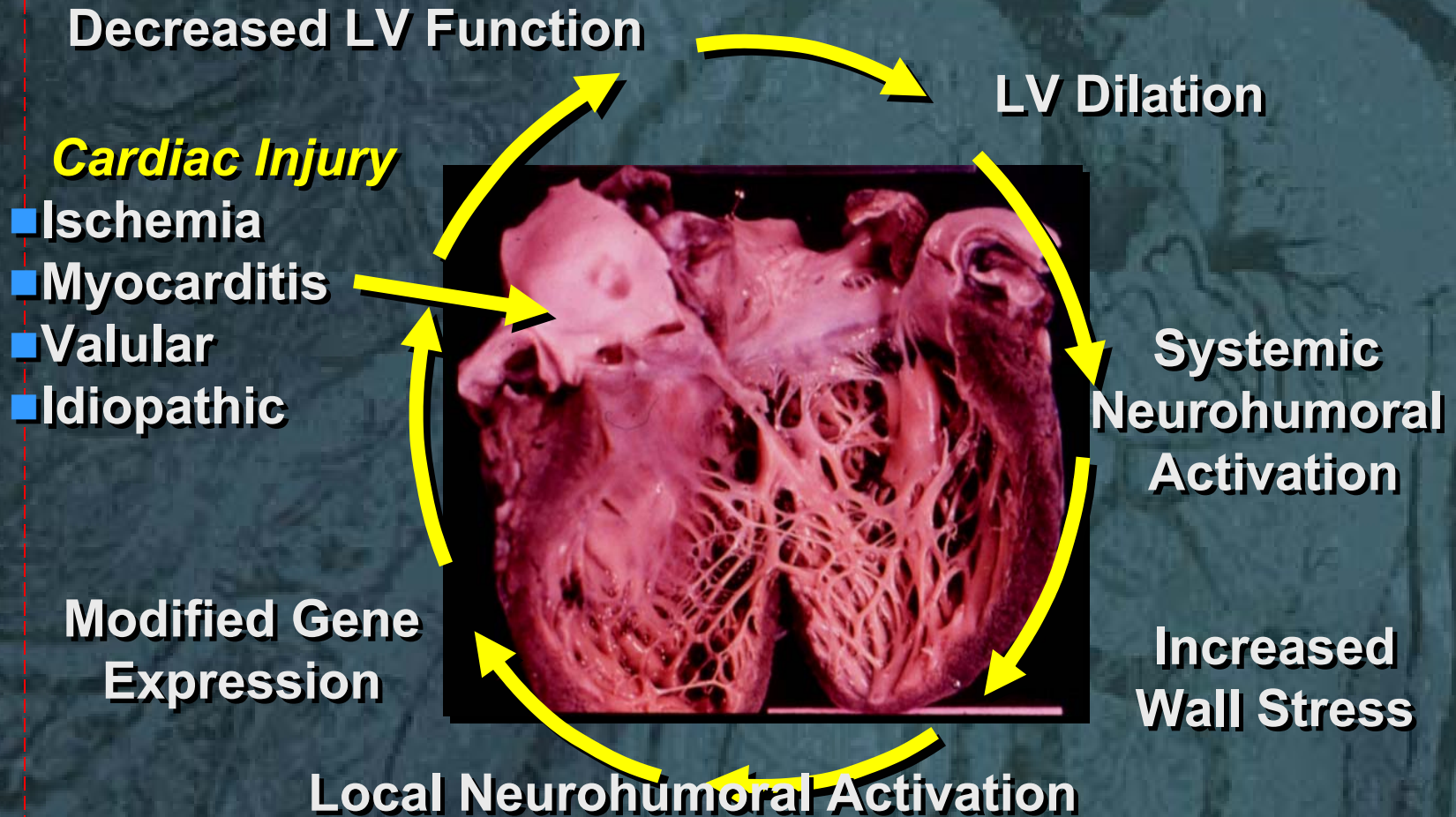
Baseline



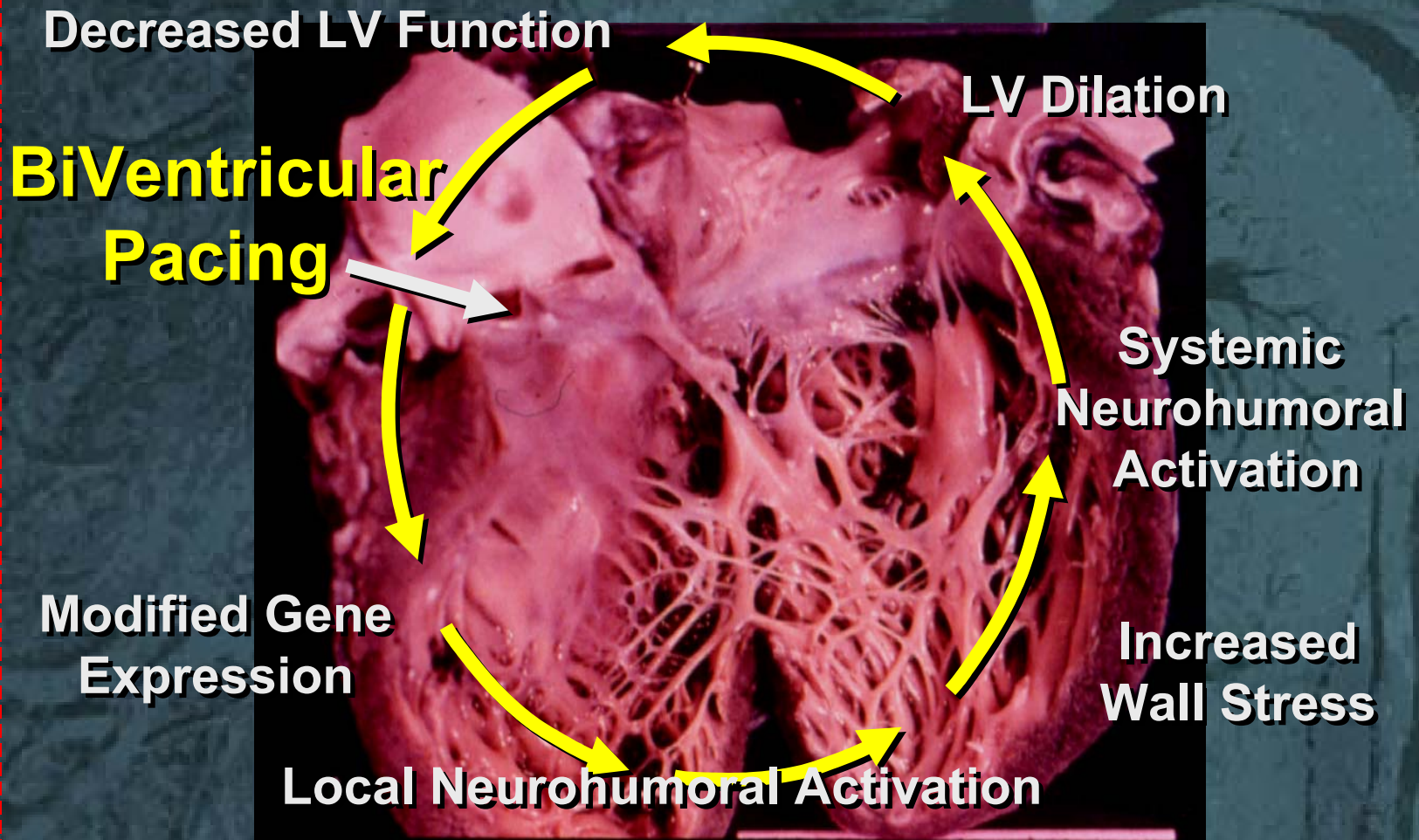
6 mos after



# Left Ventricular Remodeling in Heart Failure

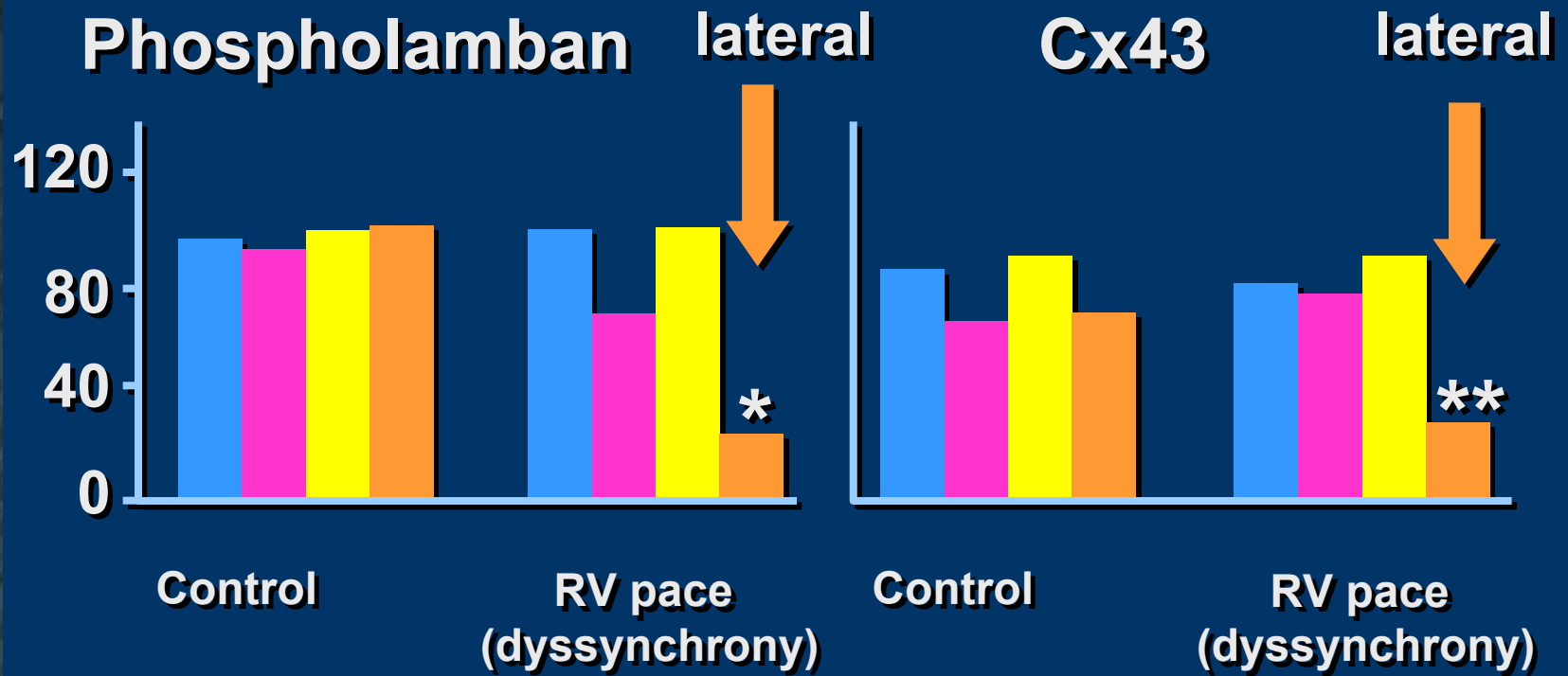


# Reverse Remodeling



# Dyssynchrony Alters