Acute Myocardial Infarction/Complications

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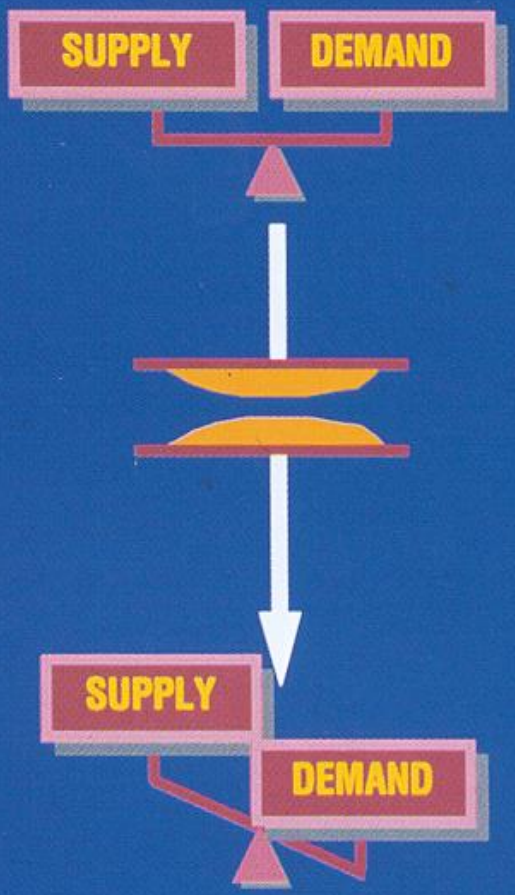
Roles of Echocardiography in Acute Myocardial Infarction

- Diagnosis/location/extent of MI
- Prognosis
- Assessing complications

The Ischemic Cascade



Metabolic effect (lactate release)

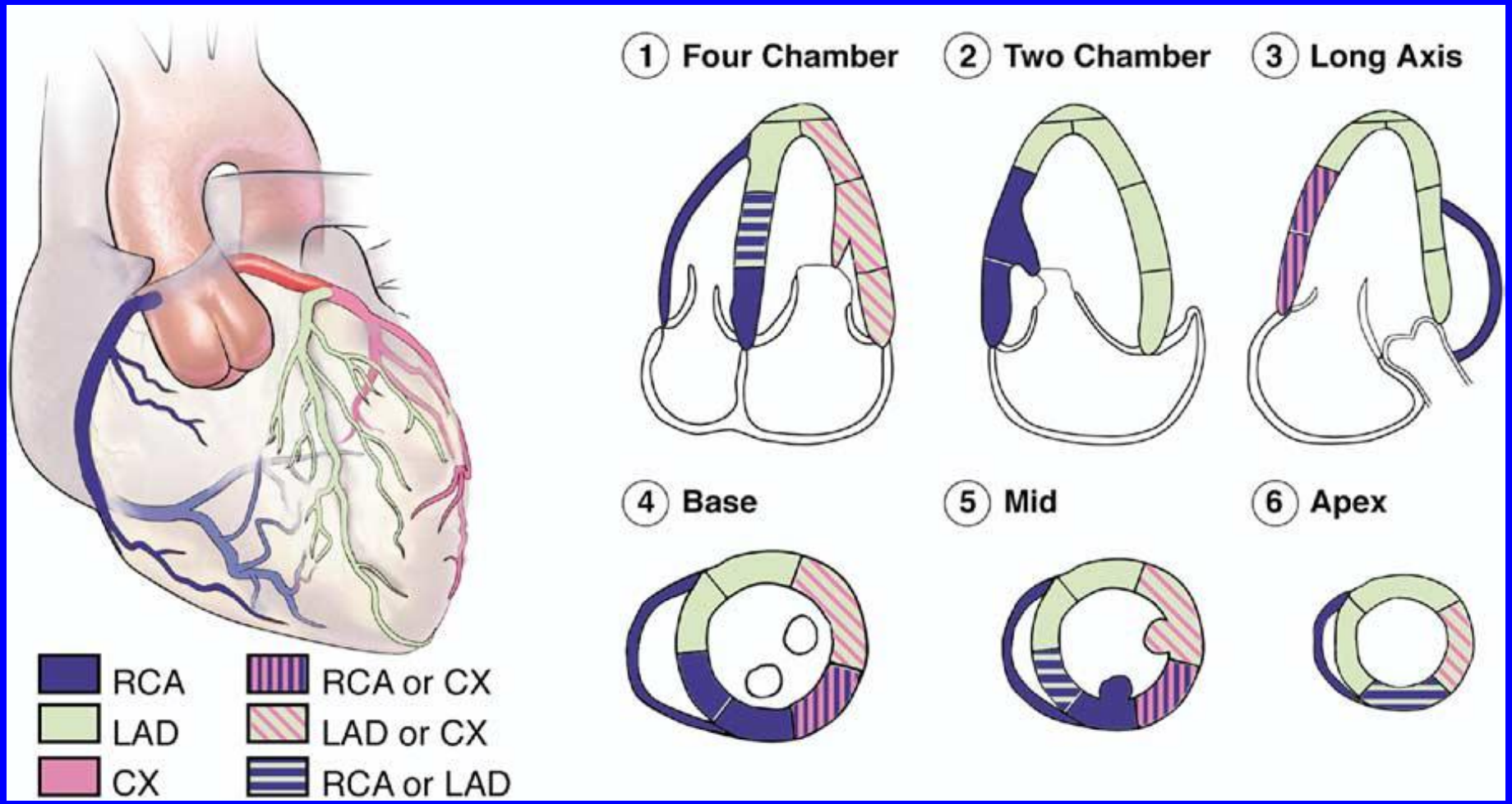
Regional diastolic dysfunction

Regional impairment of contractility

Increased filling pressures

ECG changes

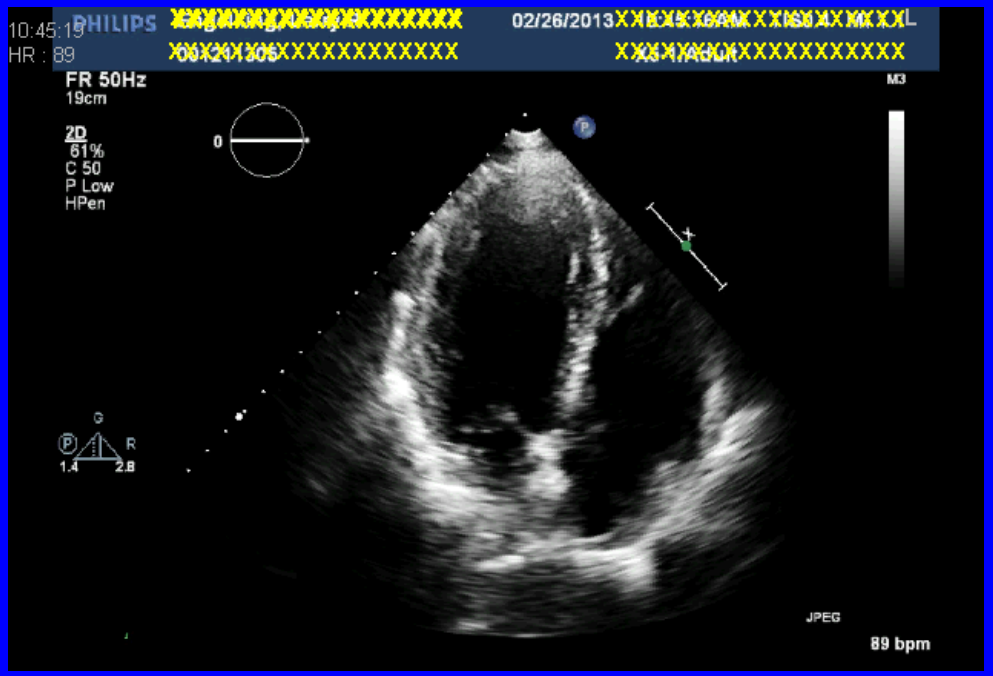
Angina

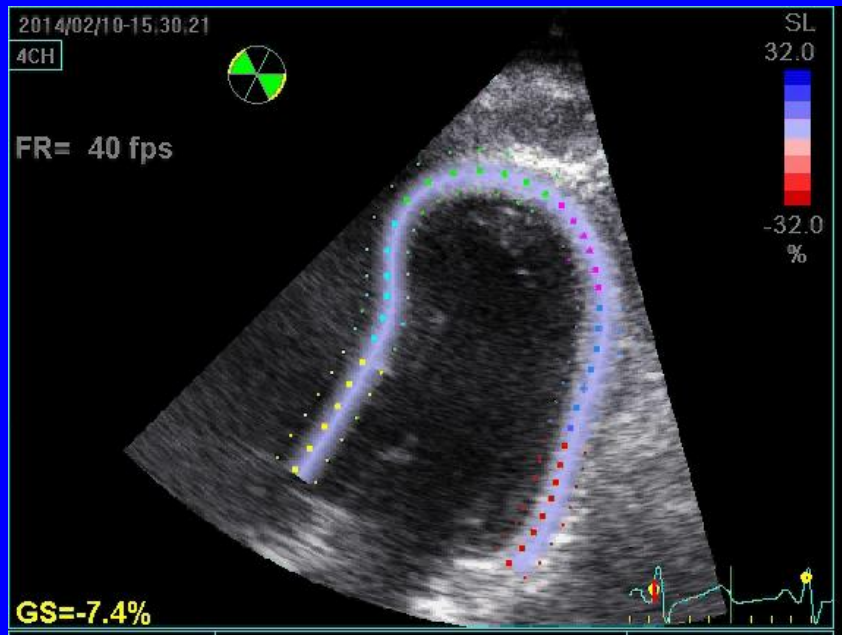


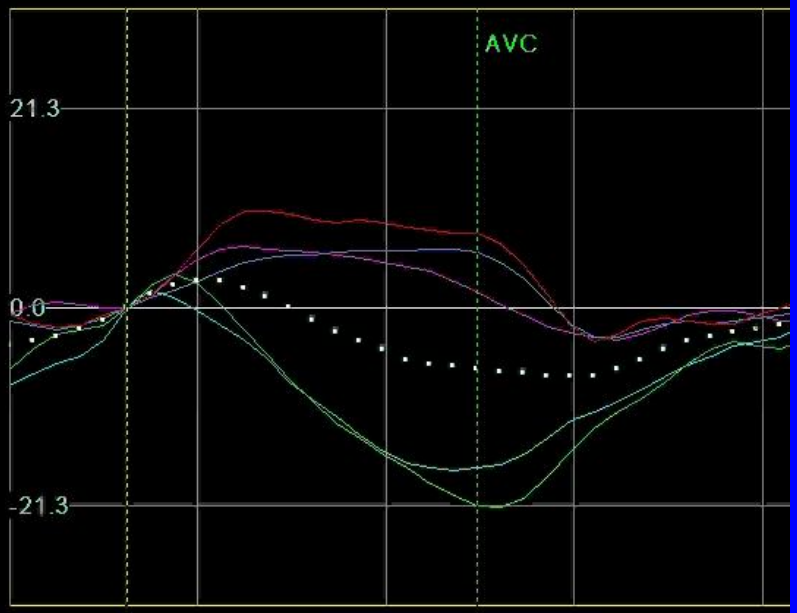
Lang RM et al. J Am Soc Echocardiogr 2005:18:1440.

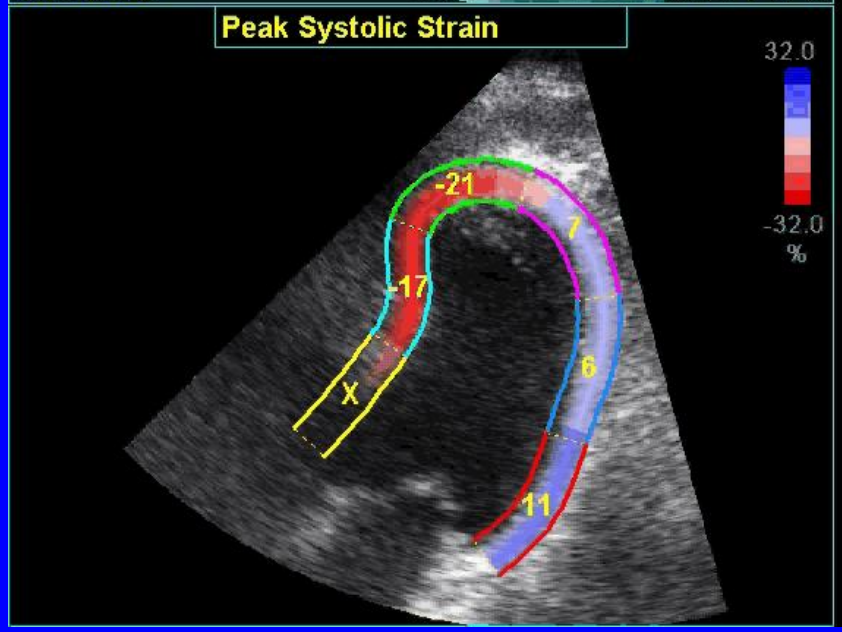
Diagnostic Role in Acute MI

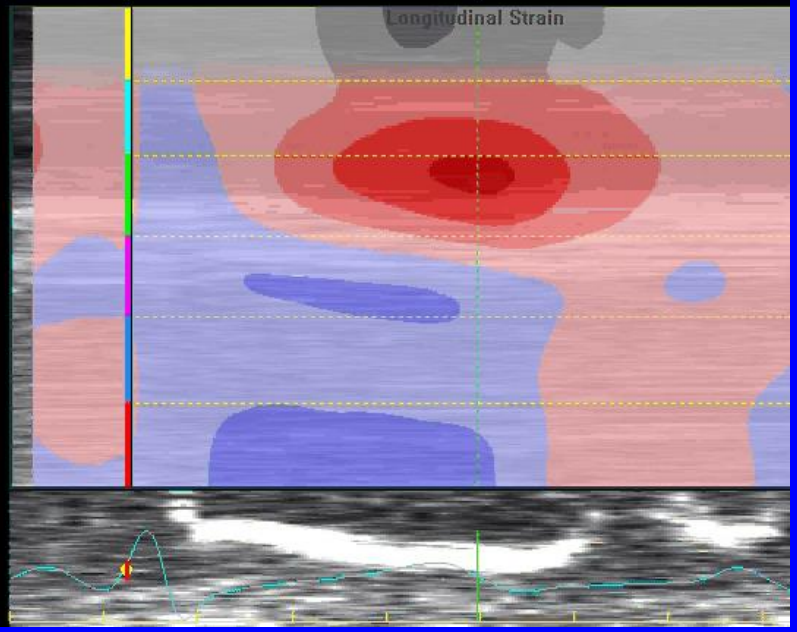
- Regional wall motion abnormality
  - Occurs within 5-10 beats of acute coronary ligation
  - Rate and amplitude of endocardial excursion decreased
  - Reduced wall thickening or wall thinning

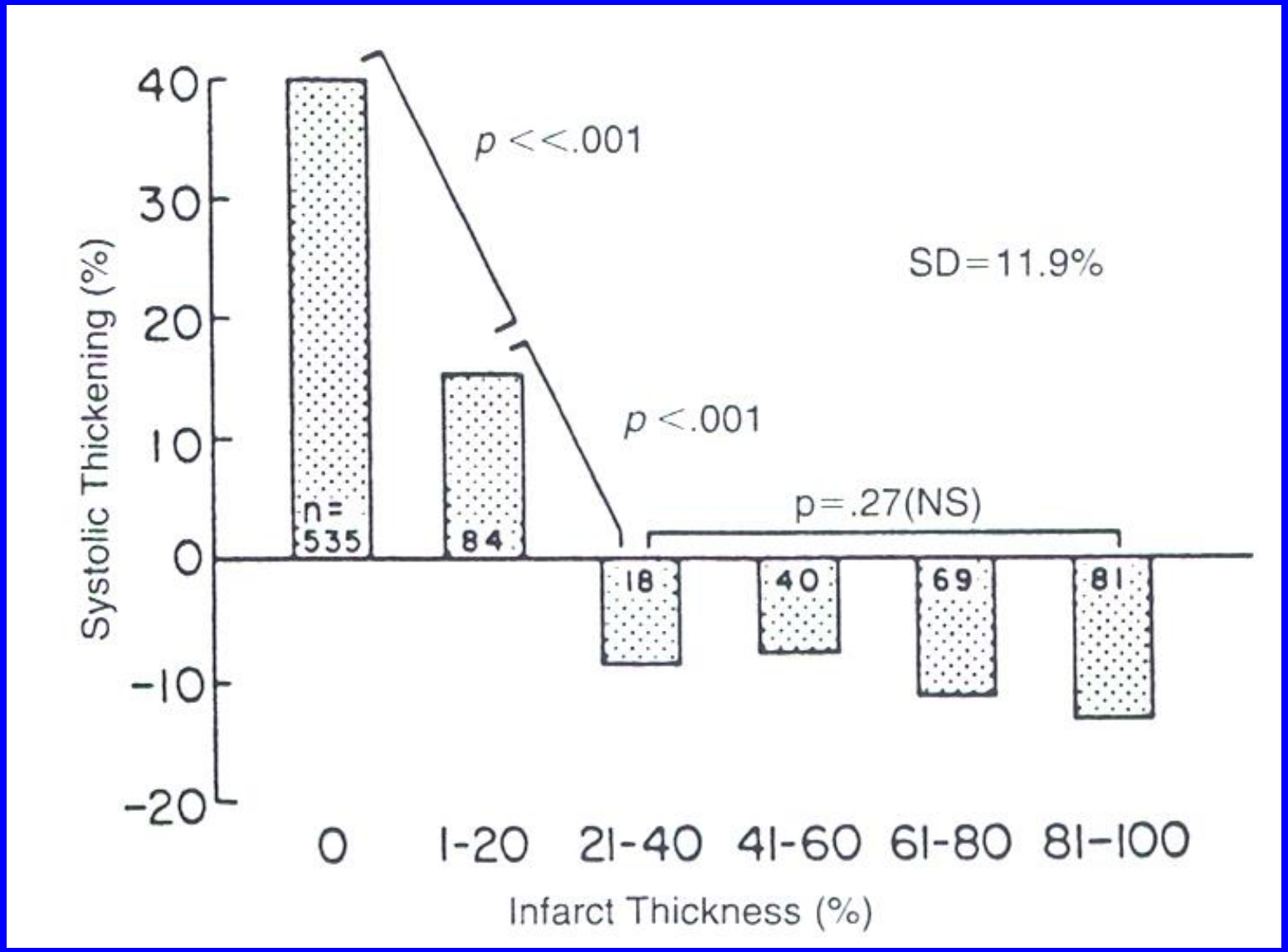



2014/02/10-15:30:21
4CH
FR= 40 fps
SL
32.0
-32.0
%
GS=-7.4%


AVC
21.3
0.0
-21.3


Peak Systolic Strain
32.0
-32.0
%
-21
7
-17
6
X
11


Longitudinal Strain



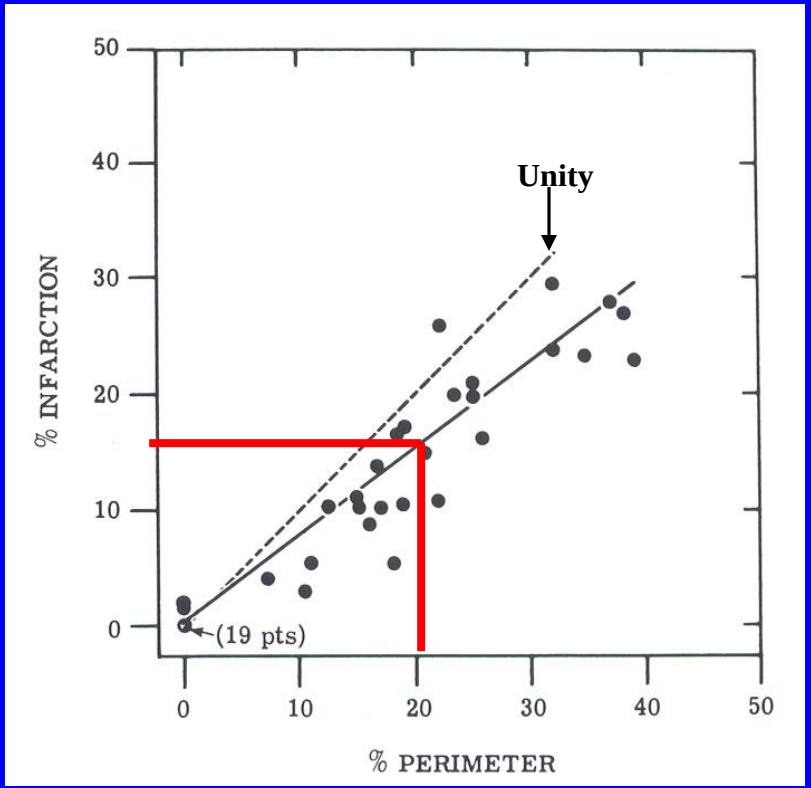
Lieberman AN et al. Circulation 1981;63:739.