Myocardial Gene Expression

## *Rapid pacing heart failure model*

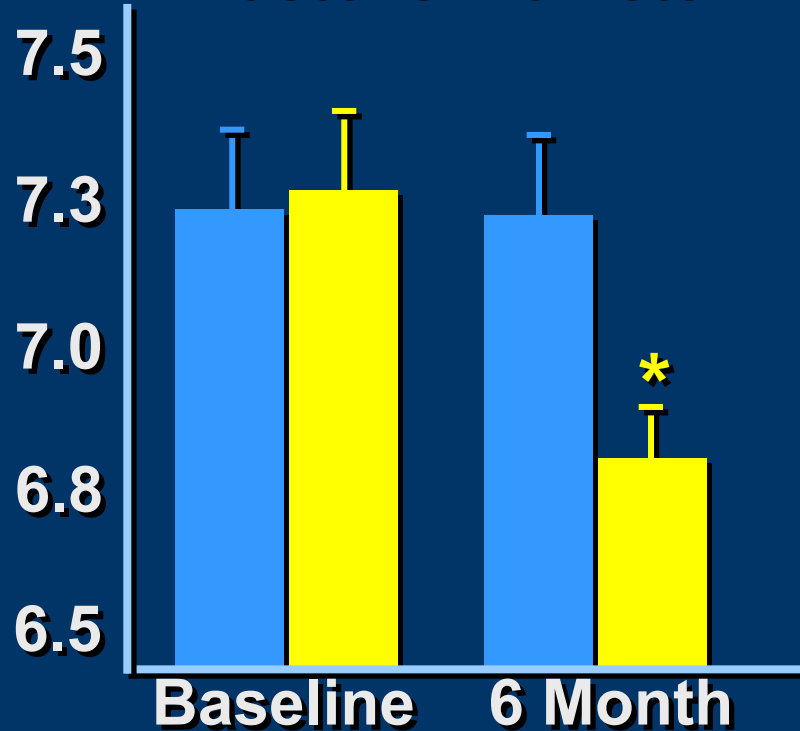


Spragg & Kass et al. *Circulation* 2003;108:929

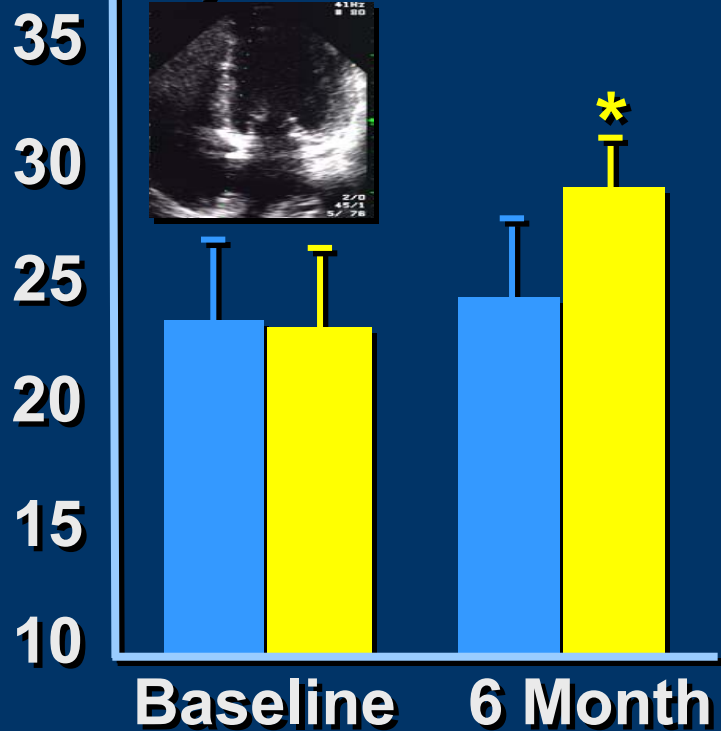
# LV Size and Function Improved by Biventricular Pacing

■ Control ■ Biventricular Pacing

cm Diastolic Diameter



% Ejection Fraction

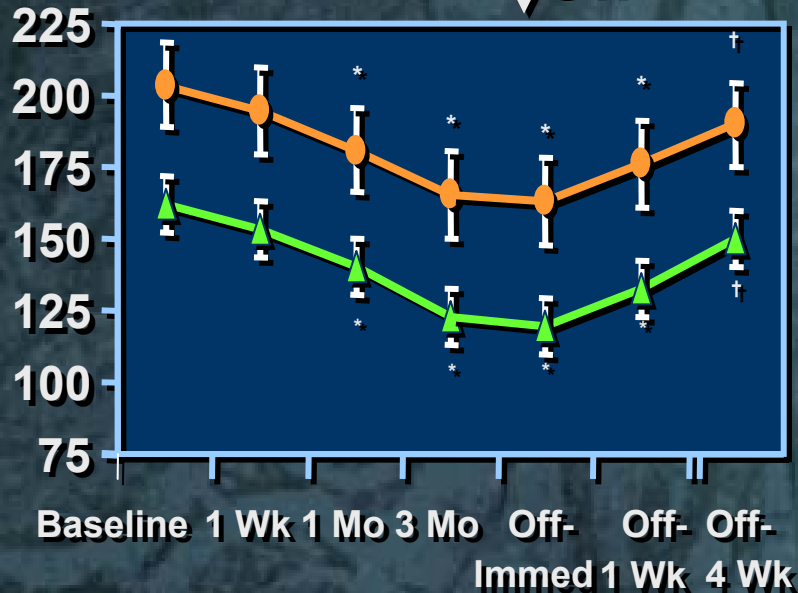


\*p < 0.05 vs. Control

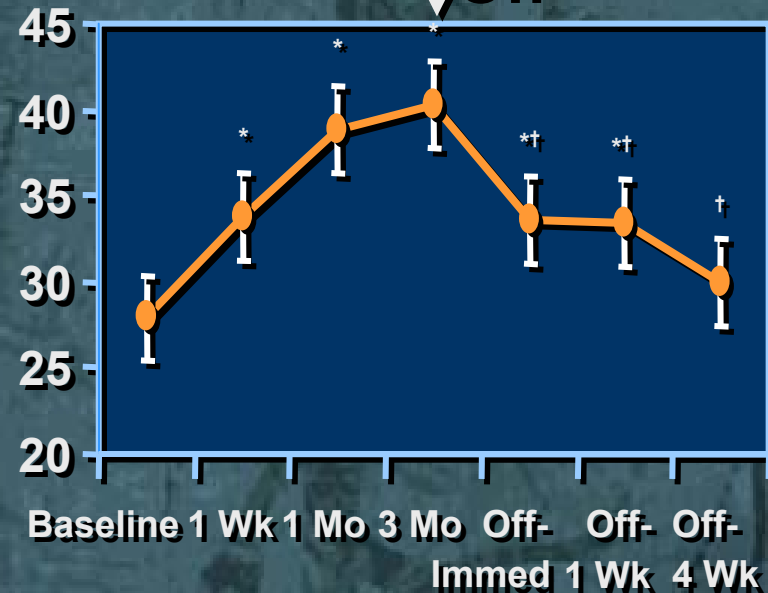
Abraham et al, N Eng J Med 2002;24:1845.