Diagnostic Role in Acute MI

- Presence of a Wall Motion Abnormality
  - Transmural MI
    - Sensitivity 89-100%
    - Segmental abnormalities
      - Akinesis/dyskinesis 72%
      - Severe hypokinesis 28%
    - Normal WM virtually excludes transmural MI
  - Nontransmural (subendocardial) MI
    - Sensitivity 0-100%
      - Pooled data approximately 80%
      - Very low when ≤5% of LV mass involved
    - A/dyskinesis 29%, hypokinesis 50%, **normal 21%**

Diagnostic Role in Acute MI

- Relationship of WMA to pathologic infarct size
  - A/dyskinesis
    - Can over-estimate infarct size
      - Adjacent to scar
  - Hypokinesis
    - Nonspecific
    - Overestimates infarct size
      - Stunning, tethering, ischemia
  - Lack of systolic thickening (wall thinning)
    - Best estimator of infarct size
  - Rate and extent of recovery of function related to duration of occlusion, collateral flow, and size of ischemic zone
    - Early (24 hr) echo underestimates functional recovery
    - Recovery may take up to 3 months

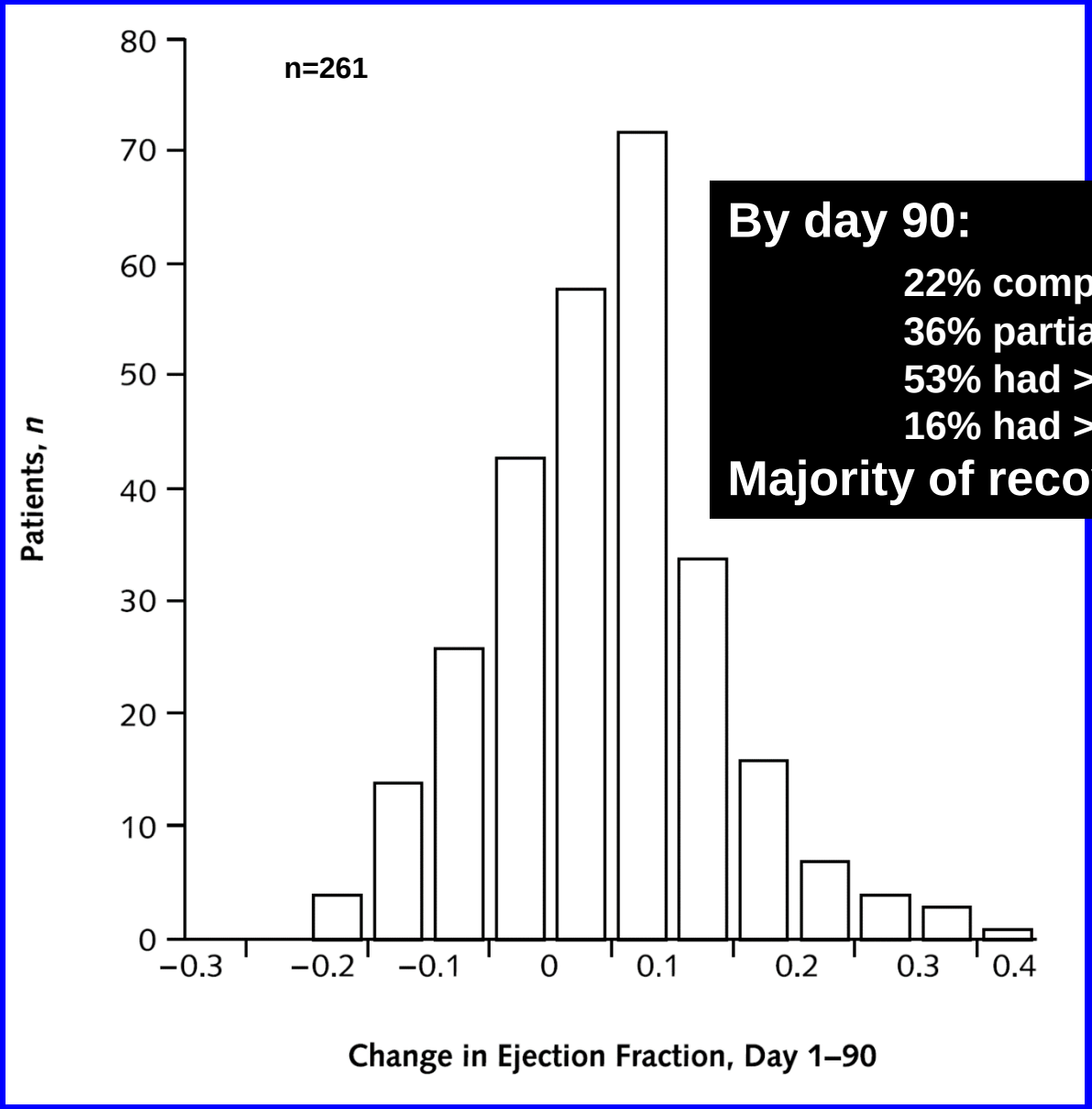


Weyman AE Prin/Prac Echo ed. 2, p. 658.

Weiss JL et al. Circulation 1981;63:401-8.

Solomon SD et al. Ann Intern Med 2001;134:451-8.

Recovery of LV Function



By day 90:

- 22% complete recovery
- 36% partial recovery
- 53% had >5% increase in EF
- 16% had >5% reduction in EF

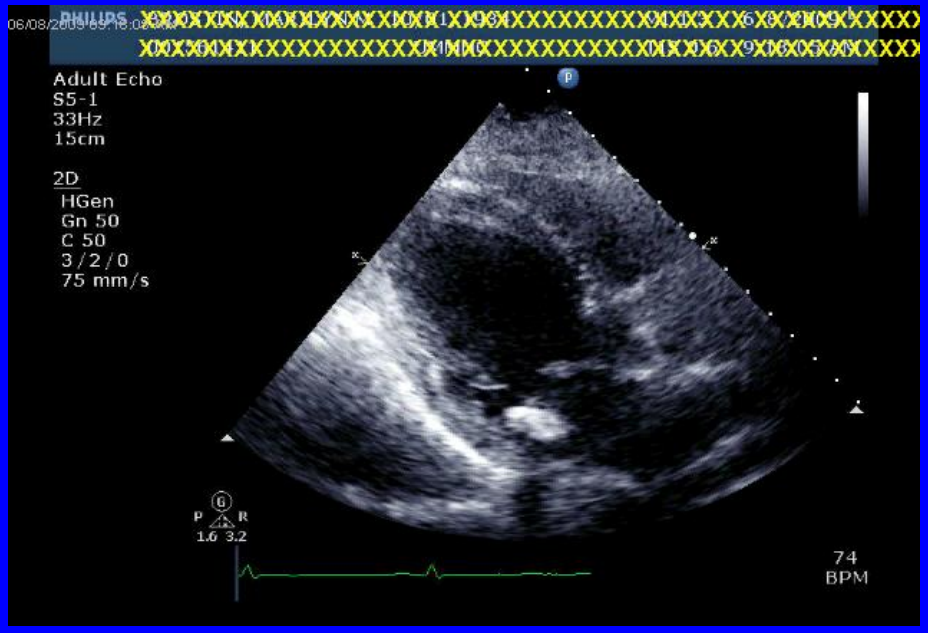
Majority of recovery occurs by day 14

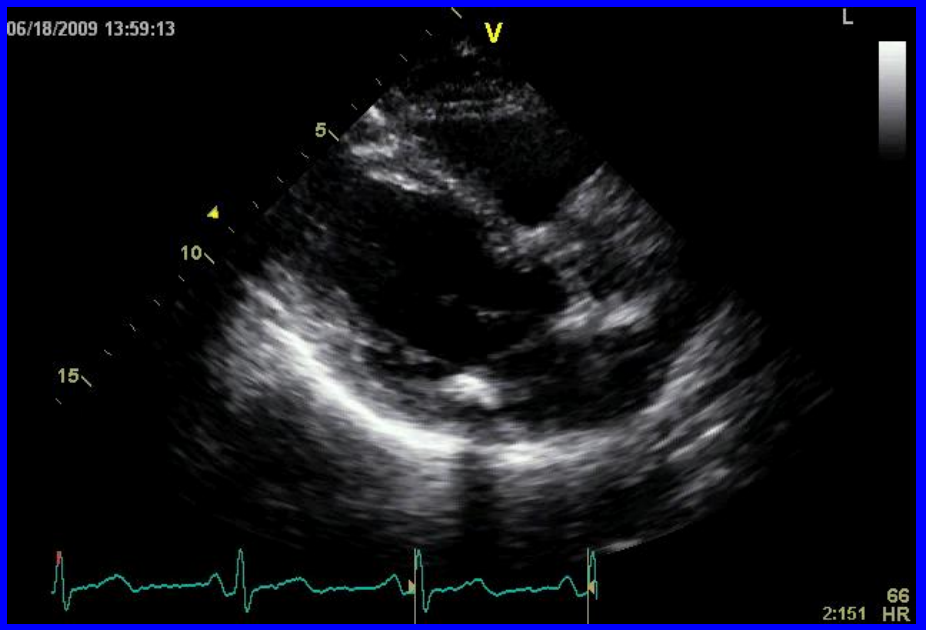
Solomon SD et al. Ann Intern Med 2001;134:451-8.

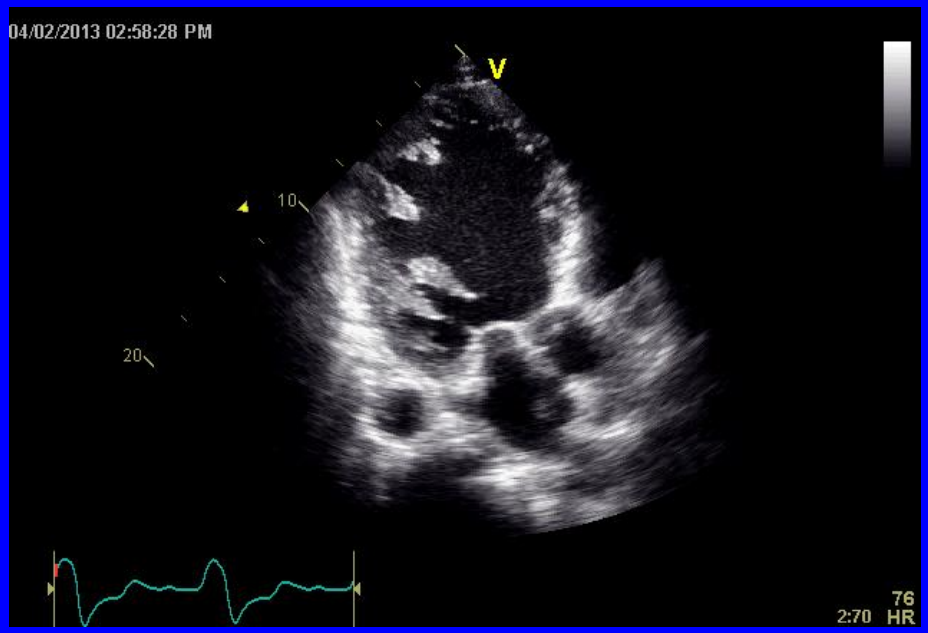
Other Causes of Segmental Dysfunction

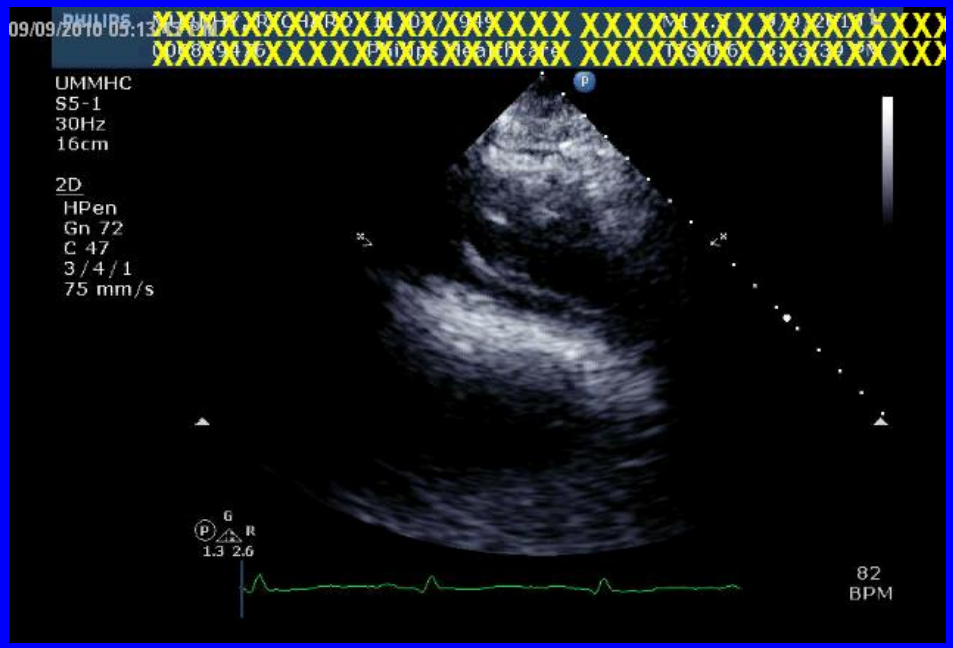
- Abnormal septal motion
  - RV pressure/volume overload
  - Post cardiac surgery
  - LBBB
- WPW syndrome
- Pseudodyskinesis
- Pacing
- Focal myocarditis
- Tako-tsubo syndrome/variants
- Cardiomyopathy

Thickening present


Adult Echo
S5-1
33Hz
15cm
2D
HGen
Gn 50
C 50
3/2/0
75 mm/s
1.6 3.2
74
BPM

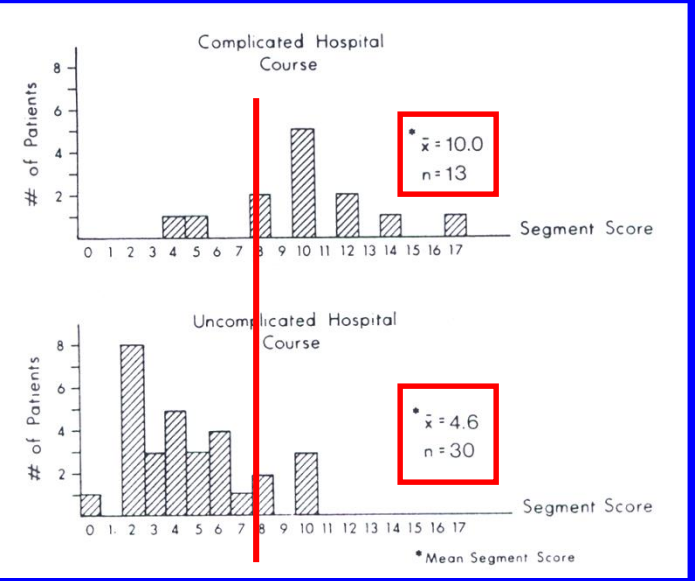

06/18/2009 13:59:13
V
L
5
10
15
2:151
66
HR


04/02/2013 02:58:28 PM
V
10
20
2:70
76
HR


UMMHC
S5-1
30Hz
16cm
2D
HPen
Gn 72
C 47
3/4/1
75 mm/s
1.3 2.6
82
BPM

Prognostic Role Early in Acute MI

- Early echocardiography can predict in-hospital complications
  - Extent of WMA
  - Remote ischemia



Horowitz RS et al. Am Heart J 1982;103:814.

Clinical Course of Patients With and Without Remote Asynergy on Two Dimensional Echocardiography*

	Location of Asynergy by Echocardiography		
	Infarct Zone (n = 36)	Remote (n = 32)	p Value
Death	3 (8%)	9 (28%)	0.03
Cardiogenic shock	3 (8%)	11 (34%)	0.01
Reinfarction	0 (0%)	5 (16%)	0.01
Progression of admission Killip class	7 (19%)	19 (59%)	0.001
Postinfarction angina	6 (17%)	11 (34%)	0.09

Gibson RS et al. Am J Cardiol 1982;49:1110.

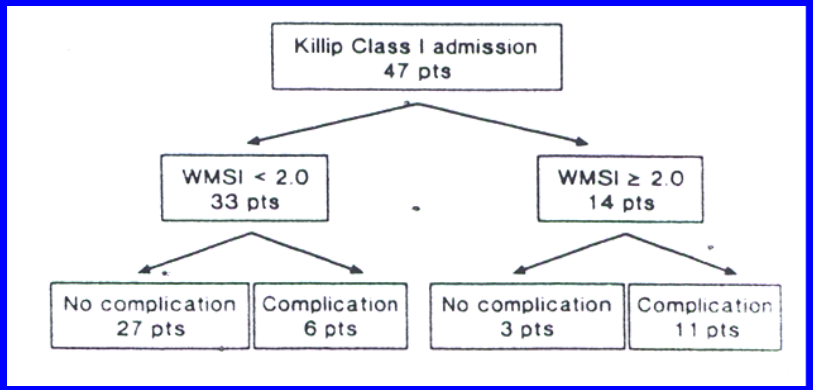
Prognostic Role Early in Acute MI

- Wall motion score index (WMSI)
  - Scored various segments
    - Normal = 1
    - Hypokinesis = 2
    - Akinesis = 3
    - Dyskinesis = 4
    - Aneurysmal = 5
  - WMSI =

    total score/#segments scored

    -WMSI index $\geq$2.0 identified pts at higher risk of complications

Complication	None	Present	P-value
HF	1.6±0.5	2.4±0.5	<0.005
VT/VF	1.8±0.6	2.4±0.5	<0.005
Death	1.8±0.6	2.5±0.5	<0.005



Nishimura RA et al. J Am Coll Cardiol 1984;4:1080.

Indications for Echocardiography STEMI guidelines*

- Class I
  - LVEF should be measured in all patients (LOE: C).
  - Patients with an initially reduced LVEF who are possible candidates for ICD therapy should undergo re-evaluation of LVEF ≥40days after discharge (LOE: B).
  - Suspected complications of MI (LOE: C).
  - Noninvasive testing for ischemia should be performed before discharge to assess the presence and extent of inducible ischemia in patients who have not had coronary angiography and do not have high-risk clinical features for which coronary angiography would be warranted (LOE: B).
- Class IIa
  - Echocardiography is reasonable to clarify the diagnosis of STEMI and allow risk stratification of patients with chest pain who present to the ED, especially if the diagnosis of STEMI is confounded by LBBB or pacing or if there is suspicion of posterior STEMI with anterior ST depressions. (Level of Evidence: B).
- Class IIb
  - Noninvasive testing for ischemia might be considered before discharge to evaluate the functional significance of a non-infarct artery stenosis previously identified at angiography (LOC: C).
  - Noninvasive testing for ischemia might be considered before discharge to guide the post-discharge exercise prescription (LOE: C).