# Reverse Remodeling with Biventricular Pacing Therapy

LV Volumes  
 ↓Off

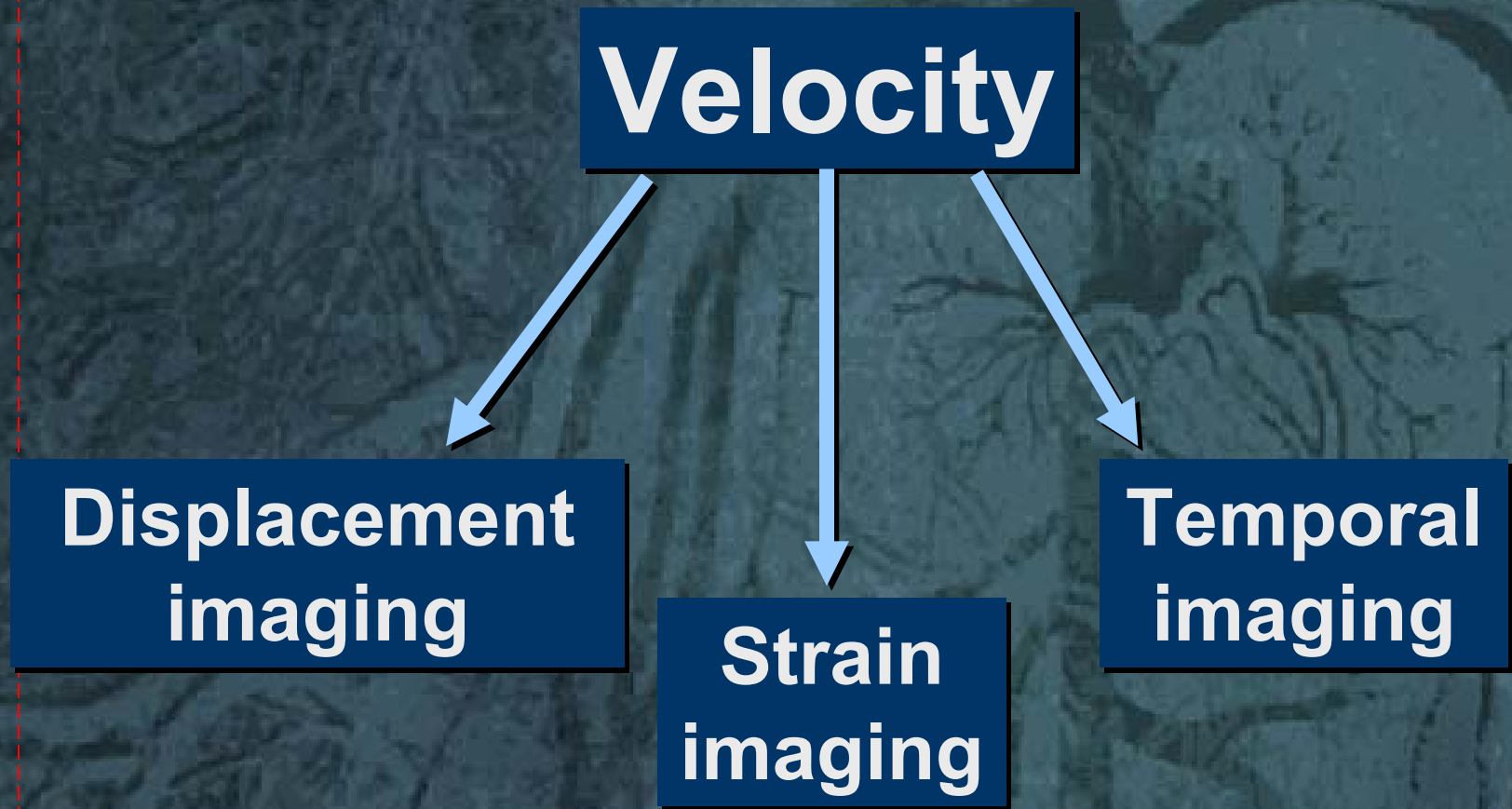


Ejection Fraction  
 ↓Off



Yu et al. *Circulation*. 2002;105:438-445.

# Tissue Doppler Modalities



# Myofiber Orientation

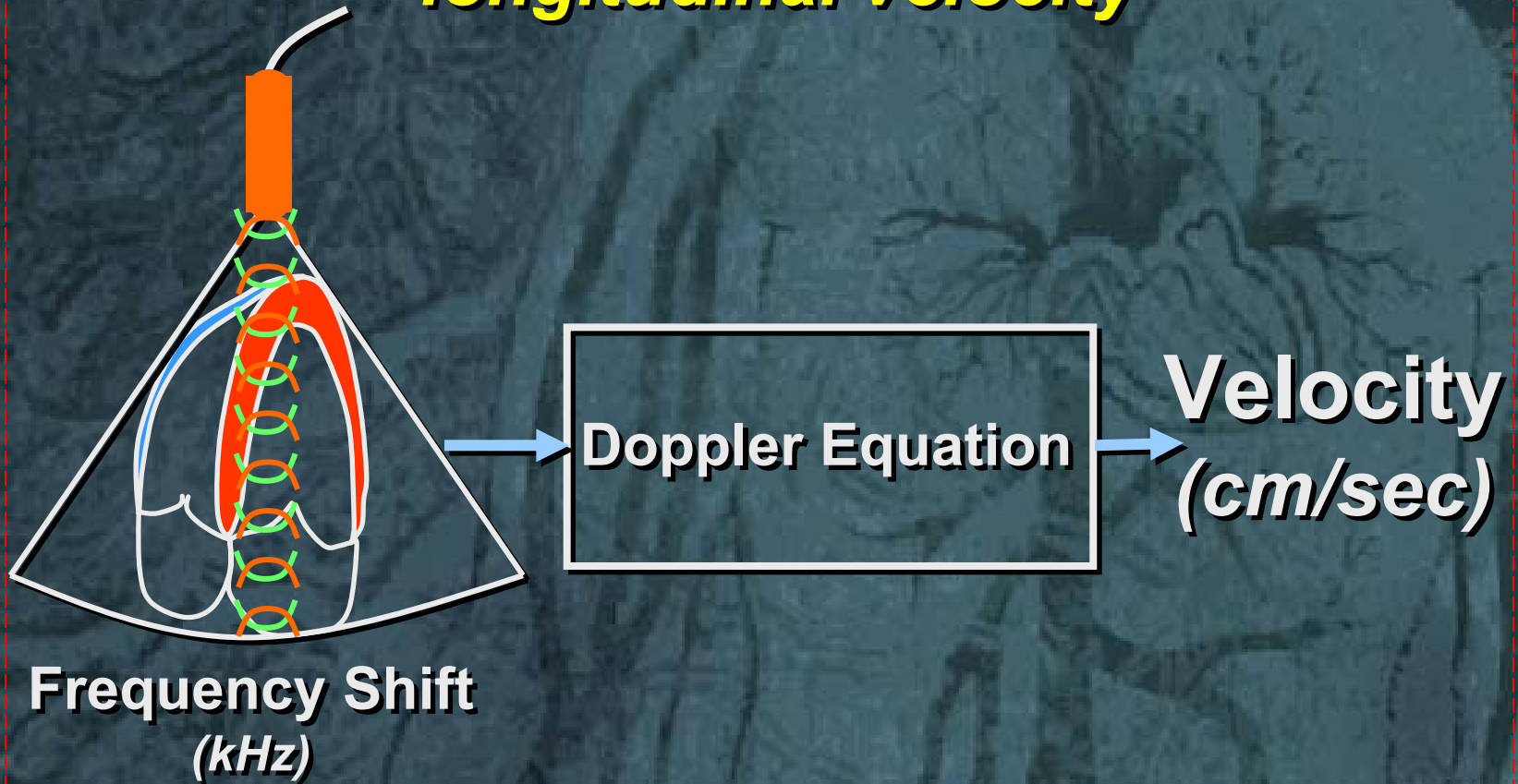
## *Longitudinal dynamics*

Longitudinal

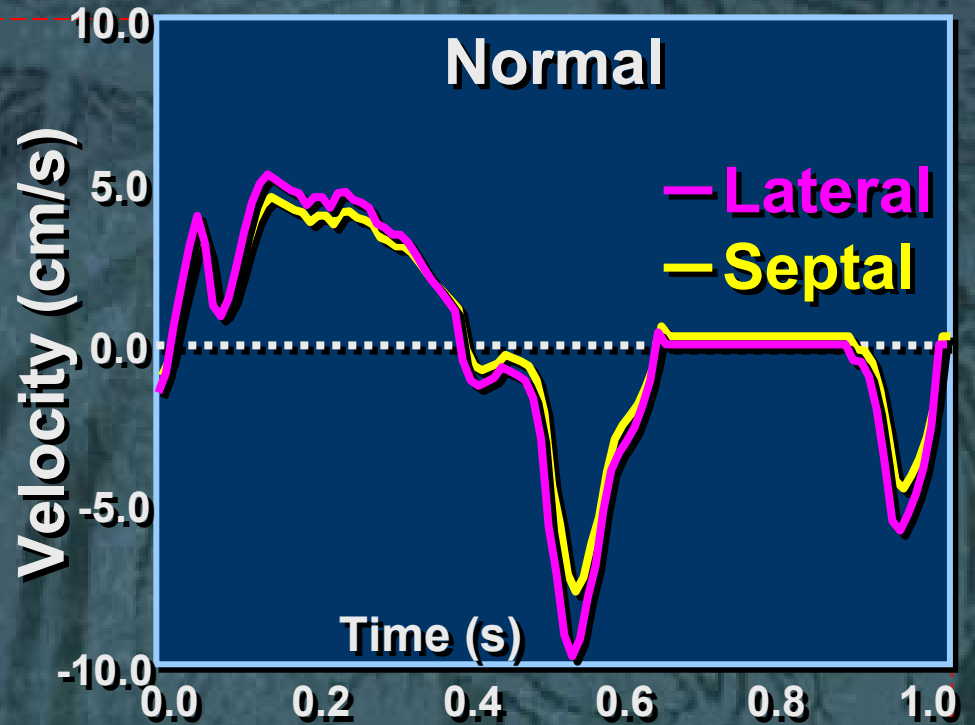
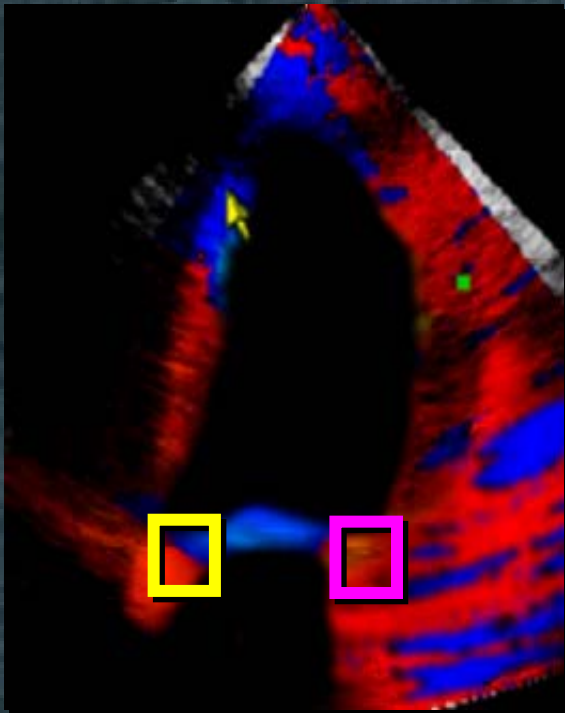


# Tissue Doppler Velocity

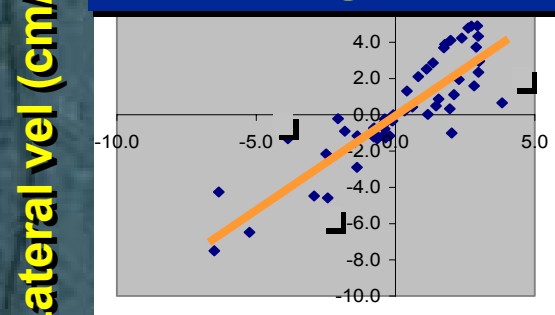
*Favorable angle of incidence for longitudinal velocity*