*Antman EM et al. ACC/AHA STEMI guideline 2004. *O'Gara PT et al. 2013 ACCF/AHA STEMI guideline. www.cardiosource.org

Indications for Echocardiography NSTE-ACS Guideline

- Risk Stratification Before Discharge for Patients With an Ischemia-Guided Strategy of NSTE-ACS: Recommendations
  - Class I
    - Stress testing with an imaging modality should be used in patients who are able to exercise but have ST changes on resting ECG that may interfere with interpretation. In patients undergoing a low-level exercise test, an imaging modality can add prognostic information (LOE: B).
    - Pharmacological stress testing with imaging is recommended when physical limitations preclude adequate exercise stress (LOE: C).
    - A noninvasive imaging test is recommended to evaluate LV function in patients with definite ACS (LOE: C).

Amsterdam EA et al. 2014 AHA/ACC NSTE ACS Guideline; www.cardiosource.org.

2011 Appropriate Use Criteria

Myocardial Ischemia/Infarction With TTE	
• Acute chest pain with suspected MI and nondiagnostic ECG when a resting echocardiogram can be performed during pain	A (9)
• Evaluation of a patient without chest pain but with other features of an ischemic equivalent or laboratory markers indicative of ongoing MI	A (8)
• Suspected complication of myocardial ischemia/infarction, including but not limited to acute mitral regurgitation, ventricular septal defect, free-wall rupture/tamponade, shock, right ventricular involvement, HF, or thrombus	A (9)

Evaluation of Ventricular Function after ACS With TTE	
• Initial evaluation of ventricular function following ACS	A (9)
• Re-evaluation of ventricular function following ACS during recovery phase when results will guide therapy	A (9)

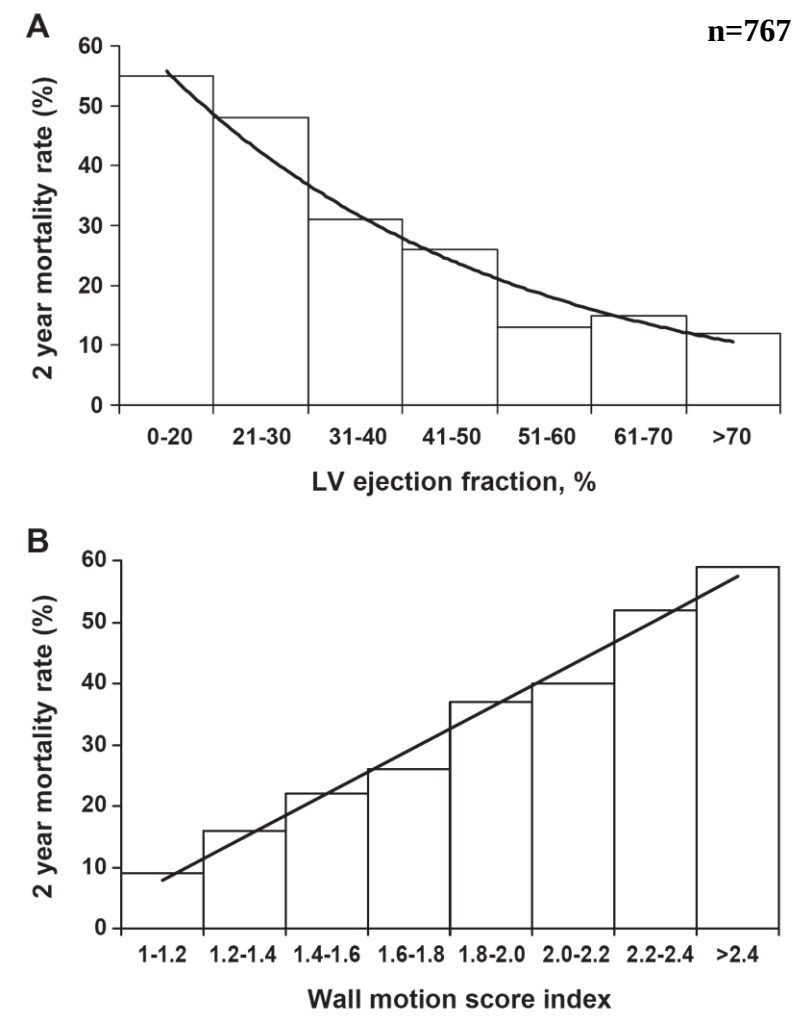
STEMI With Stress Echocardiography	
• Primary PCI with complete revascularization • No recurrent symptoms	I (2)
• Hemodynamically stable, no recurrent chest pain symptoms, or no signs of HF • To evaluate for inducible ischemia • No prior coronary angiography since the index event	A (7)
• Hemodynamically unstable, signs of cardiogenic shock, or mechanical complications	I (1)
UA/NSTEMI With Stress Echocardiography	
• Hemodynamically stable, no recurrent chest pain symptoms, or no signs of HF • To evaluate for inducible ischemia • No prior coronary angiography since the index event	A (8)
ACS—Asymptomatic Postrevascularization (PCI or CABG) With Stress Echocardiography	
• Prior to hospital discharge in a patient who has been adequately revascularized	I (1)

Douglas PS et al. J Am Coll Cardiol 2011;57:1126.

Echocardiographic Predictors of Prognosis Post-MI

- Ejection fraction
- Wall motion score index
- Extent of residual ischemia
- Ventricular volumes
- Mitral regurgitation
- RV dysfunction
- Diastolic function
  - Restrictive filling pattern
  - E/e' ratio
  - LA volume index
- Newer parameters/techniques
  - Strain/strain rate imaging
  - LV dyssynchrony
  - Myocardial contrast echocardiography
  - 3D echocardiography

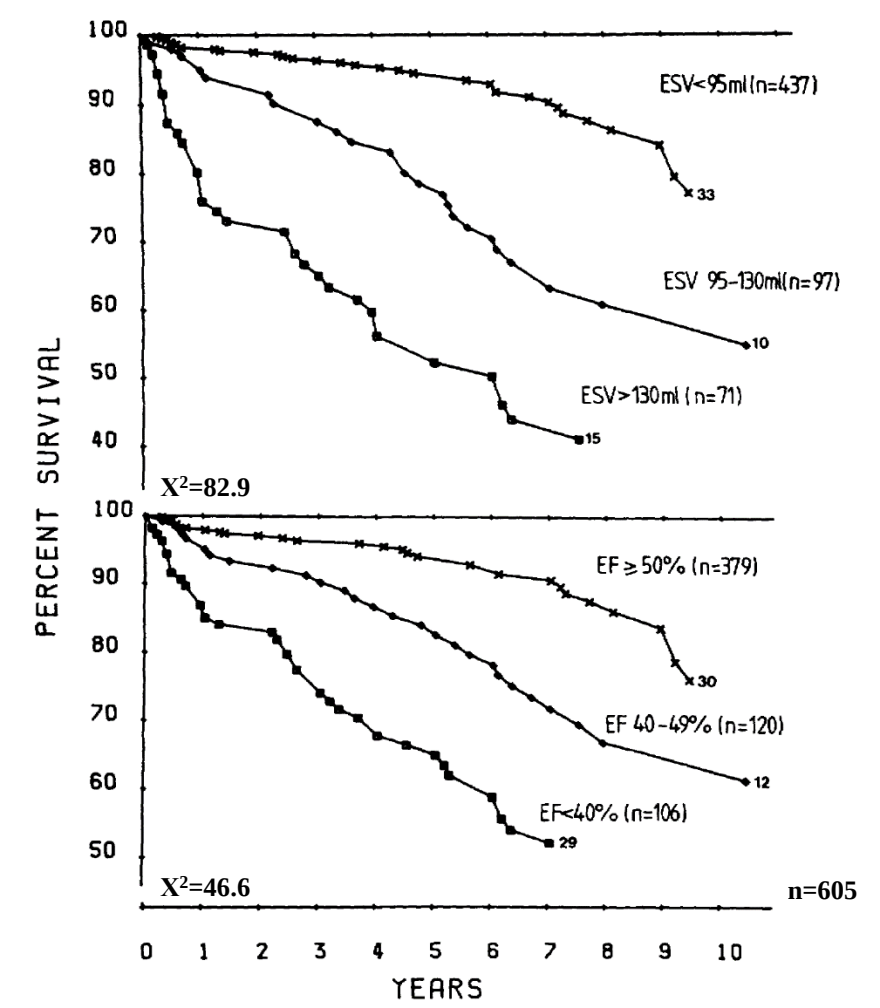
Ejection Fraction and WMSI



Moller JE et al. Am Heart J 2006;151:419.

WMSI was a more powerful predictor than LVEF. Incremental to clinical variables.

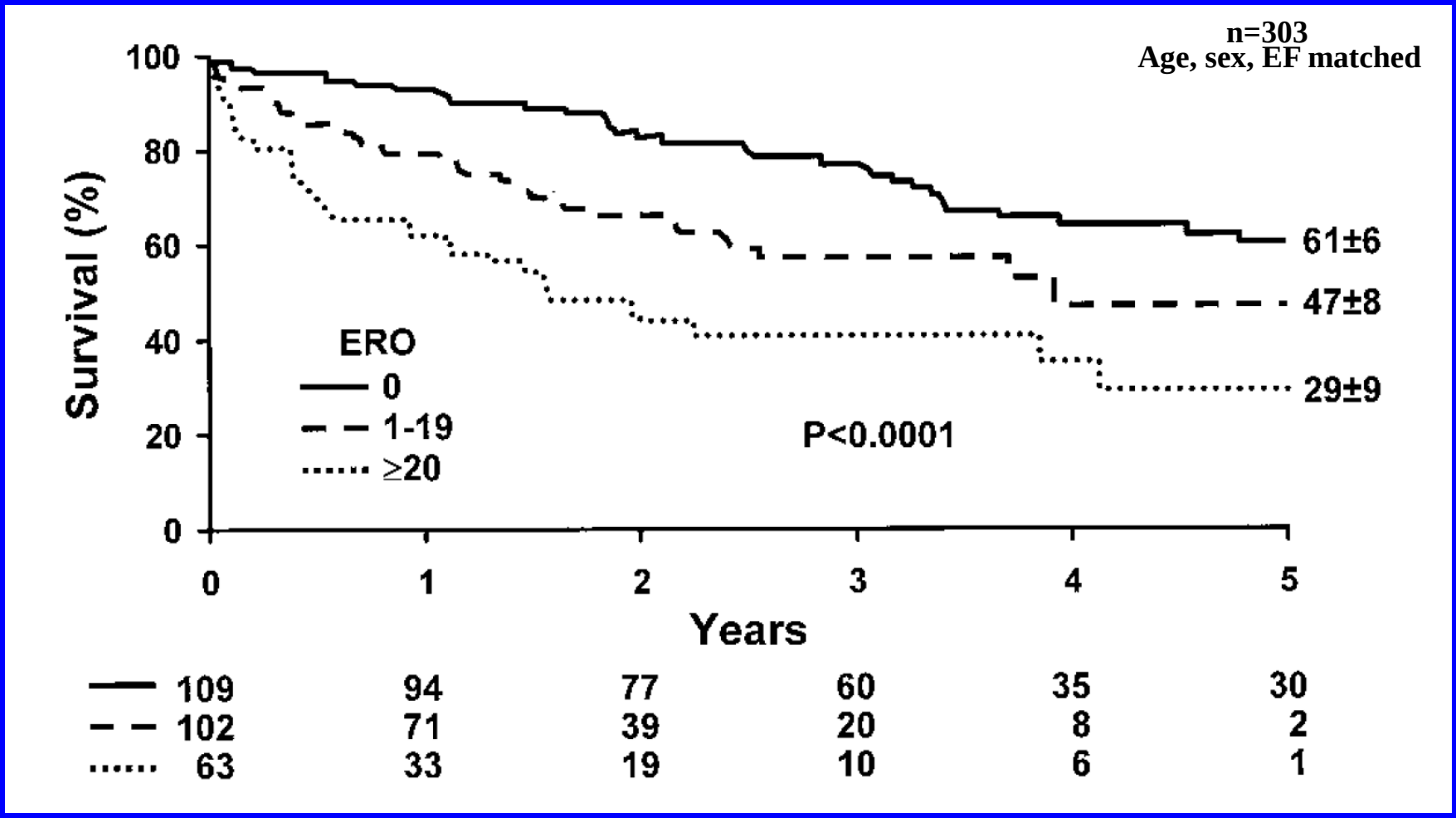
LV End-systolic Volume



White HD et al. Circulation 1987;76:44.

ESV Superior to EDV and LVEF

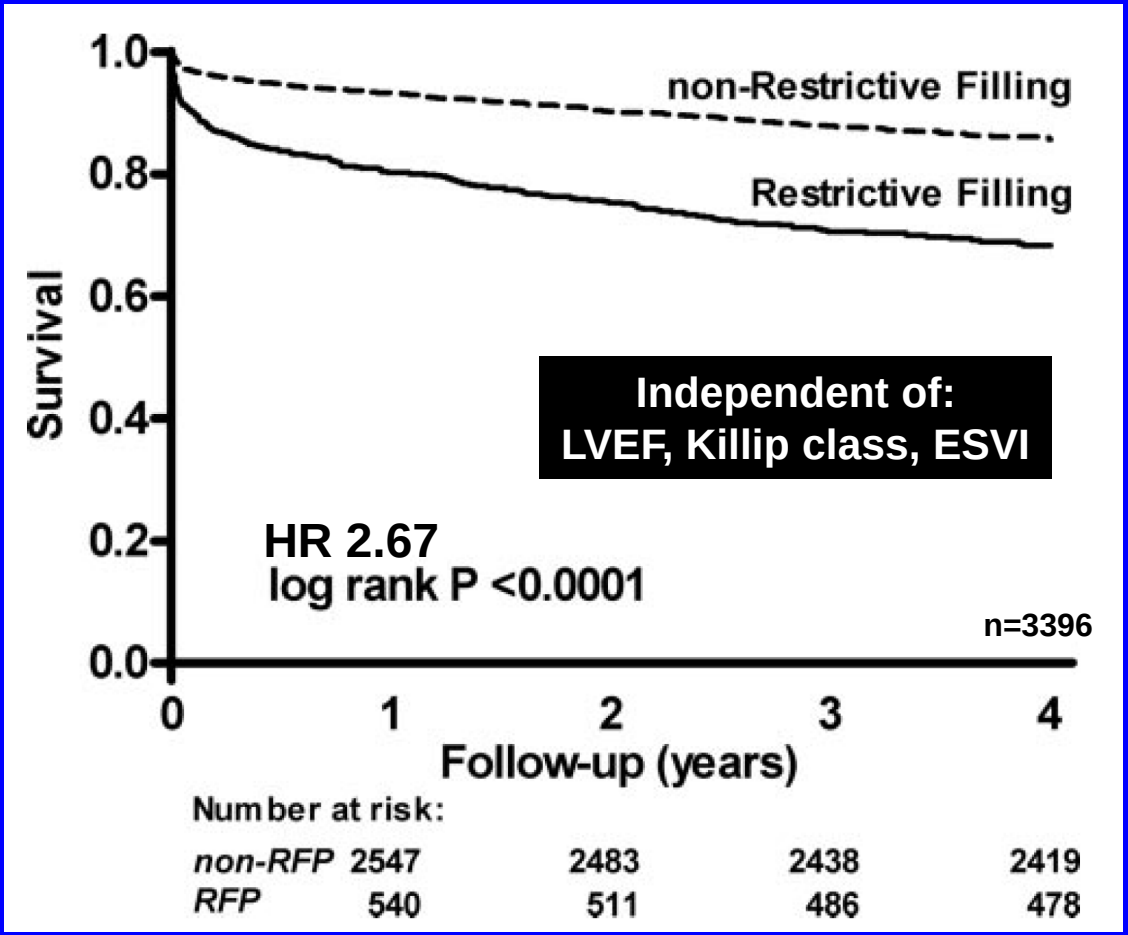
Ischemic Mitral Regurgitation



Grigioni F et al. Circulation 2001;103:1759.

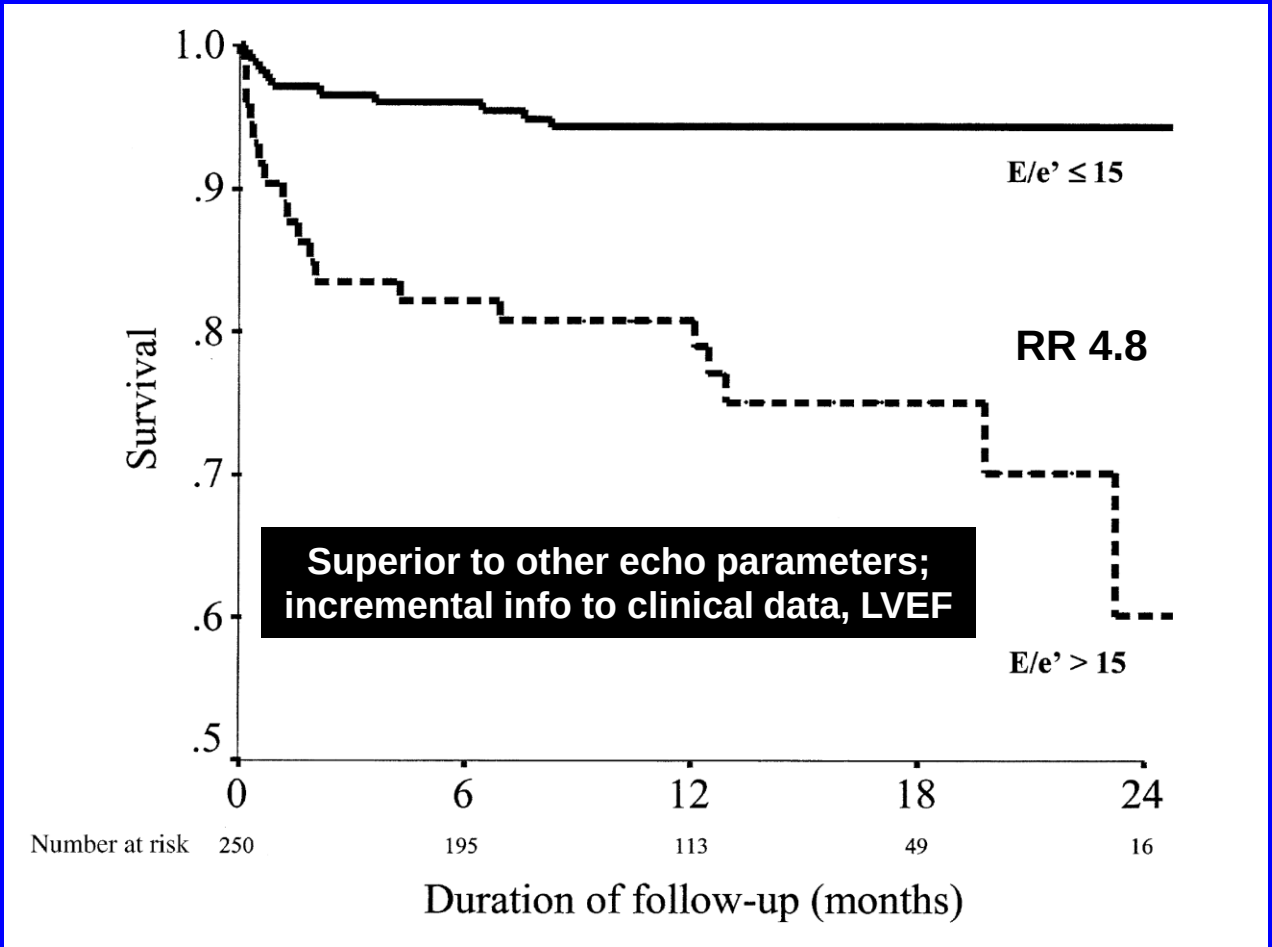
IMR predictive of survival independent of LVEF and clinical characteristics

Restrictive Filling Pattern



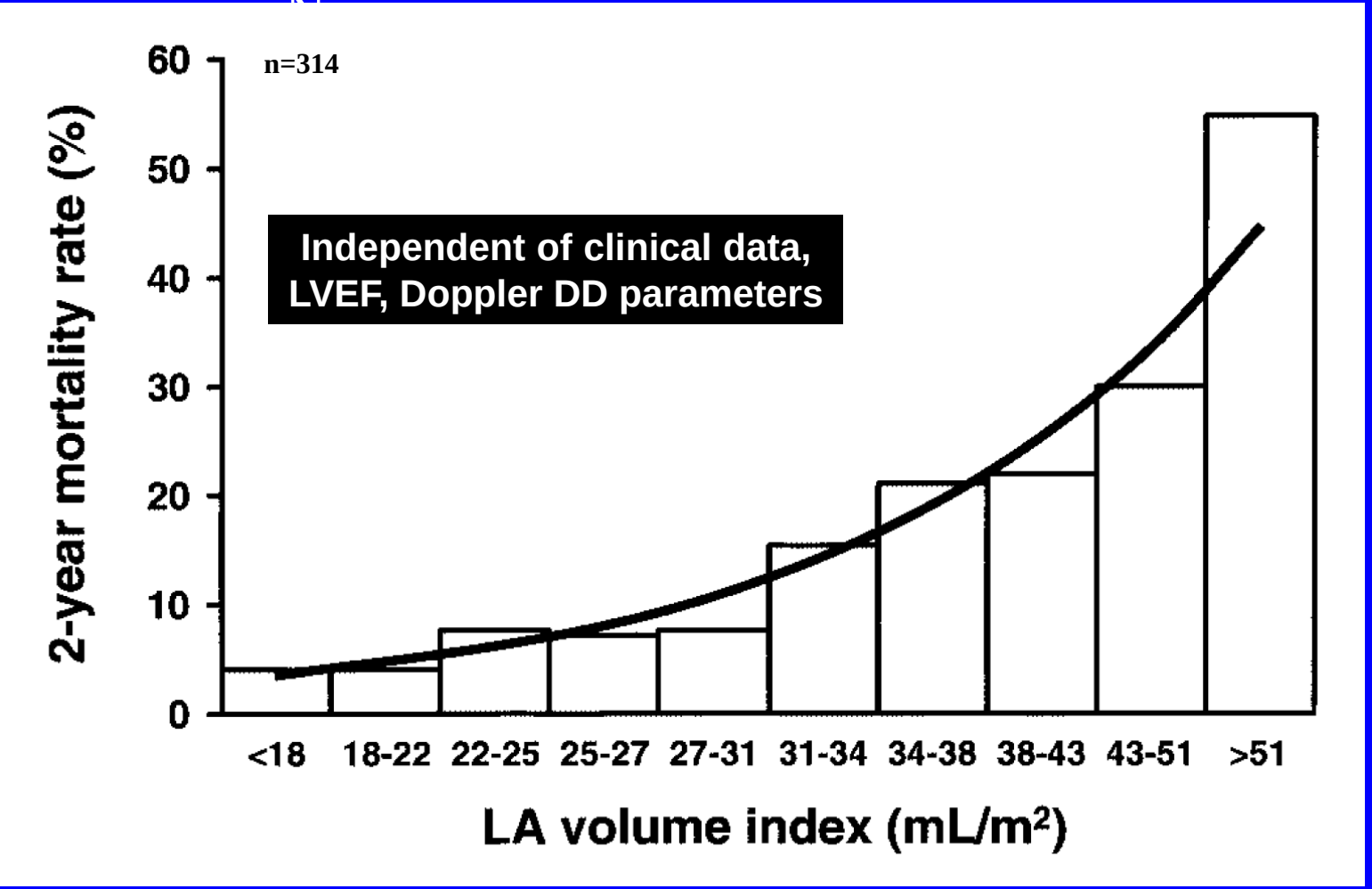
MeRGE Group. Circulation 2008;117:2591.

E/e' Ratio



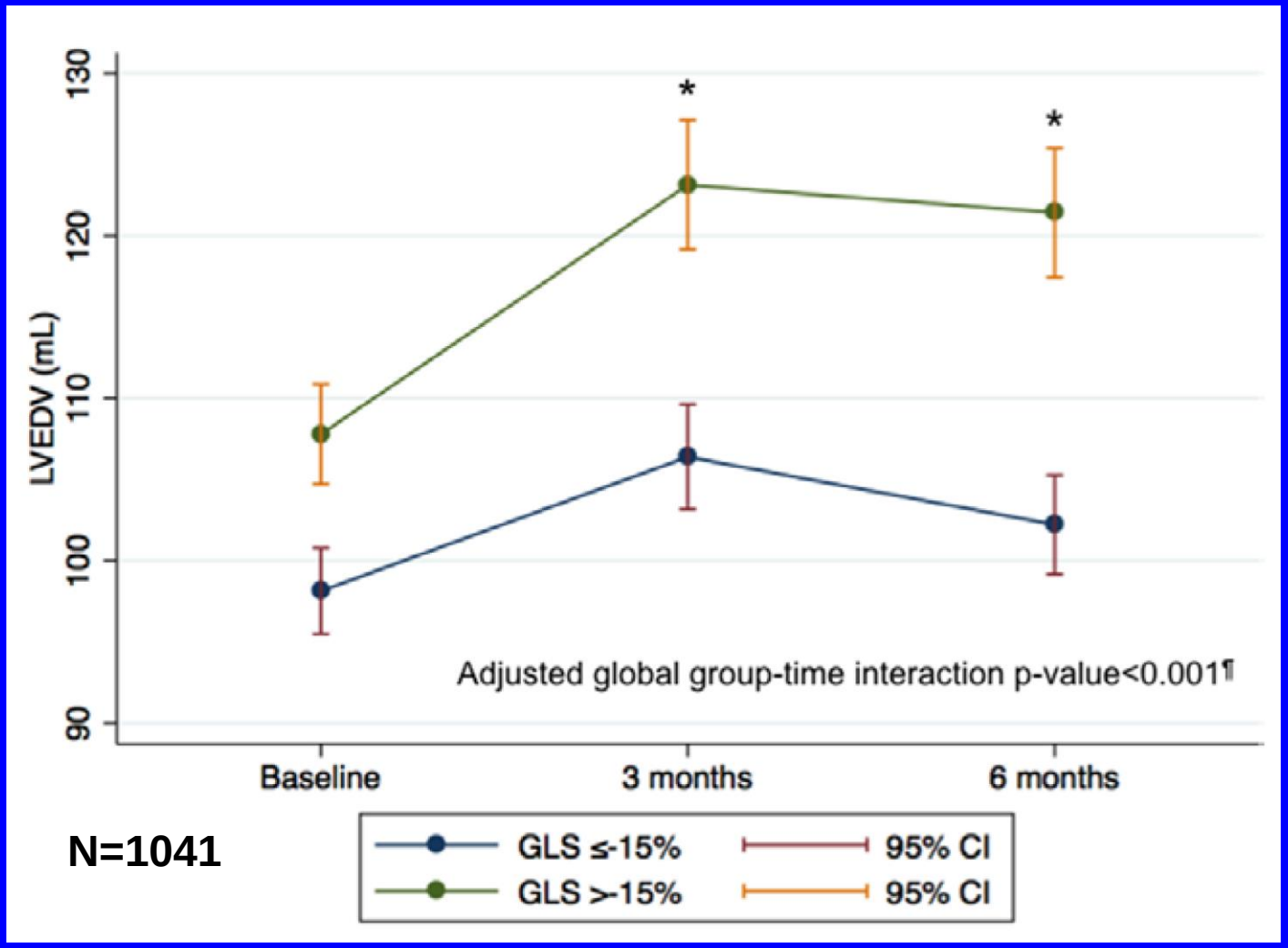
Hillis GS et al. J Am Coll Cardiol 2004;43:360.

Left Atrial Volume Index



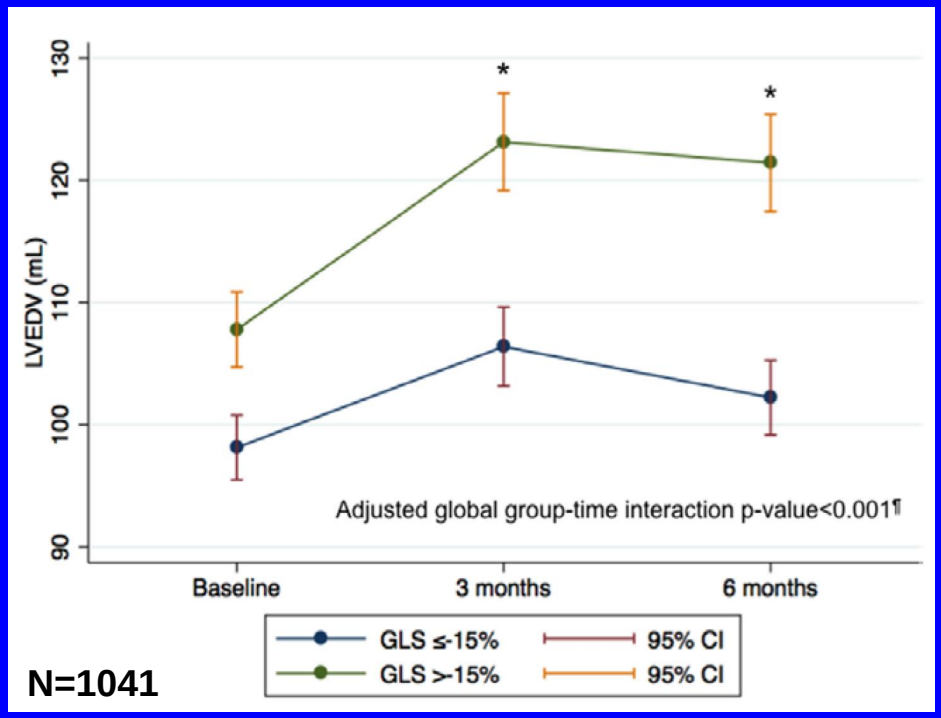
Moller JE et al. Circulation 2003;107:2207.

Global Longitudinal Strain



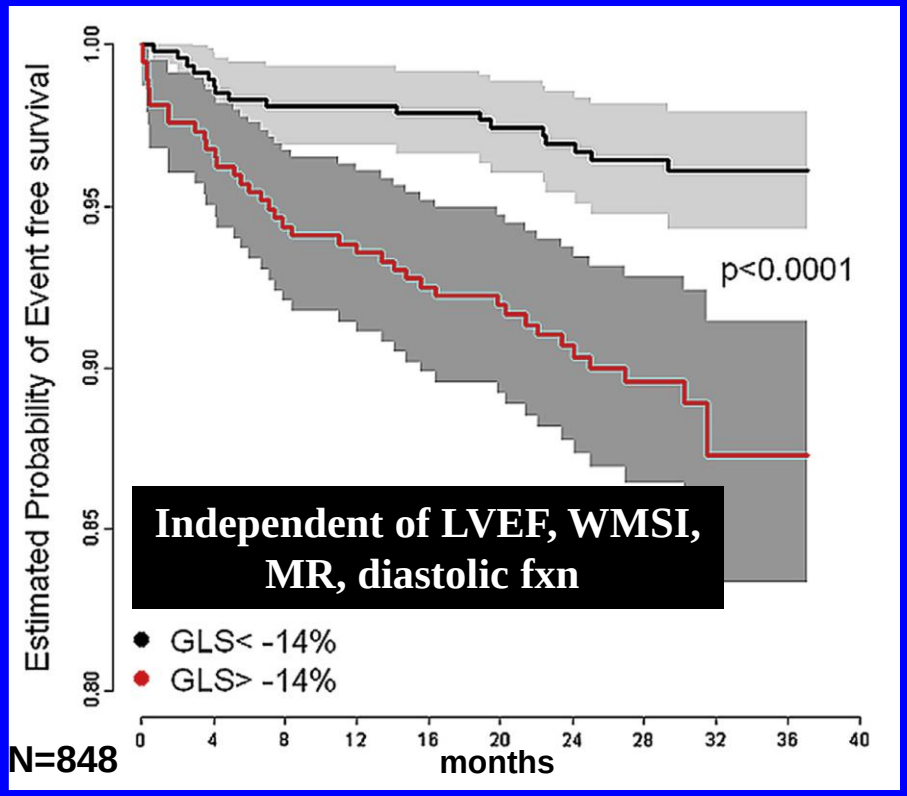
Joyce E et al. Circ Cardiovasc Imaging 2014;7:74.

Global Longitudinal Strain



N=1041

Remodeling, MI size



N=848

Prognosis

Joyce E et al. Circ Cardiovasc Imaging 2014;7:74.
Ersboll M et al. J Am Coll Cardiol 2013;61:2365.
Gjesdal O et al. Circ Cardiovasc Imaging 2008;1:189.
Antoni ML et al. Eur Heart J 2010;31:1640.

Shock Associated with Acute MI

- **LV (pump) failure**
  - Large infarctions
  - Smaller infarctions with pre-existing conditions
    - AS, dilated CMO, HCM, prior MI
  - Infarct extension or expansion
  - Re-infarction
- **RV infarction/dysfunction**
- **Mechanical complications**
  - Free wall rupture/tamponade
  - Ventricular septal rupture
  - Acute severe MR
    - Papillary muscle displacement
    - Papillary muscle rupture
- **LV outflow tract obstruction**
- **Miscellaneous Conditions**
  - Sepsis
  - Pulmonary embolism
  - Bleeding (hypovolemia)
  - Aortic dissection
  - Medication effects

Complications of Myocardial Infarction

- Free wall rupture
- Pseudoaneurysm formation
- Ventricular septal rupture
- Papillary muscle rupture
- RV myocardial infarction
- Dynamic LV outflow obstruction
- LV thrombus

Free Wall Rupture

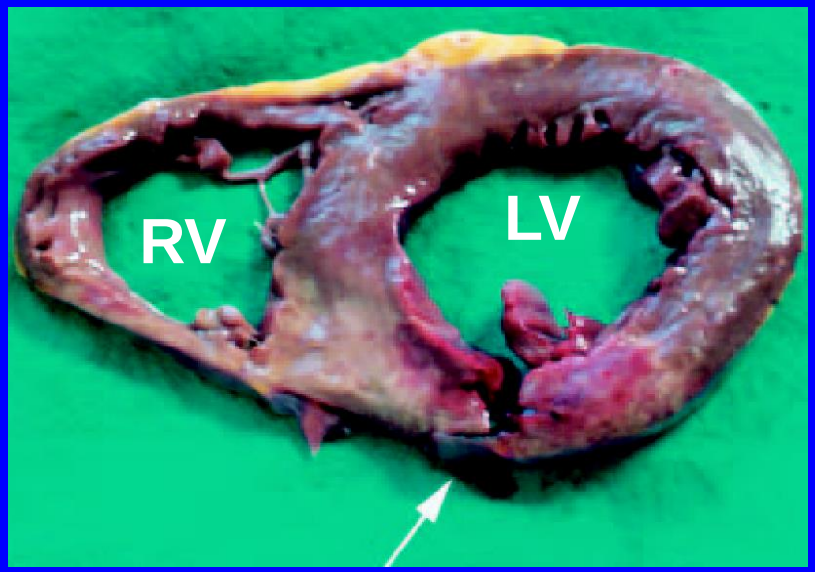
- Most common, least recognized complication
  - ≤1% to 6.2% pts with acute MI
  - Accounts for 14-to-26% of infarct-related mortality and 7% of in-hospital deaths
  - Time course
    - First 5 days post-MI in 50%
    - 90% occur within 2 weeks
- Risk factors for rupture
  - No prior history angina or MI
  - STEMI or Q-waves on initial ECG
  - Peak CK-MB >150 IU/L
  - Age >70 yrs
  - Female sex
  - Closed infarct-related artery
  - Fibrinolytic therapy > 1^{o} PCI
  - NSAID or corticosteroid use

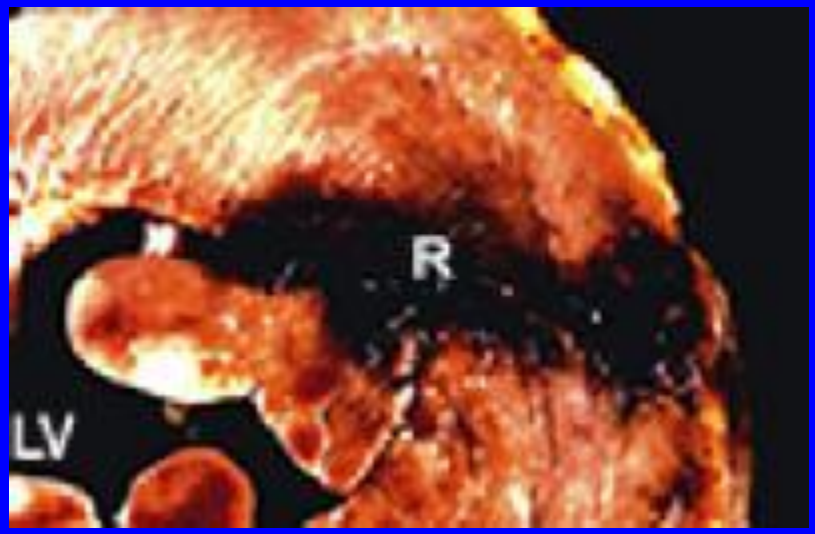
Free Wall Rupture

- Mid-ventricle and lateral wall most common sites
  - May affect any wall
    - Can involve the RV
    - Atria affected rarely
  - Adjacent to junction of normal with infarcted tissue
- Presentation
  - Acute free wall rupture
    - Rapid PEA/death
  - Subacute free wall rupture (30%)
    - Slow ooze, warning symptoms/signs

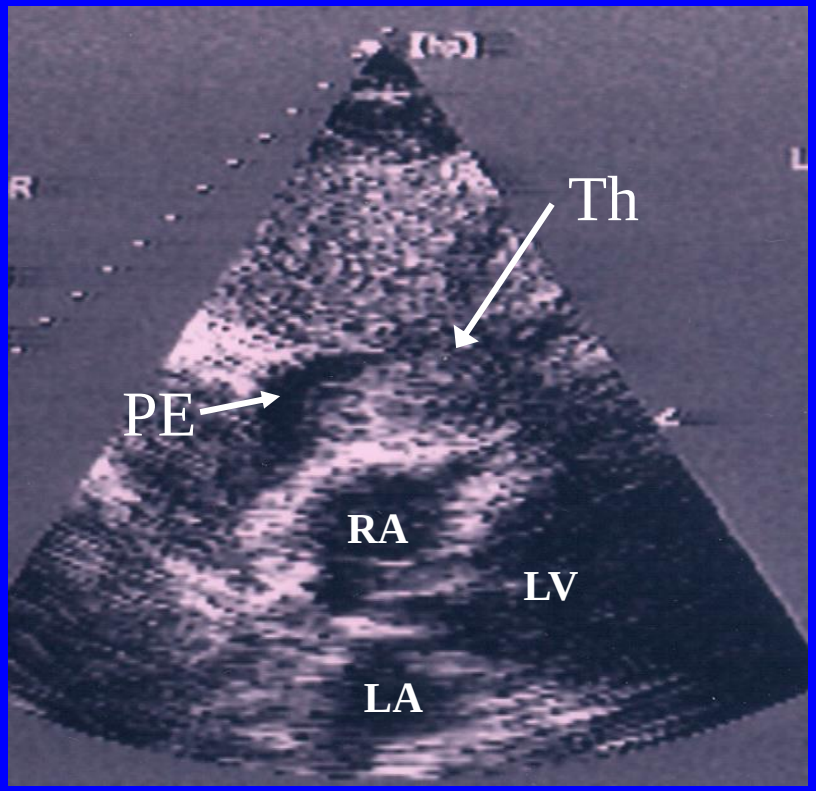
Free Wall Rupture

- Clinical signs
  - Pericarditis, emesis, agitation
  - Recurrent chest pain
  - Transient hypotension and bradycardia
  - Deviation from expected T-wave evolution
- Echocardiographic features
  - Pericardial effusion >5 mm (end-diastole)
  - High density intrapericardial echoes (thrombus)
  - RV or RA compression (tamponade)
  - Direct 2D identification of tear is unusual
    - Contrast use may be helpful