# Normal synchrony



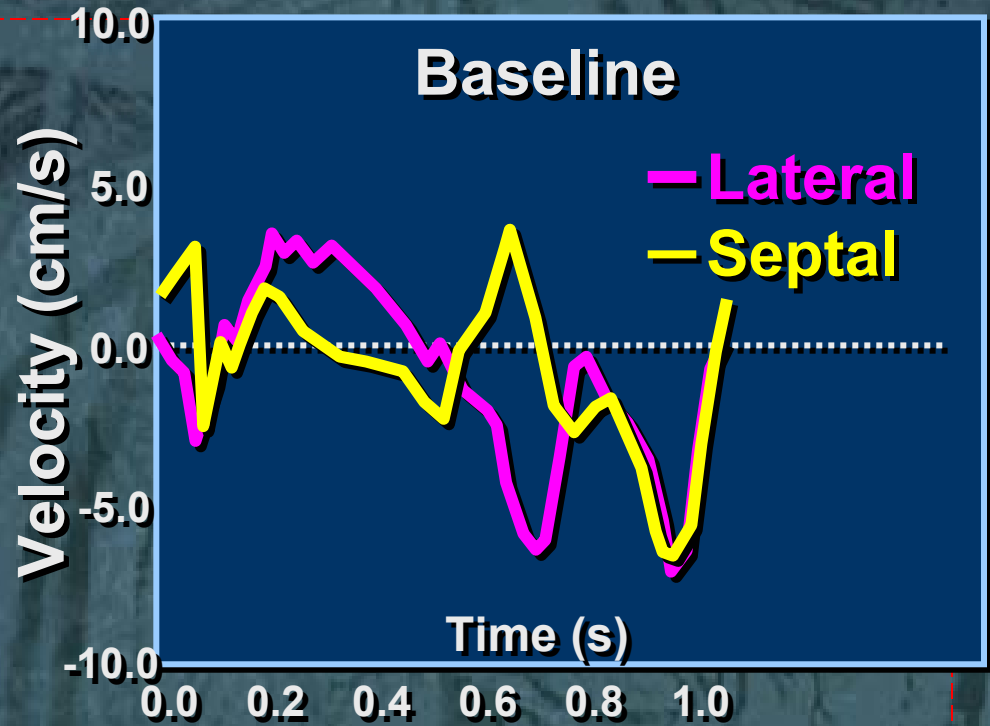
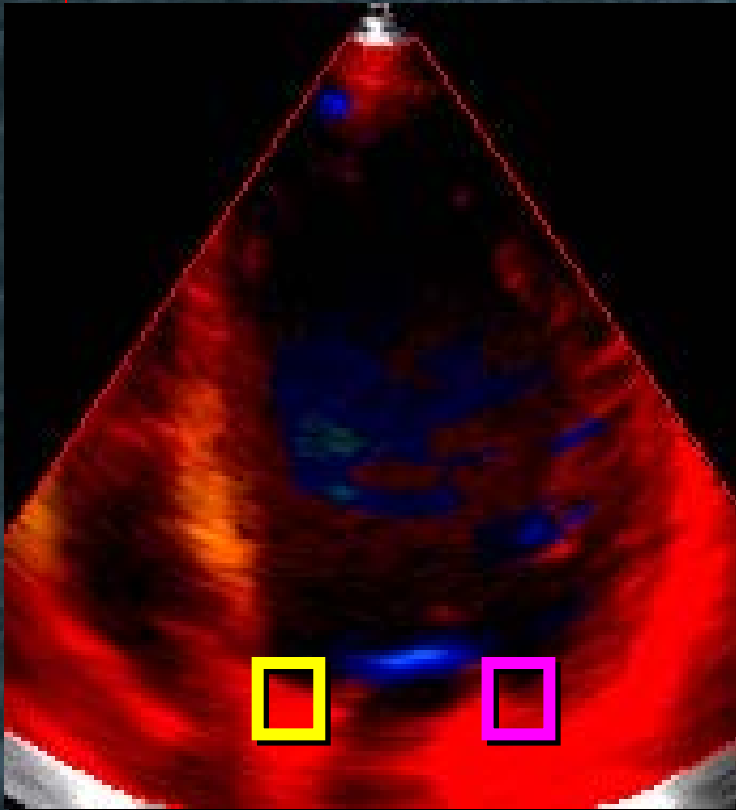
## Linear regression



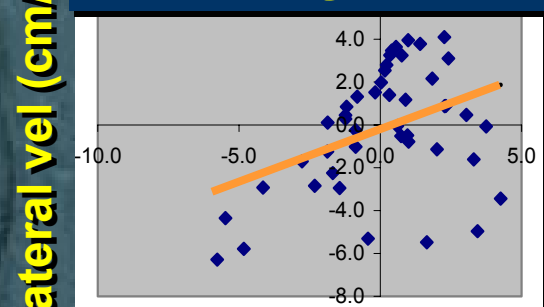
**$r = 0.92$**

*Kanzaki & Gorcsan et al. AJC.  
Sept 15, 2003*

# Cardiomyopathy with LBBB



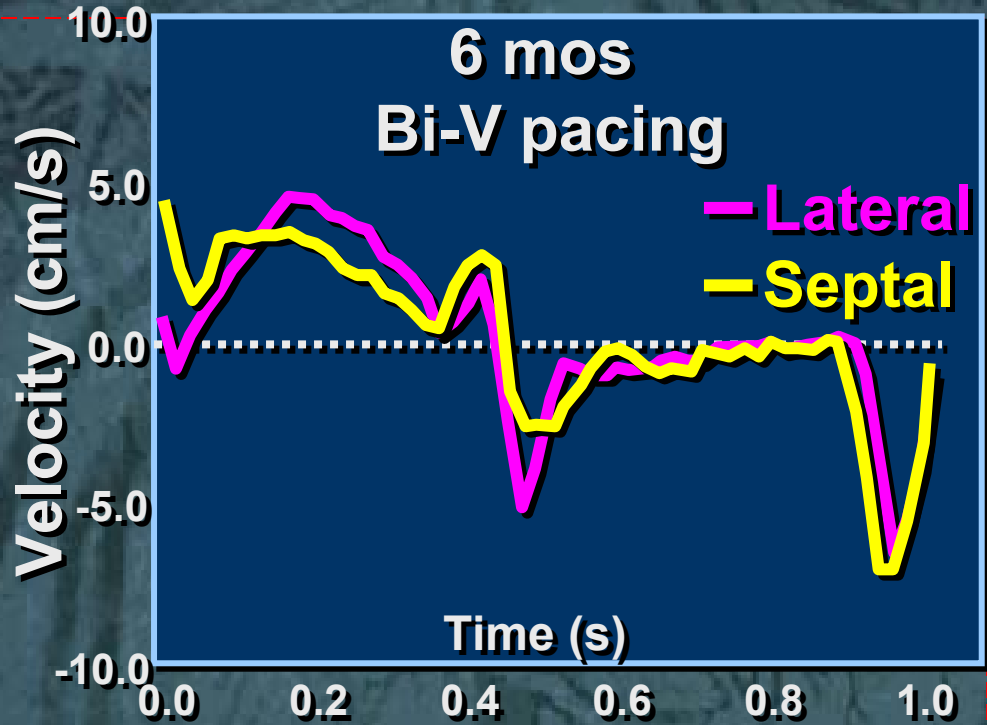
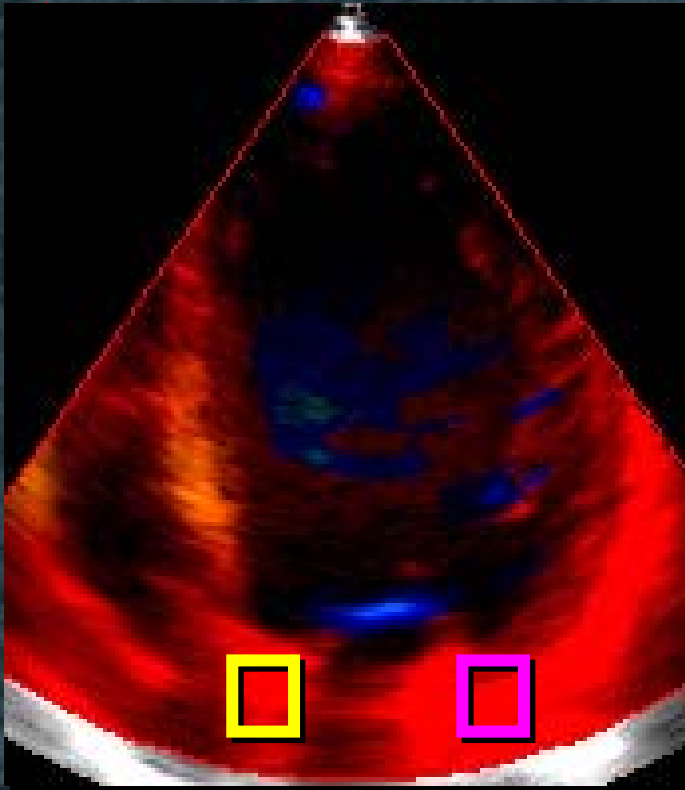
## Linear regression