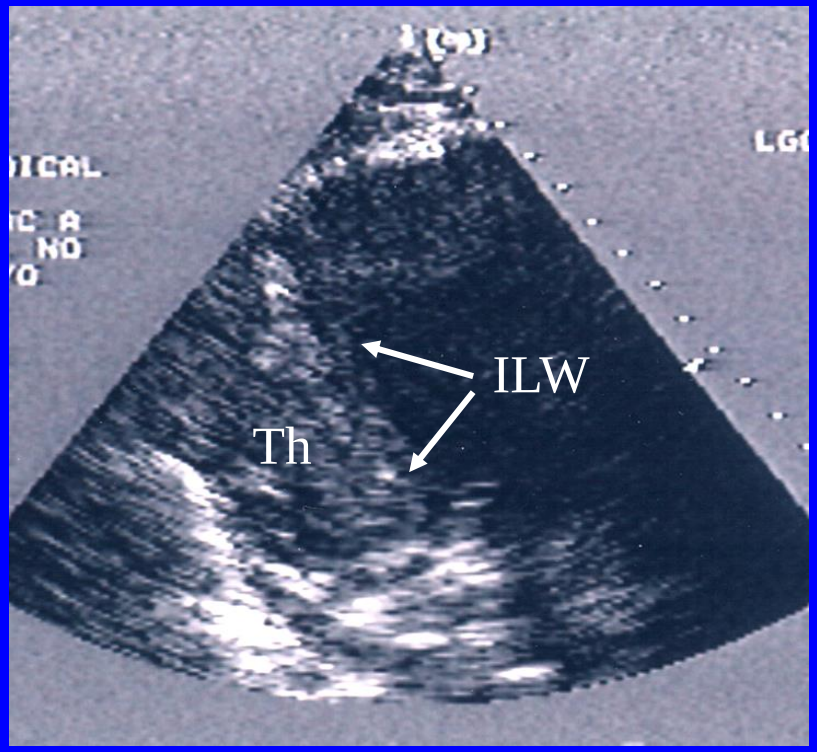




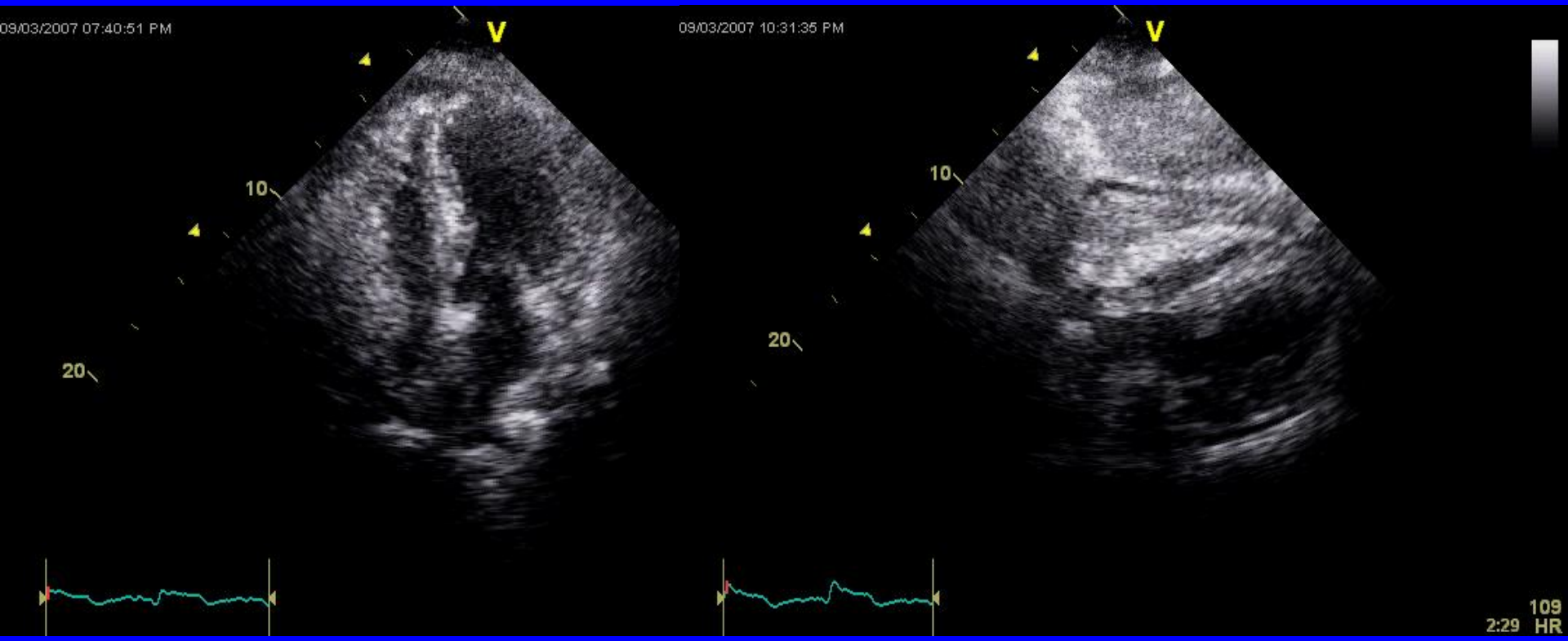
Zoni A et al. Circulation 2003;108:498



Subcostal



Parasternal

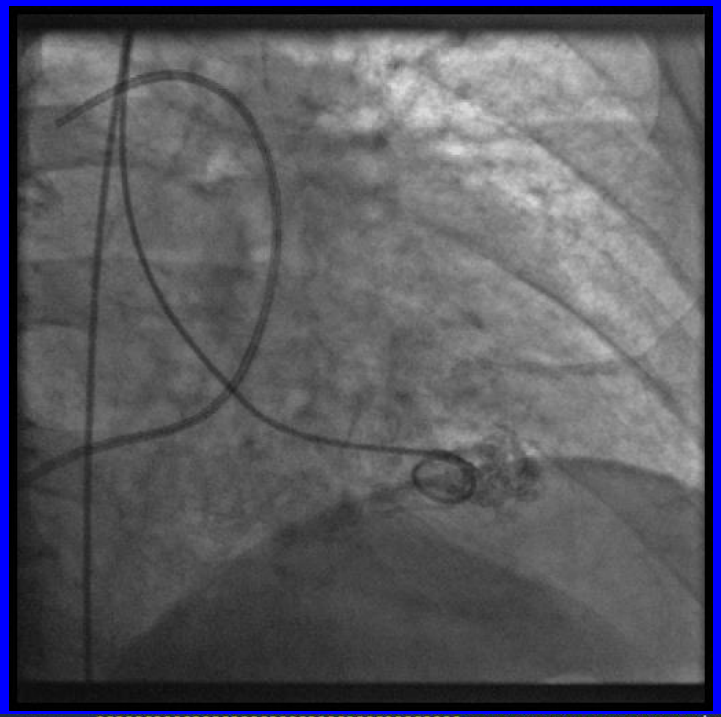

09/03/2007 07:40:51 PM
V
10
20
09/03/2007 10:31:35 PM
V
10
20
109
2:29 HR

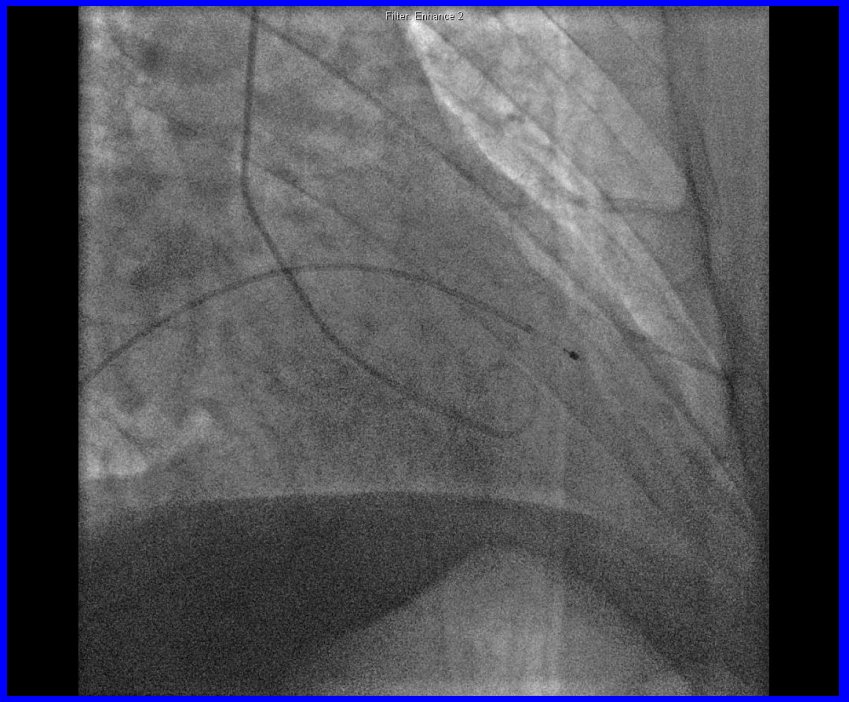
Free Wall Rupture

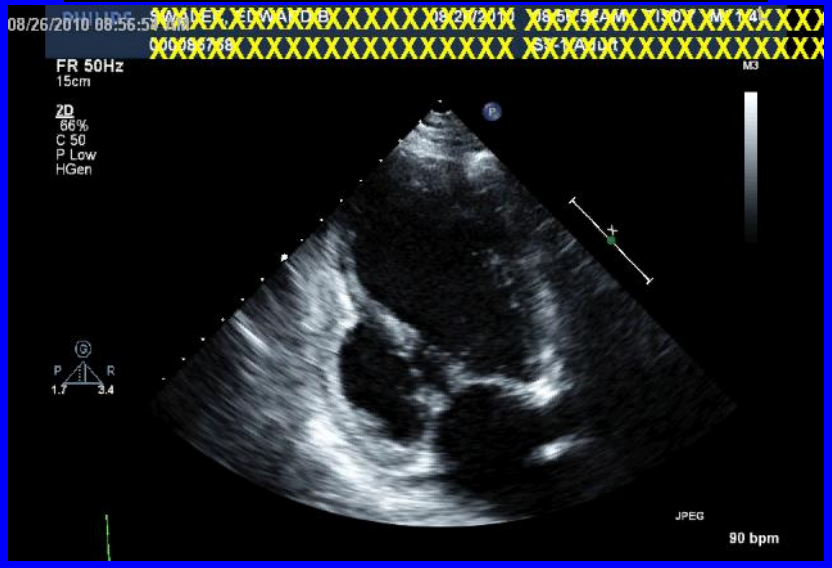
- Treatment
  - Acute rupture often fatal
  - Subacute rupture
    - Clinical suspicion
    - Echocardiography
    - Fluids/inotropic agents
    - Pericardial tap
    - Surgery
    - Medical (conservative) therapy (?)

LV Pseudoaneurysm

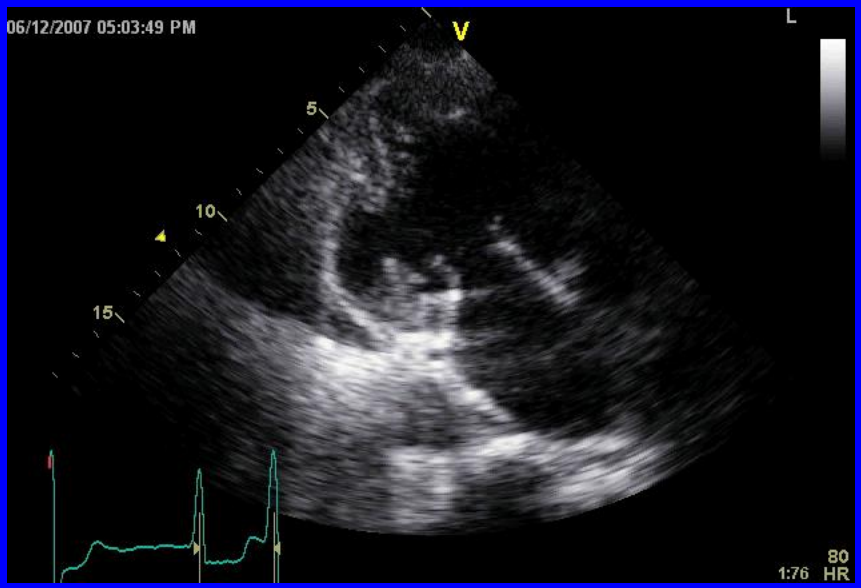
- Incomplete rupture
  - Sealed by pericardium and hematoma
  - Lacks elements of myocardial wall
- Echo-lucent space external to LV
- “Narrow” neck
  - Ratio of diameter of the entry point to the maximal diameter <40-50%
- May contain thrombus
- Characteristic Doppler profile
  - Bidirectional (“to-and-fro”) flow pattern



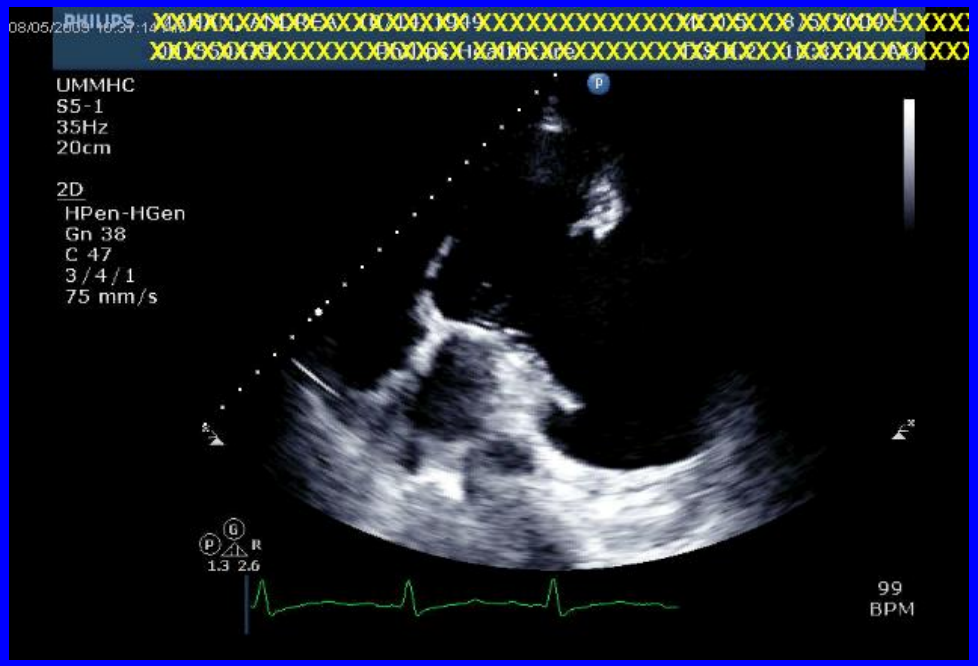


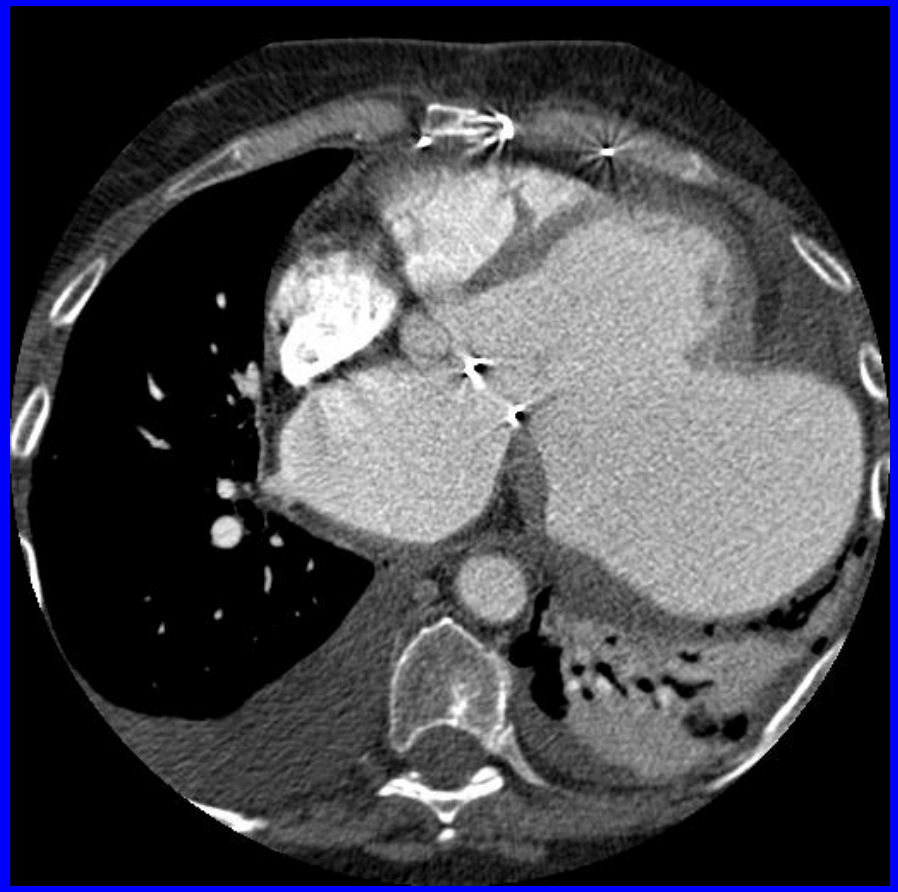


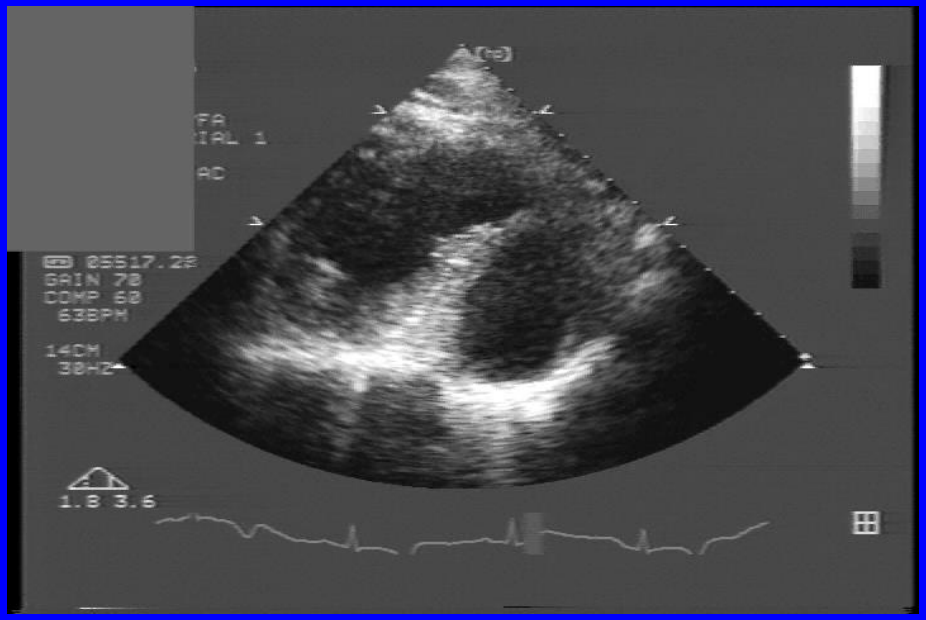
Aneurysm

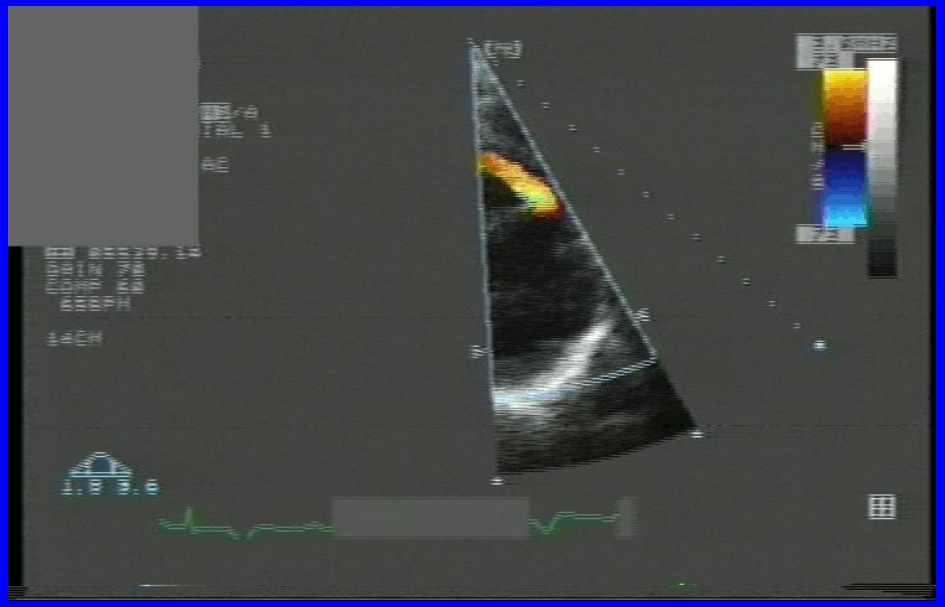


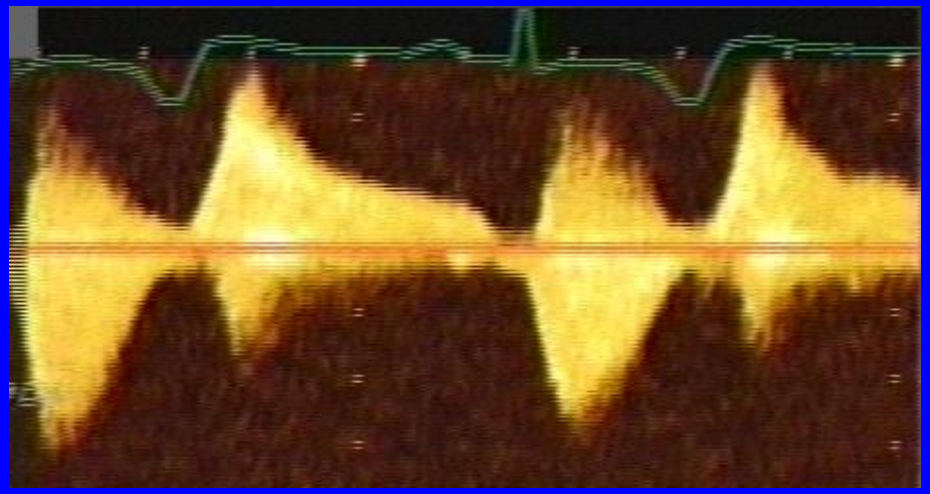
Pseudoaneurysm


PHILIPS
UMMHC
S5-1
35Hz
20cm
2D
HPen-HGen
Gn 38
C 47
3/4/1
75 mm/s
1.3 2.6
99
BPM




GAIN 70
COMP 60
14CM
30HZ
1.8 3.6


1.8 3.6



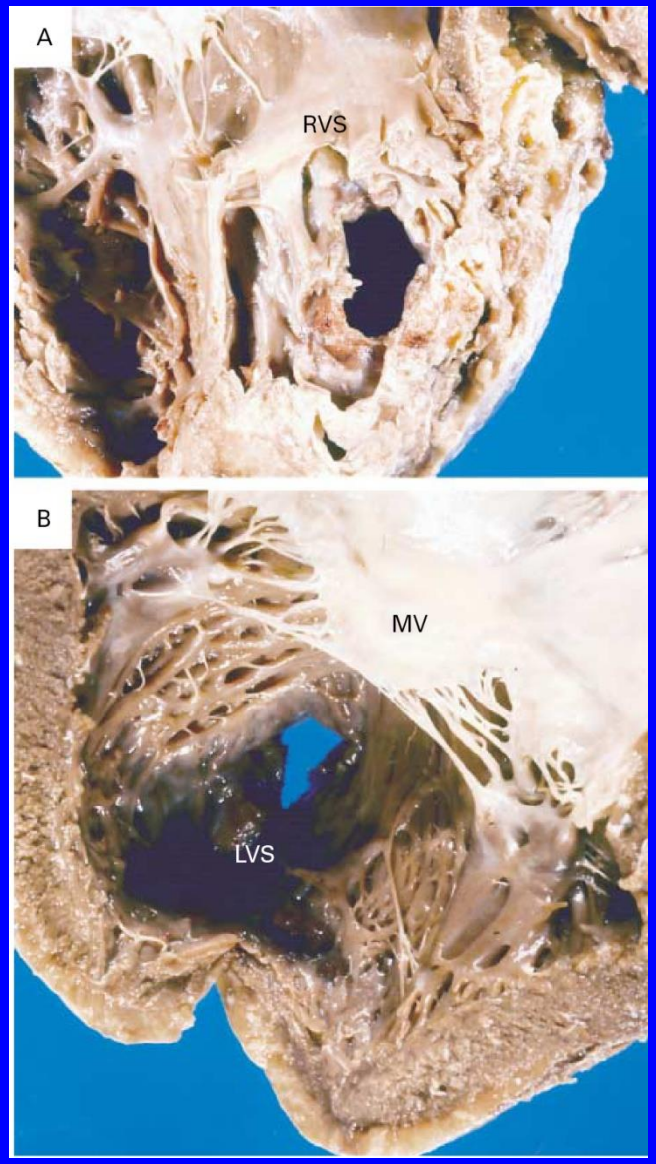
Ventricular Septal Rupture

- Occurs in 0.2-to-1.0% patients with MI
  - Bimodal distribution: 24-hrs and days 3-to-5
- Any portion of the septum may be involved
  - Margin between necrotic and non-necrotic myocardium
- Anterior VSRs tend to be located distally with defects that perforate the septum at the same level
  - ***"Simple"***
- Inferior VSRs located more toward the base and follow a serpiginous course
  - ***"Complex"***

Ventricular Septal Rupture

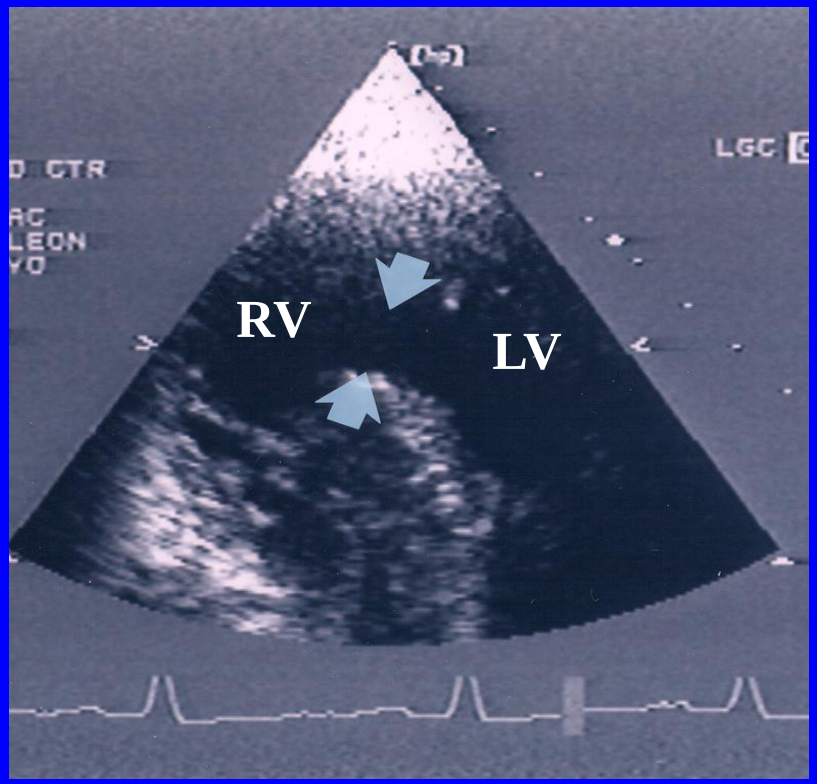
- Pathophysiology
  - Acute volume and pressure overload of right heart
  - Increased flow volume in pulmonary circuit
  - Pulmonary edema and decreased forward cardiac output
- Presentation
  - Holosystolic murmur
    - Often loud
  - Thrill
  - Heart failure

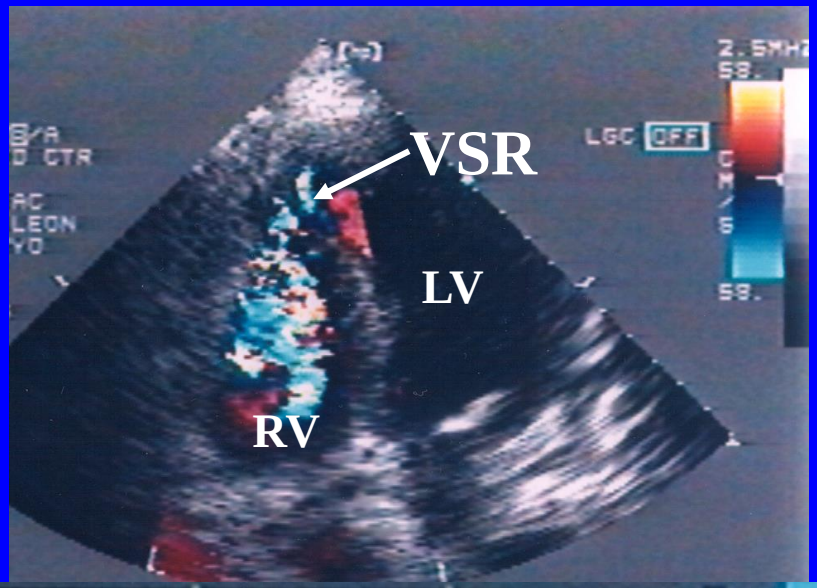
“Simple” VSR



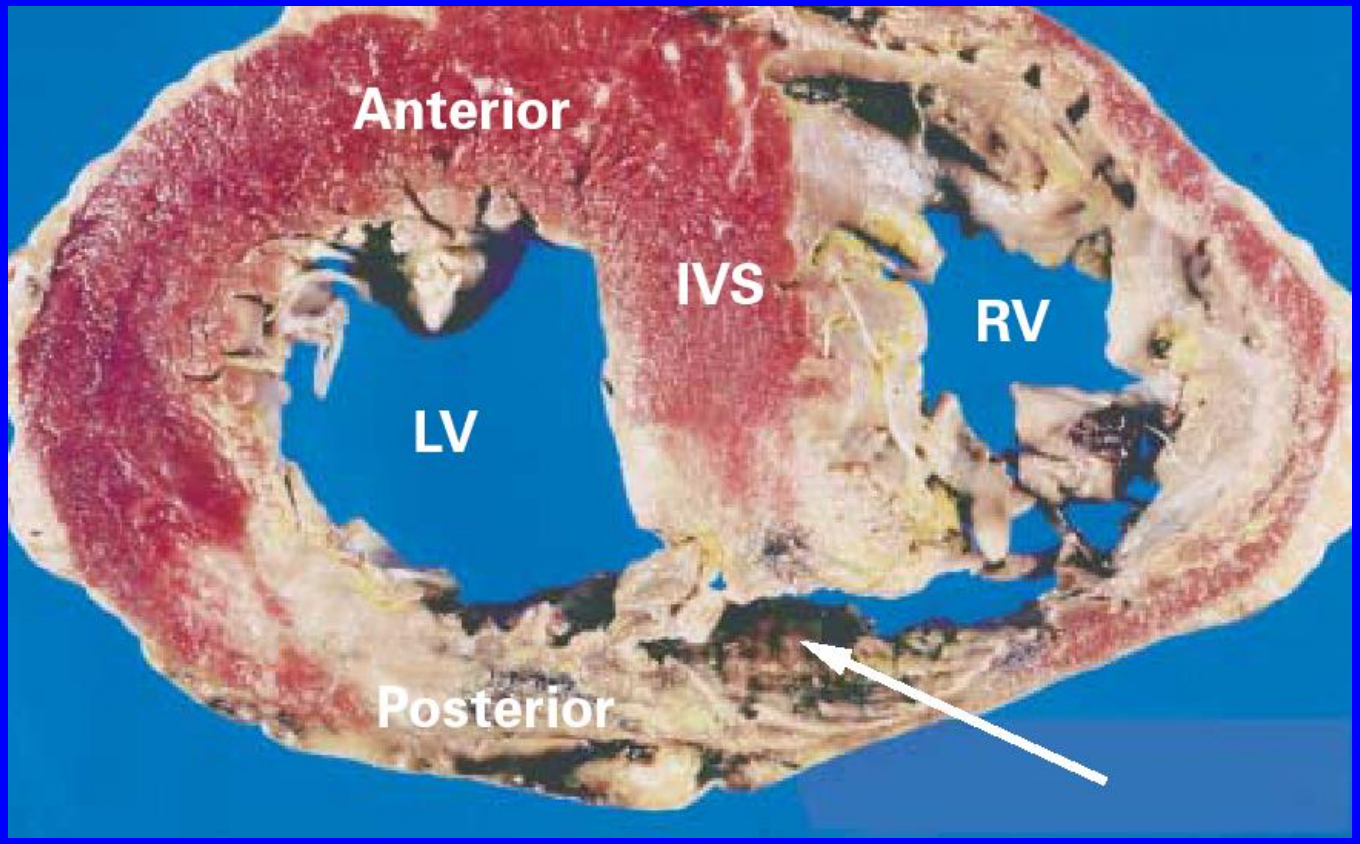
Birnbaum Y et al. N Engl J Med 2002;347:1426.

Anterior VSR



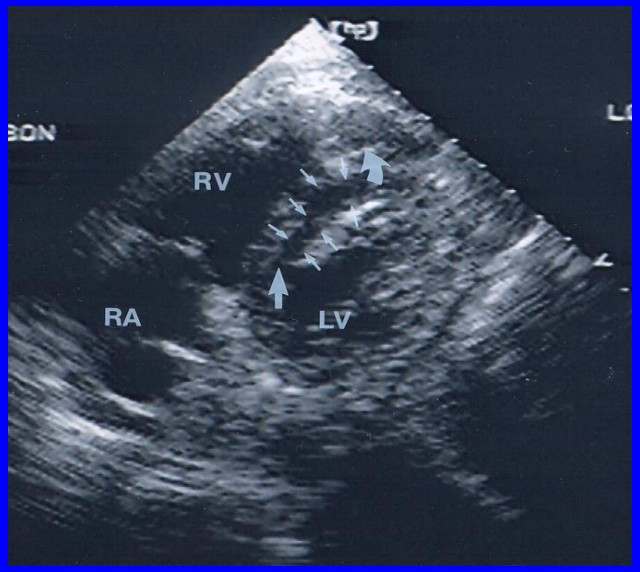


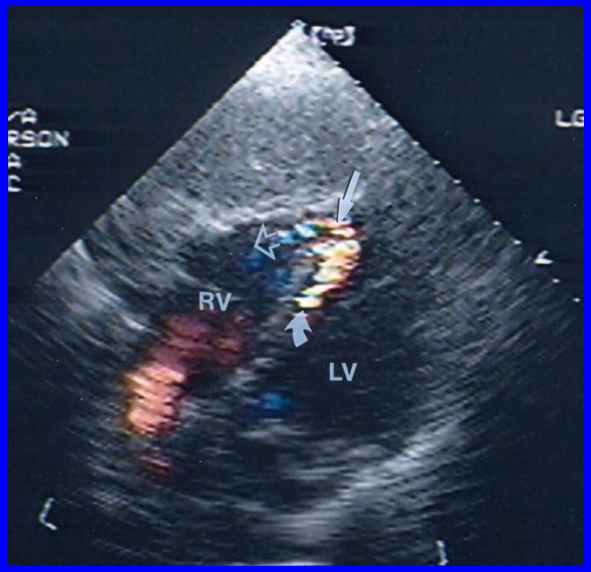
“Complex” VSR

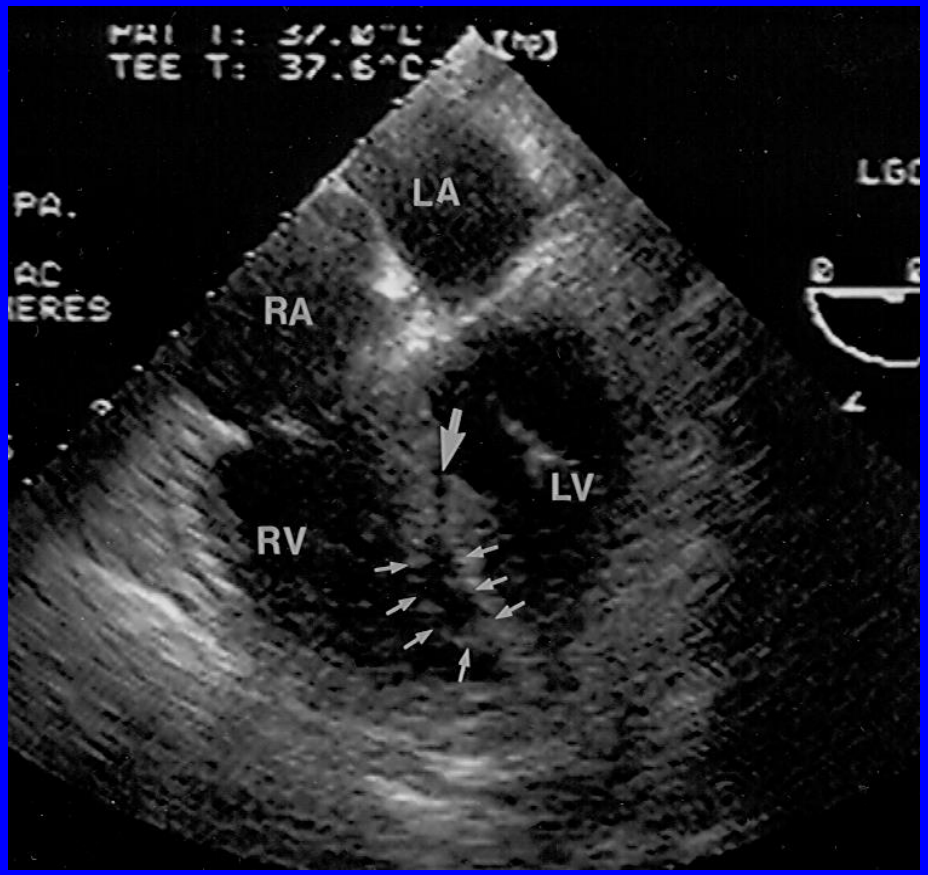


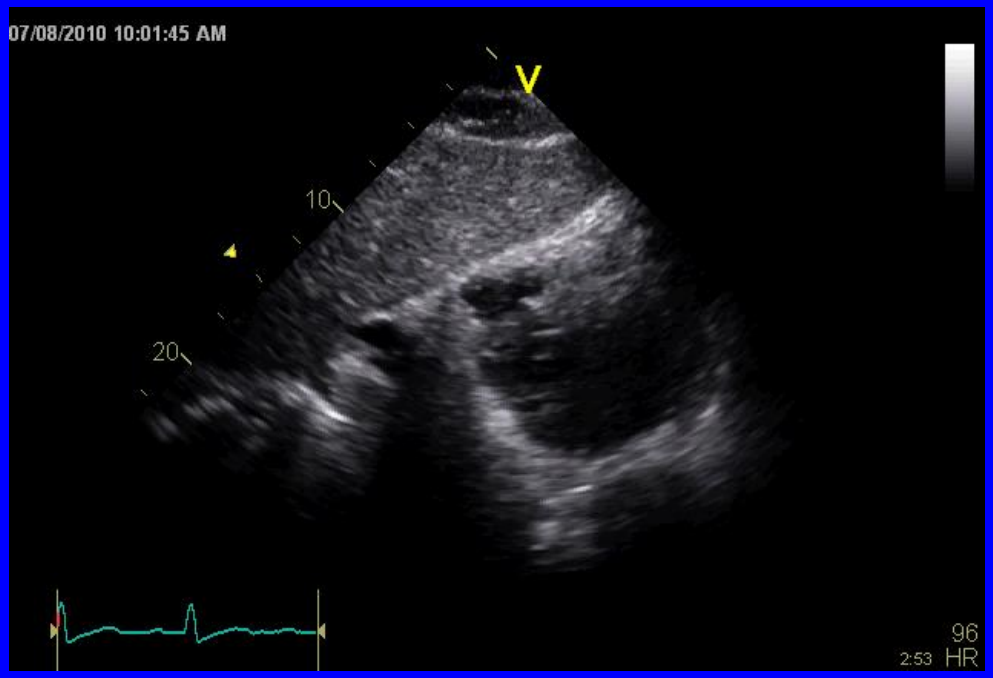
Birnbaum Y et al. N Engl J Med 2002;347:1426.