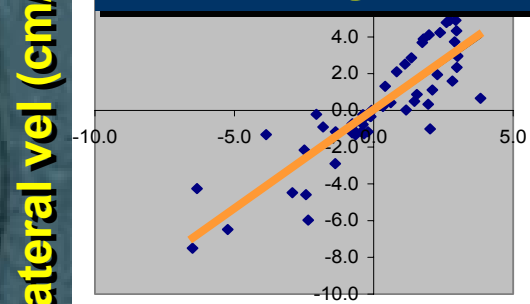
**$r = 0.40$**

*Kanzaki & Gorcsan et al. AJC.  
Sept 15, 2003*

# Cardiomyopathy with LBBB



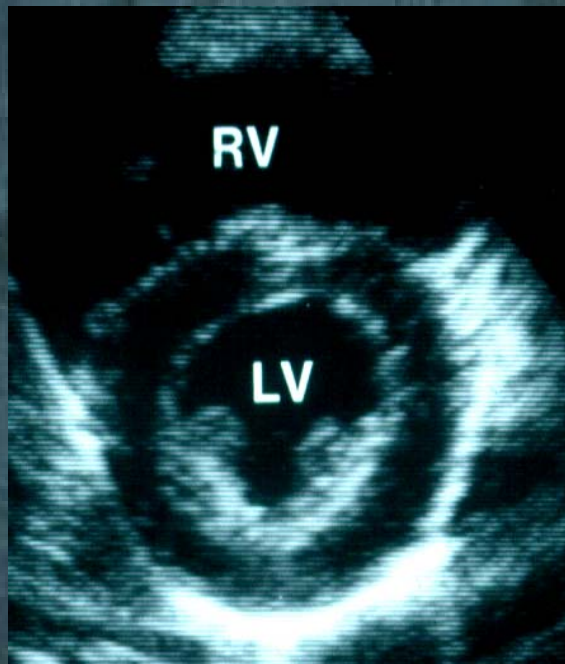
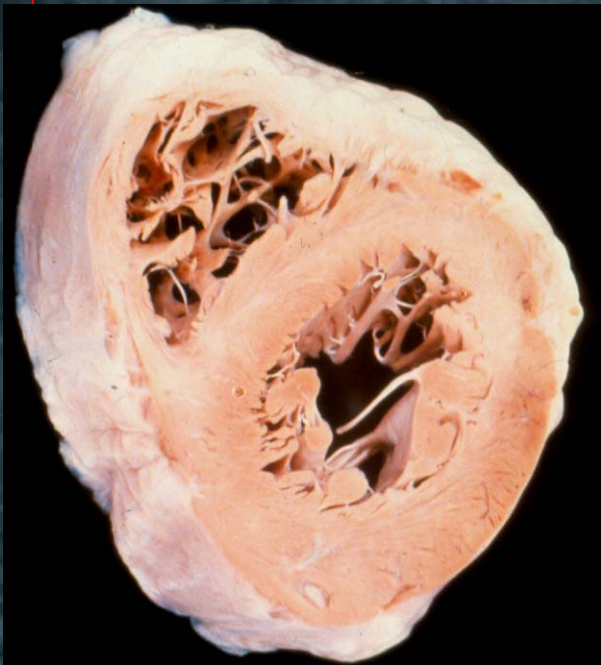
## Linear regression



$r = 0.87$

Kanzaki & Gorcsan et al. *AJC*.  
Sept 15, 2003

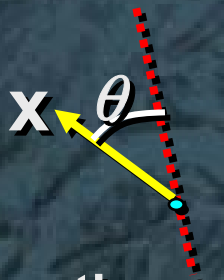
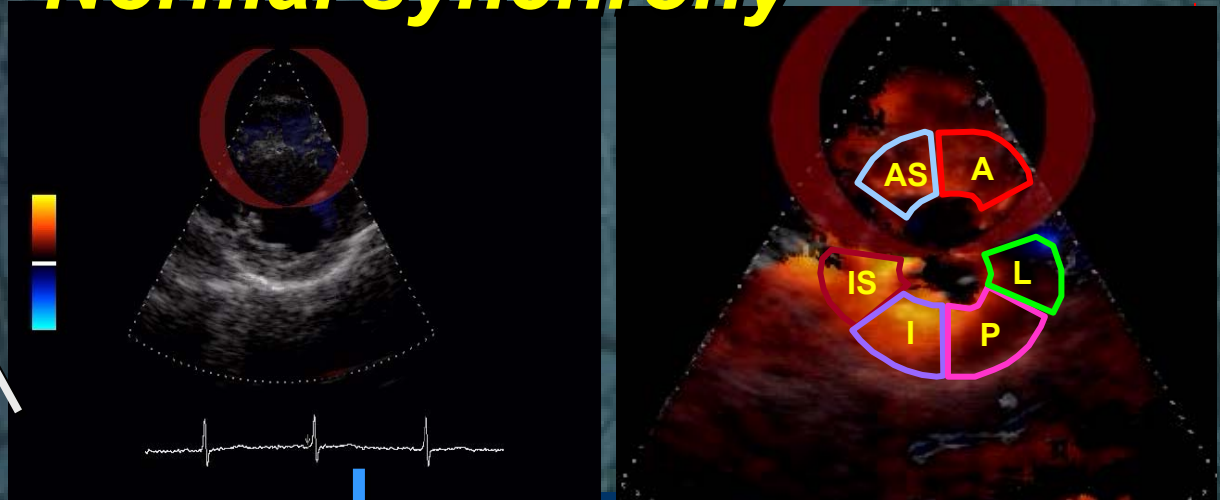
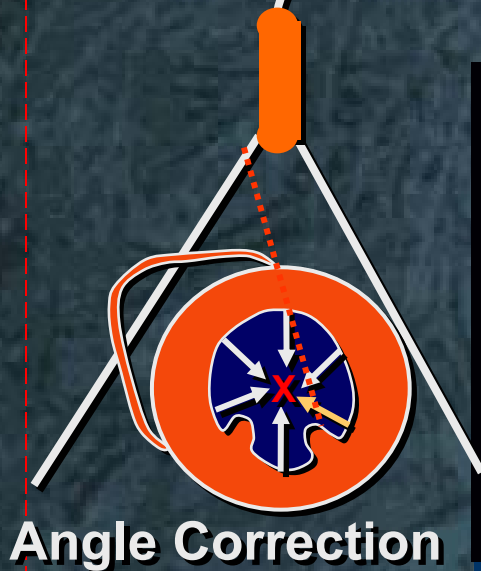
# Radial Shortening: Major vector of LV contraction