Inferior VSR





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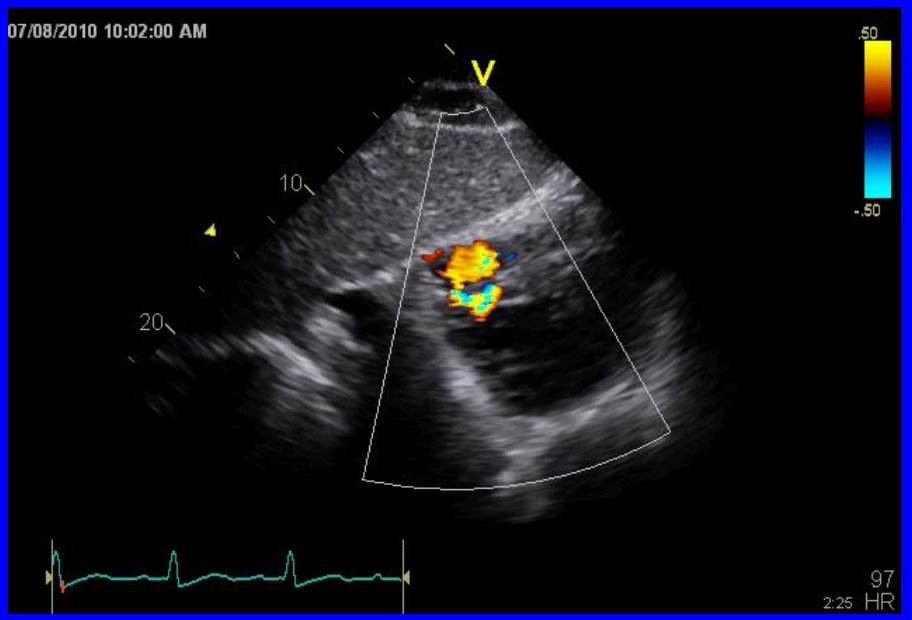
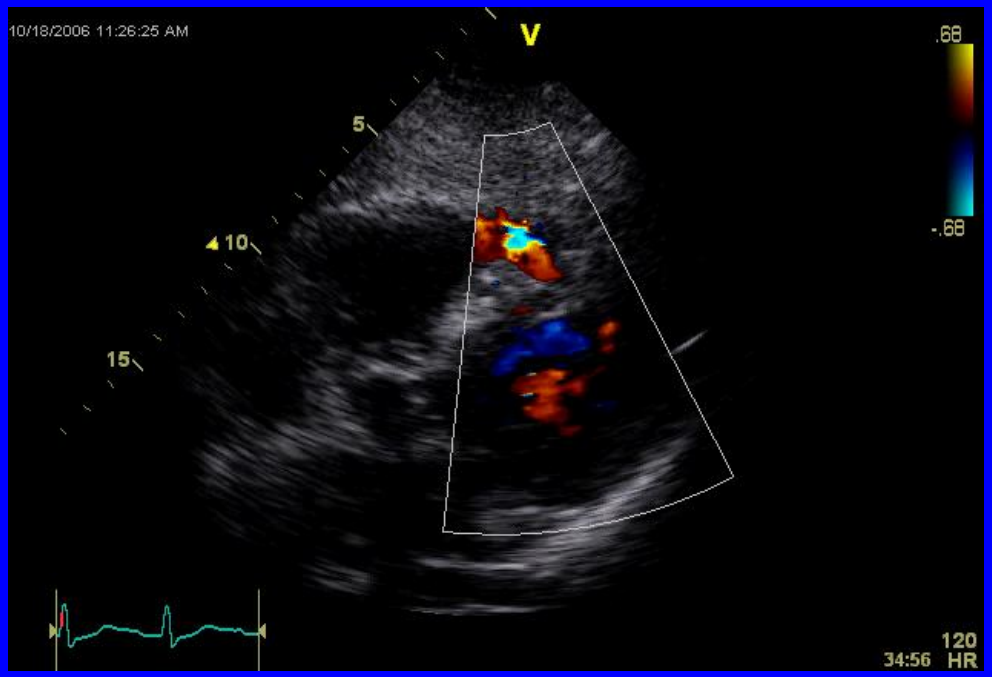
V
10
20
96
2:53 HR


07/08/2010 10:02:00 AM
V
.50
-.50
10
20
97
2:25 HR


10/18/2006 11:26:25 AM
V
.68
-.68
5
10
15
120
34:56 HR

Ventricular Septal Rupture

- Treatment
  - Medical therapy
    - Diuretics
    - Inotropes
    - Vasodilators
    - IABP
  - Surgery
  - Percutaneous closure

Papillary Muscle Rupture

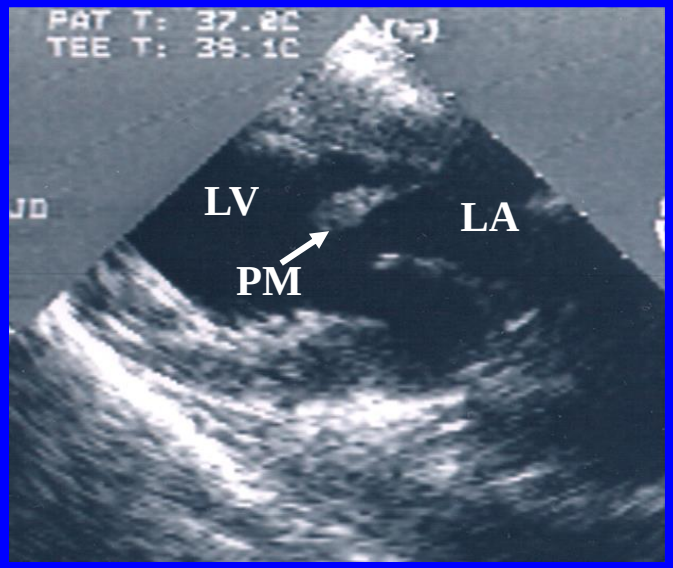
- Least common mechanical complication
- Pathology
  - Complete
  - Partial
    - Muscle heads/tips
- Posteromedial papillary muscle more often involved
  - Single blood supply
- Often occurs with relatively small infarcts
  - Poor collaterals

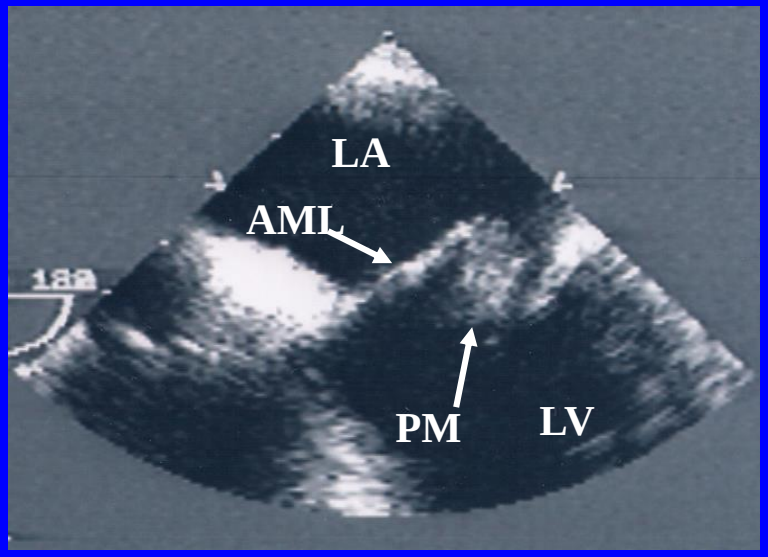
Papillary Muscle Rupture

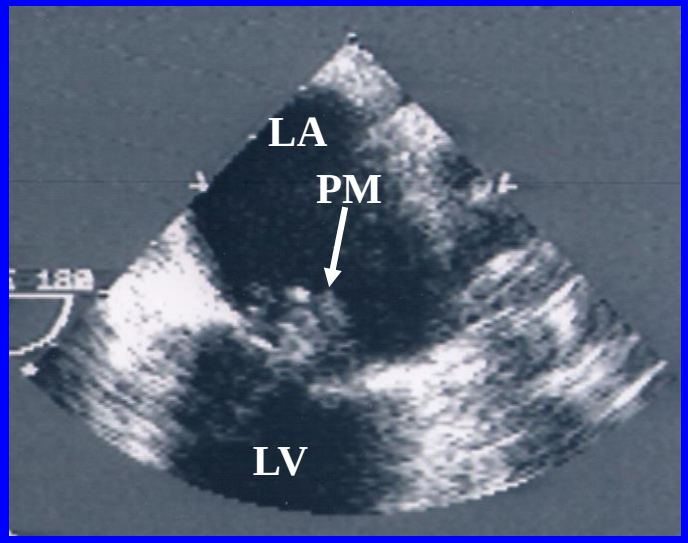
- Pathophysiology
  - Acute volume overload into noncompliant LA
  - Massive increases in LA and pulmonary artery pressures
  - Low cardiac output state
- Presentation
  - 1-to-7 days after MI
  - Heart failure
  - Shock
  - MR murmur
    - May be soft/indistinct
    - Often no thrill present (vs. VSR)

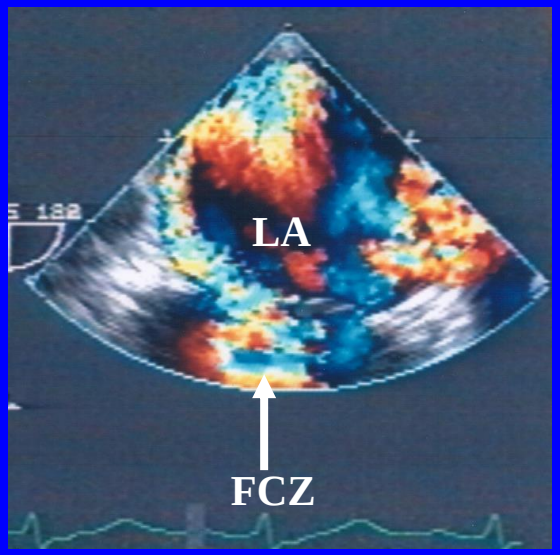
Papillary Muscle Rupture: Echocardiographic Features

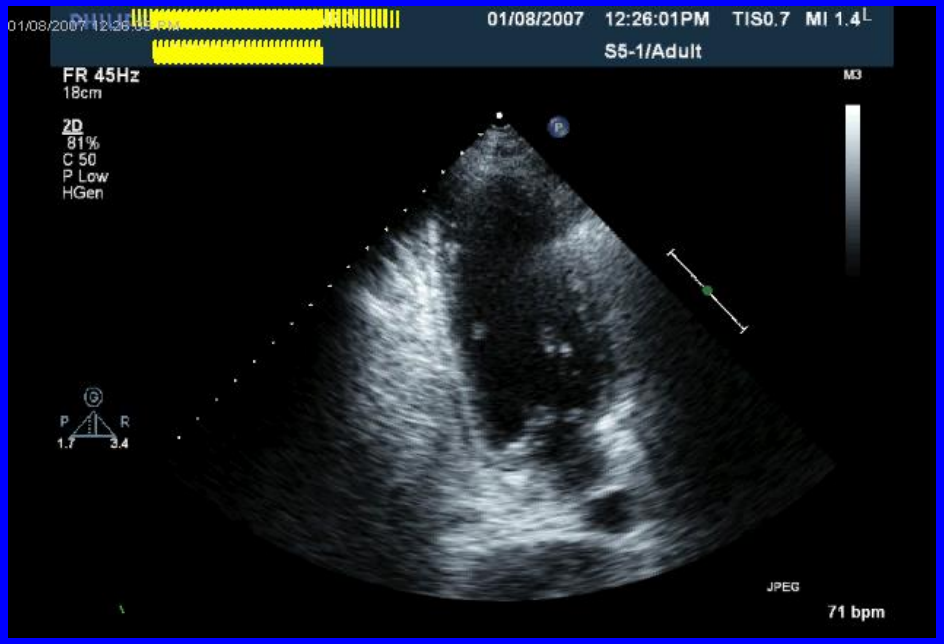
- Flail mitral leaflet with systolic cusp prolapse into the LA
- Mobile echogenic mass attached to chordae tendineae and to the mitral valve
  - No prolapse of PM head into LA observed in ~35%
- Abnormal cutoff of one papillary muscle
- Severe MR
  - Color-flow disturbance area can be small
  - Cut-off sign on CW spectral profile
- Hyperdynamic LV function

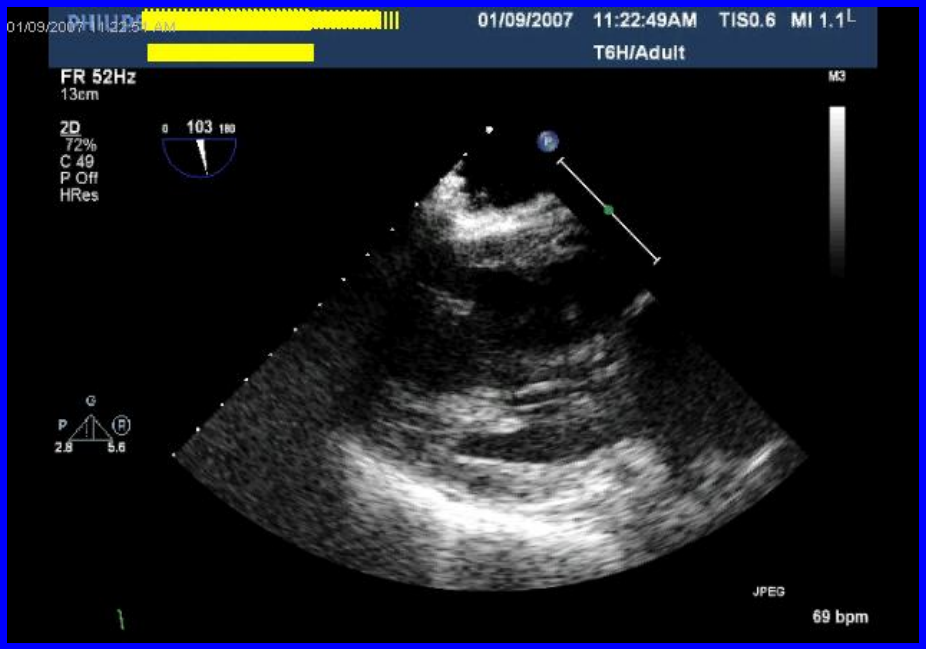

PAT T: 37.2C
TEE T: 39.1C
LV
LA
PM


LA
AML
PM
LV


LA
PM
LV


LA
FCZ


01/08/2007 12:26:01PM TIS0.7 MI 1.4
S5-1/Adult
FR 45Hz
18cm
2D
81%
C 50
P Low
HGen
M3
JPEG
71 bpm


01/09/2007 11:22:49AM TIS0.6 MI 1.1
T6H/Adult
FR 52Hz
13cm
2D
72%
C 49
P Off
HRes
103
M3
JPEG
69 bpm

Acute Mitral Regurgitation

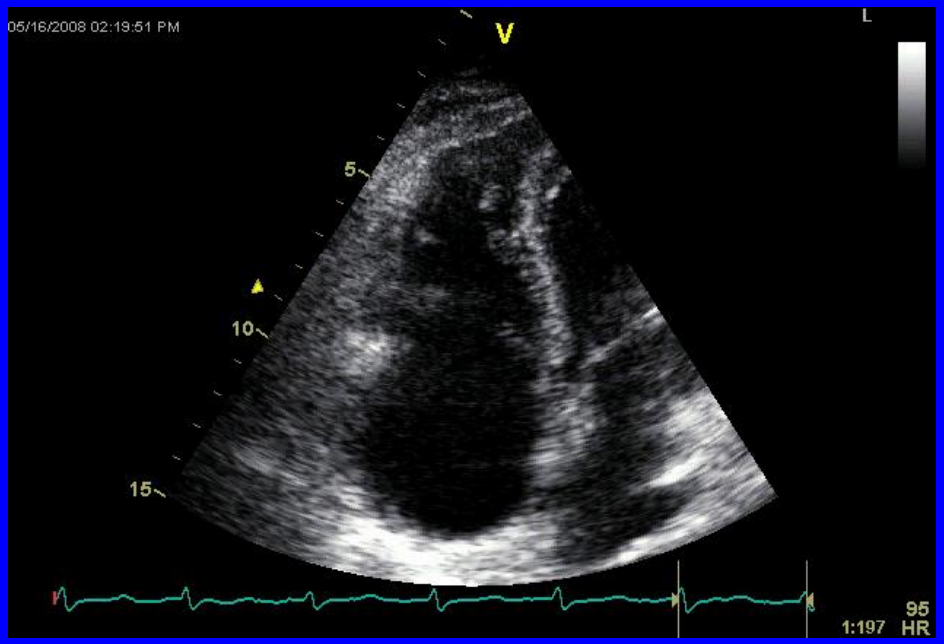
- Treatment
  - Medical therapy
    - Inotropic support
    - Diuretics
    - Afterload reduction
  - IABP
  - Surgery

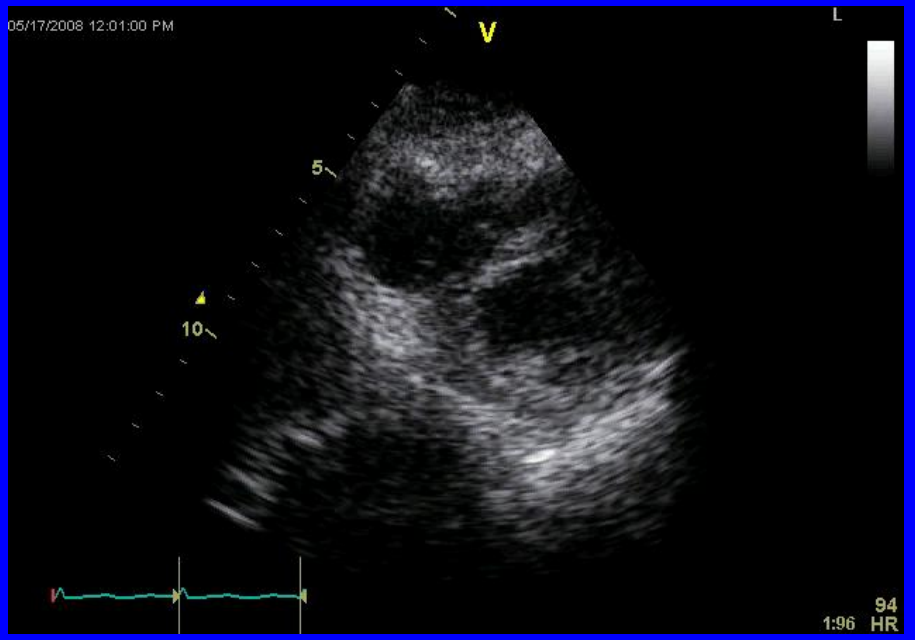
Right Ventricular MI

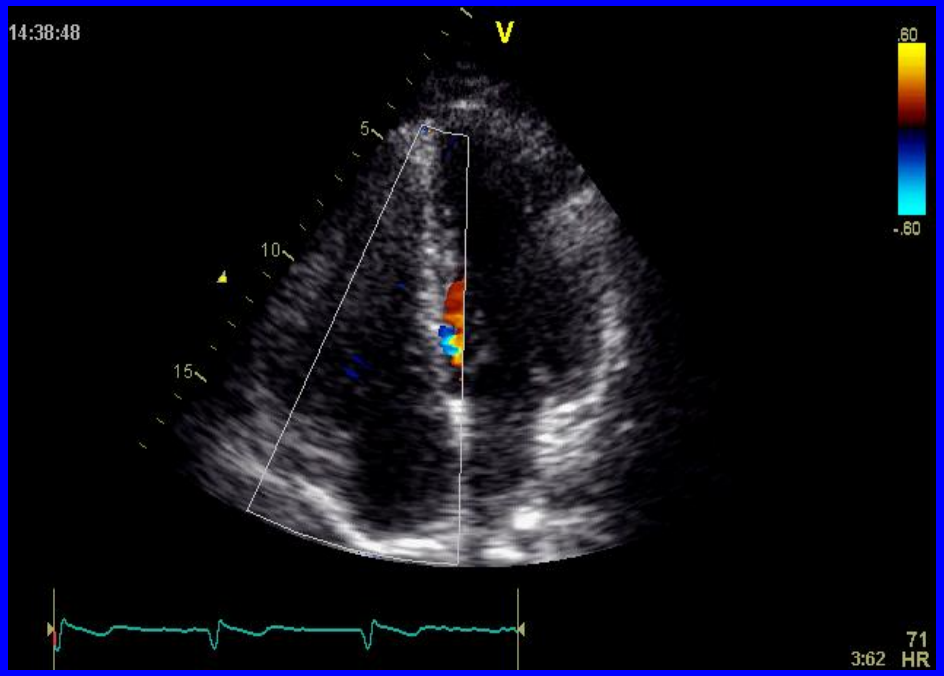
- Common association with inferior MI
  - RV apical segment may be involved with LAD occlusions
  - ST-segment elevation V1 and/or V4R-V6R
  - Mortality higher vs. IMI
- Clinical
  - Hypotension
    - Preload sensitive
  - Clear lung fields
  - Increased JVP
    - Kussmaul sign may be present
  - Lack of pulmonary congestion
  - Hypoxemia
    - Right-to-left shunting via PFO

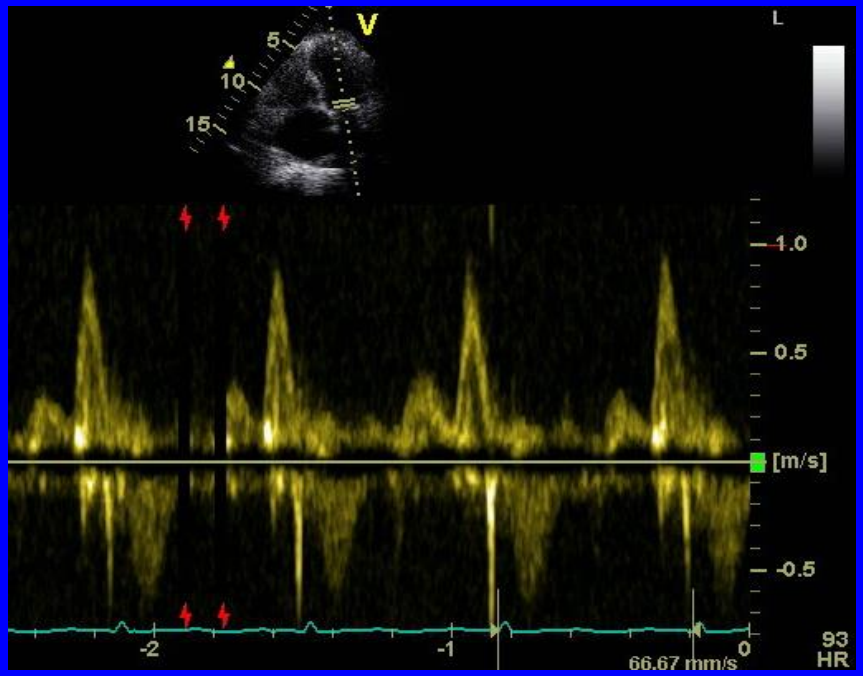
Right Ventricular MI: Echocardiographic Features

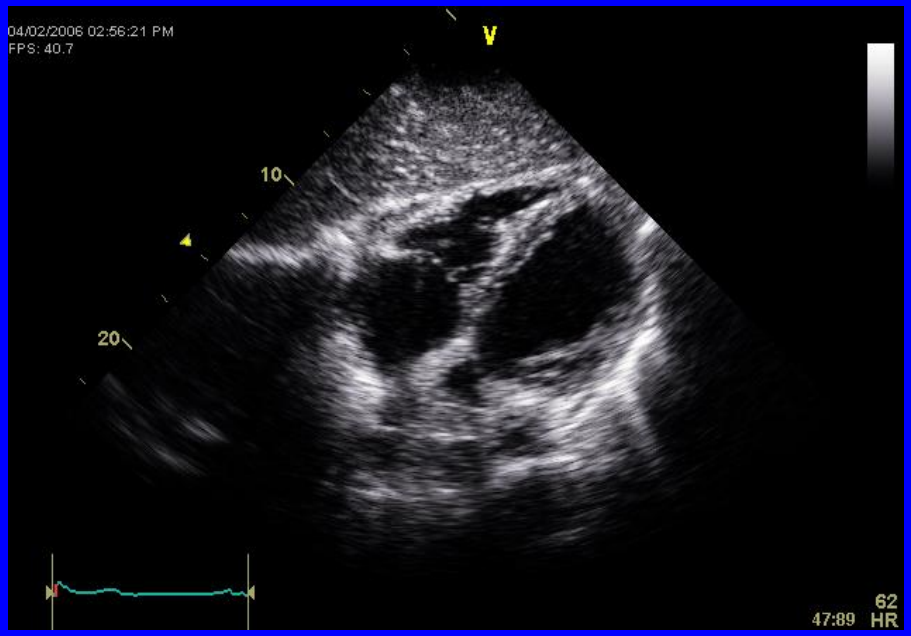
- Focal RV wall motion abnormalities
  - McConnell sign
- Paradoxical septal motion due to acute volume overload
- Dilatation of RV (and often RA)
- Small left ventricle
- Bowing of interatrial septum from right-to-left
- RV thrombus
- Tricuspid regurgitation
- Reduced systolic tricuspid annular excursion and annular velocities
- Reduced longitudinal strain
- IVC plethora
- Right-to-left shunting via PFO


05/16/2008 02:19:51 PM
V
L
5
10
15
95
1:197 HR


05/17/2008 12:01:00 PM
V
L
5
10
94
1:96 HR


14:38:48
V
.60
-.60
5
10
15
71
3:62 HR


V
L
5
10
15
1.0
0.5
[m/s]
-0.5
-2
-1
0
66.67 mm/s
93
HR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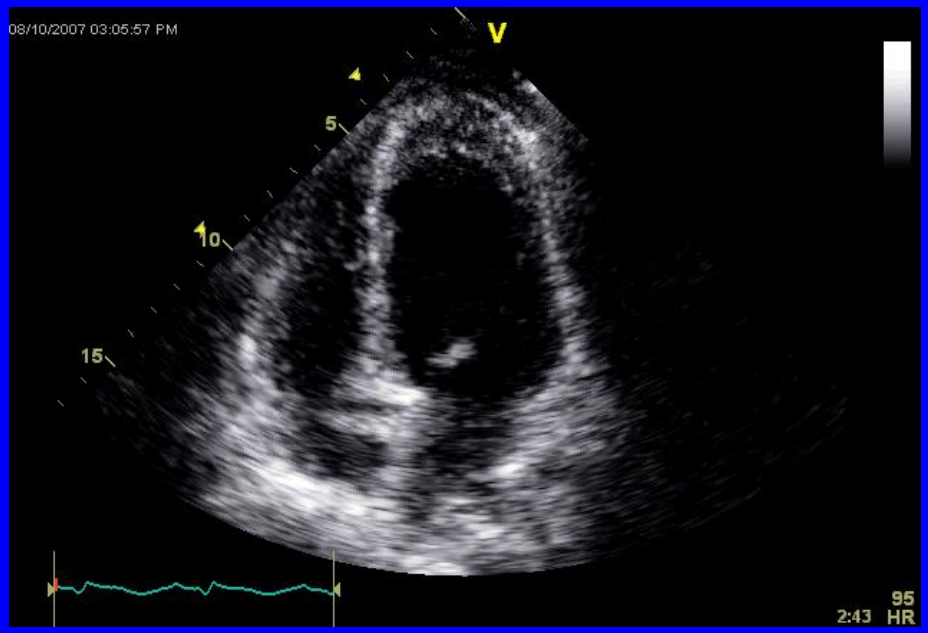
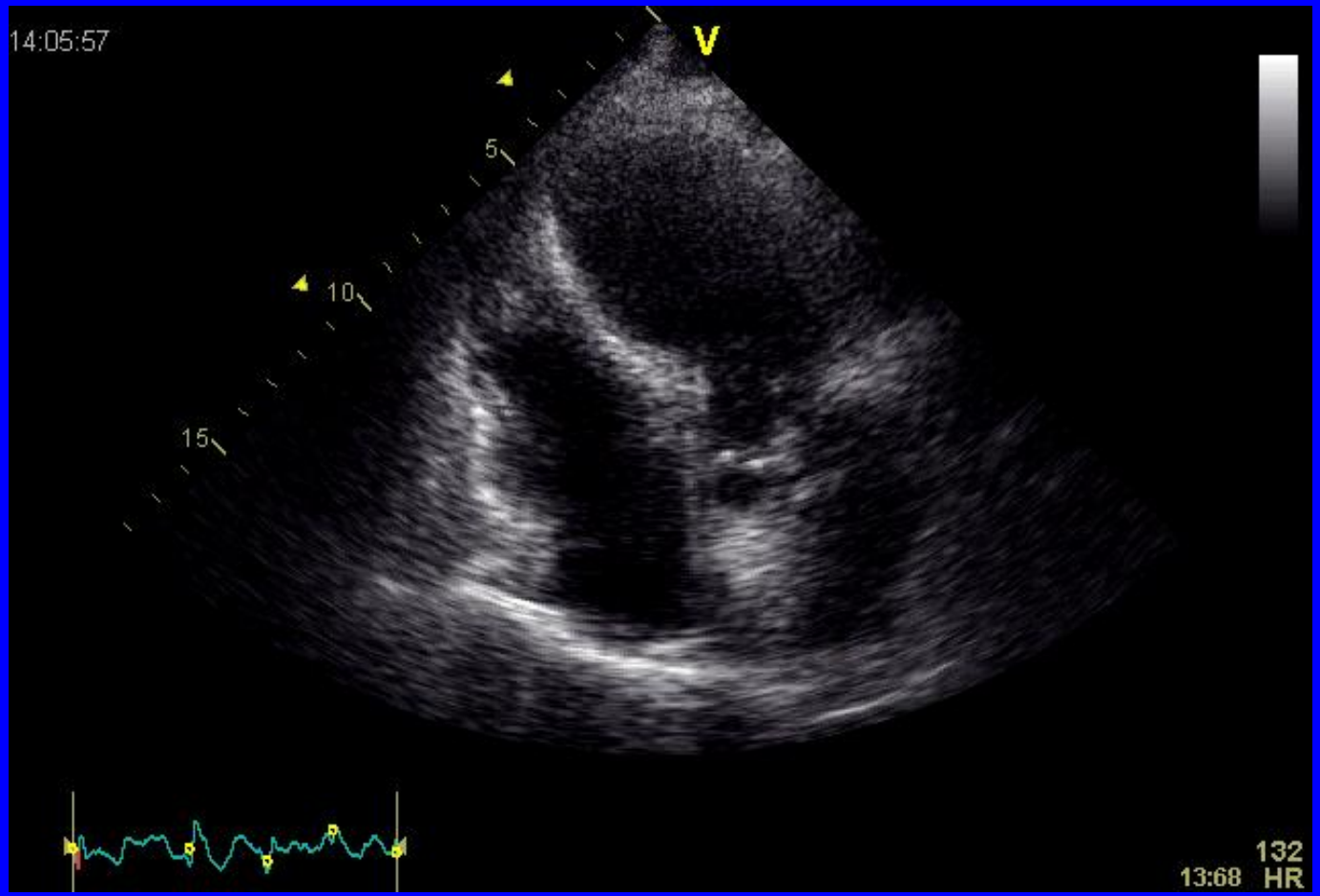
FPS: 40.7
V
10
20
62
47:89 HR


08/10/2007 03:05:57 PM
V
5
10
15
95
2:43 HR

RV involvement in Stress Cardiomyopathy

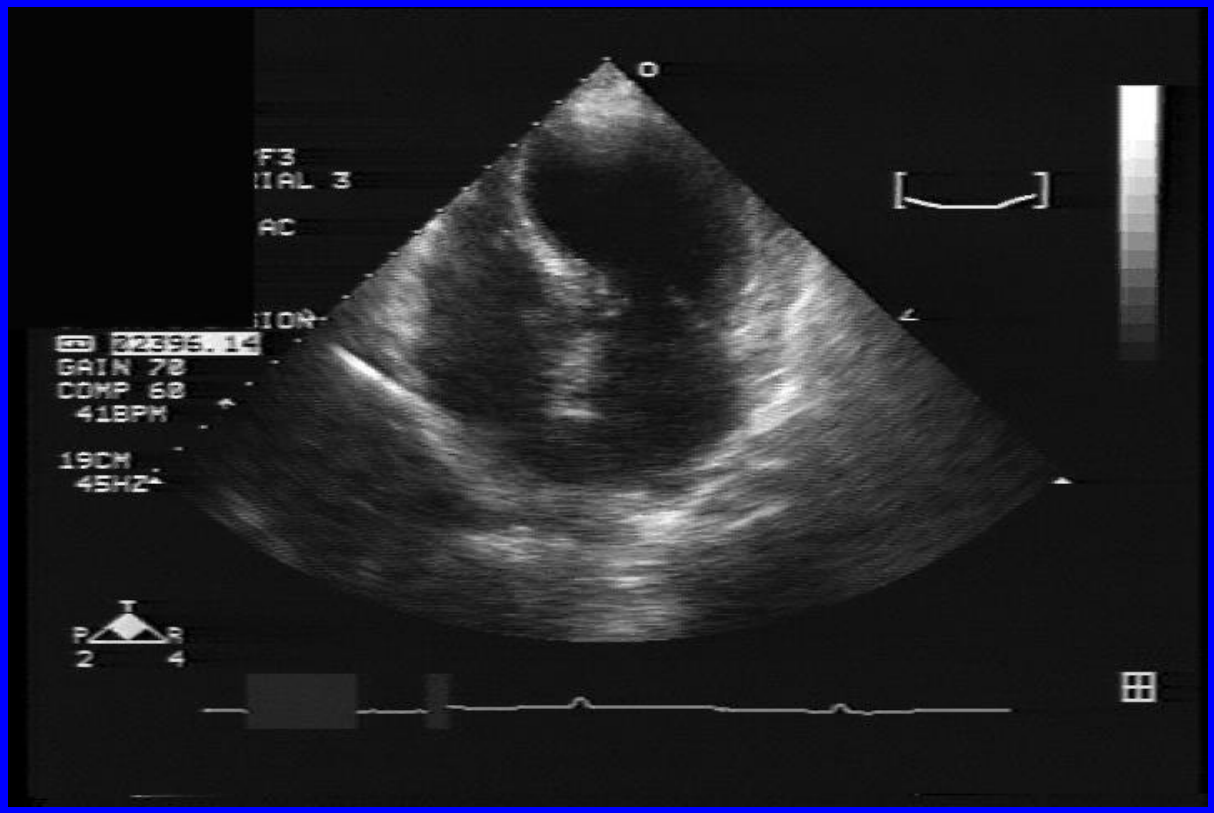


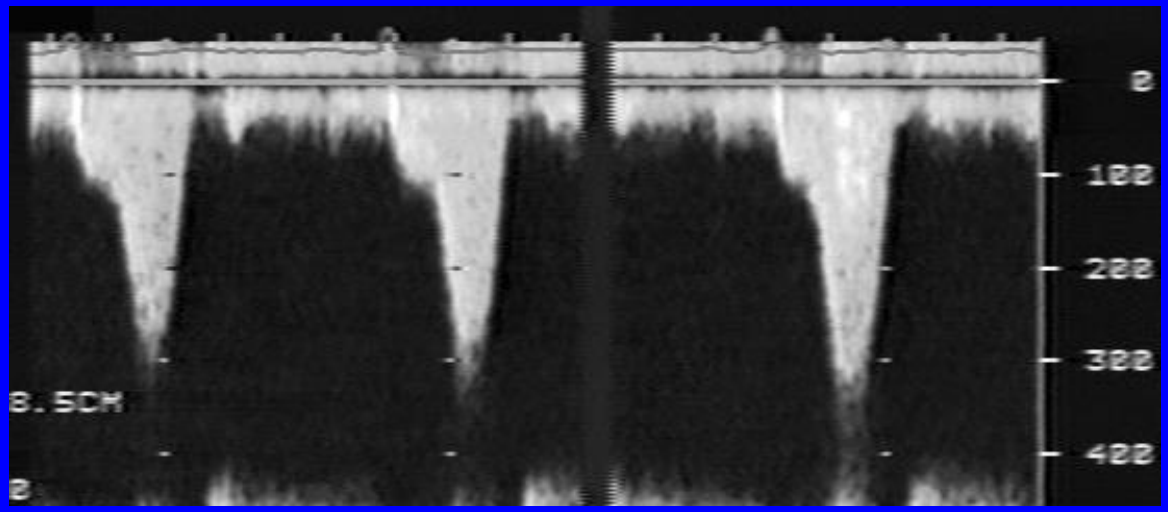
Right Ventricular MI

- Treatment
  - Mortality high for patients with shock
    - Fluids
    - Dobutamine
    - Pressor agents
    - Cardioversion
    - A-V sequential pacing
    - Revascularization
    - IABP

Dynamic LV Outflow Obstruction

- Setting of apical infarction sparing the base
- Basal hyperkinesis
  - Systolic anterior motion of the mitral valve
  - Dynamic LV outflow tract obstruction
  - Hypotension
  - Systolic murmur
- Exacerbation by inotropic agents or IABP


F3
IAL 3
AC
ION
22396.14
GAIN 70
COMP 60
41BPM
19CM
45HZ
P
R
2
4


0
100
200
300
400
3.5CM
0

Thank you for your attention

Good Luck on Your Examination