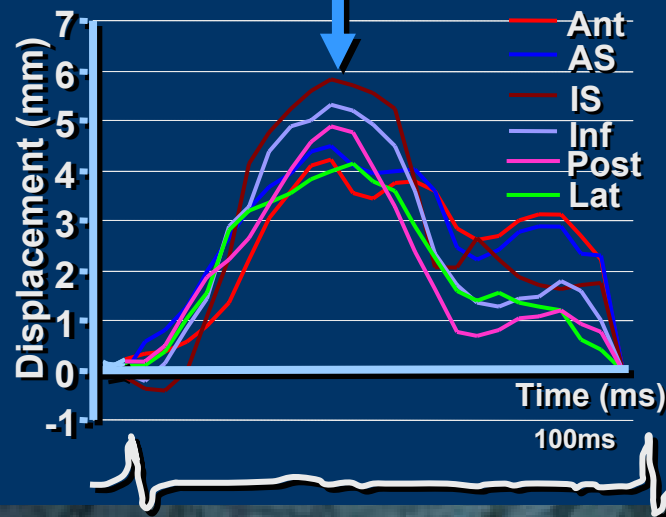
*Anatomic and echo courtesy Kisslo, Adams & Leech: Echo in Context*

# Tissue Displacement Imaging

## Normal synchrony

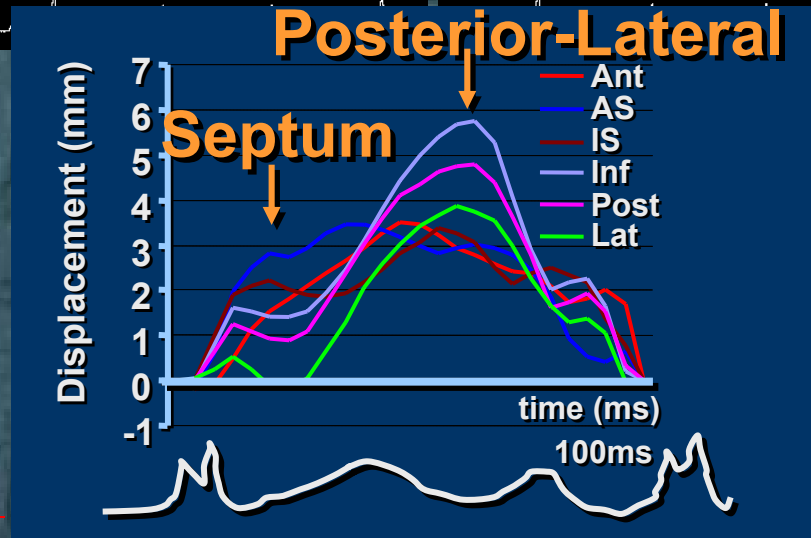
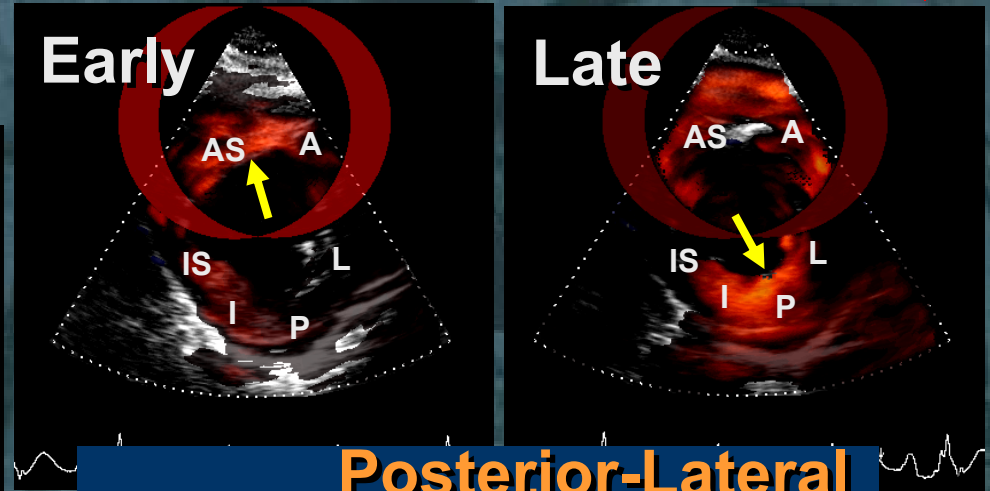
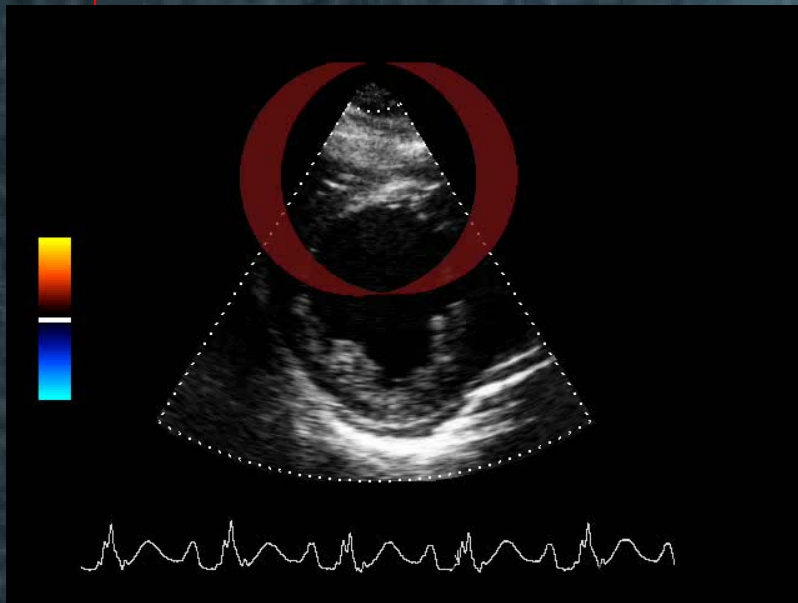


$V \text{ motion} = V \text{ beam} / \cos$



Sade & Gorcsan et al.  
AJC. 2004;94:514-8

# Regional Time-Displacement Left Bundle Branch Block



Sade & Gorcsan et al.  
AJC. 2004;94:514-8

