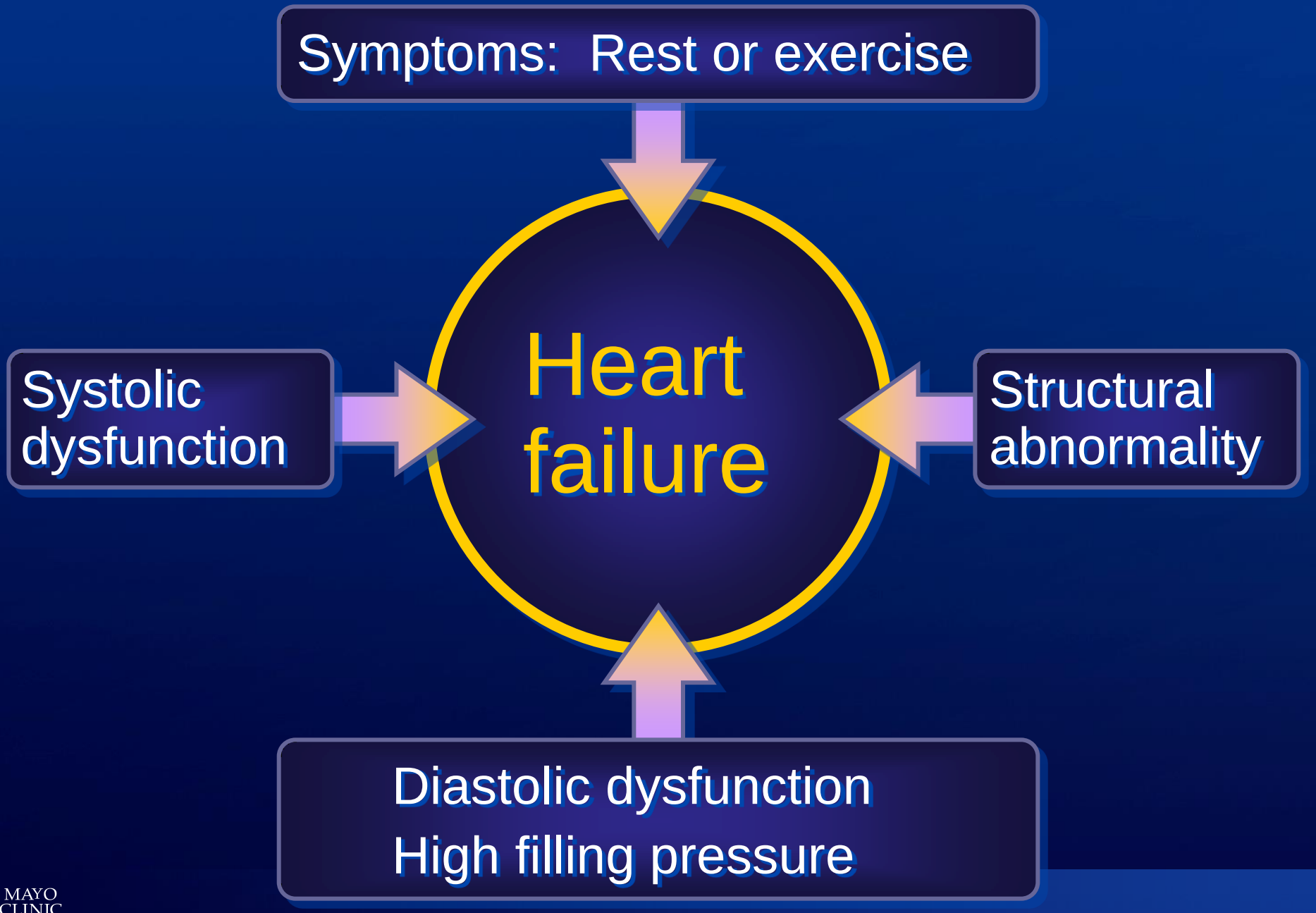
MAYO CLINIC

Echocardiography in HF
Case Studies

Jae K. Oh MD

ASE Echo Board Review 2017



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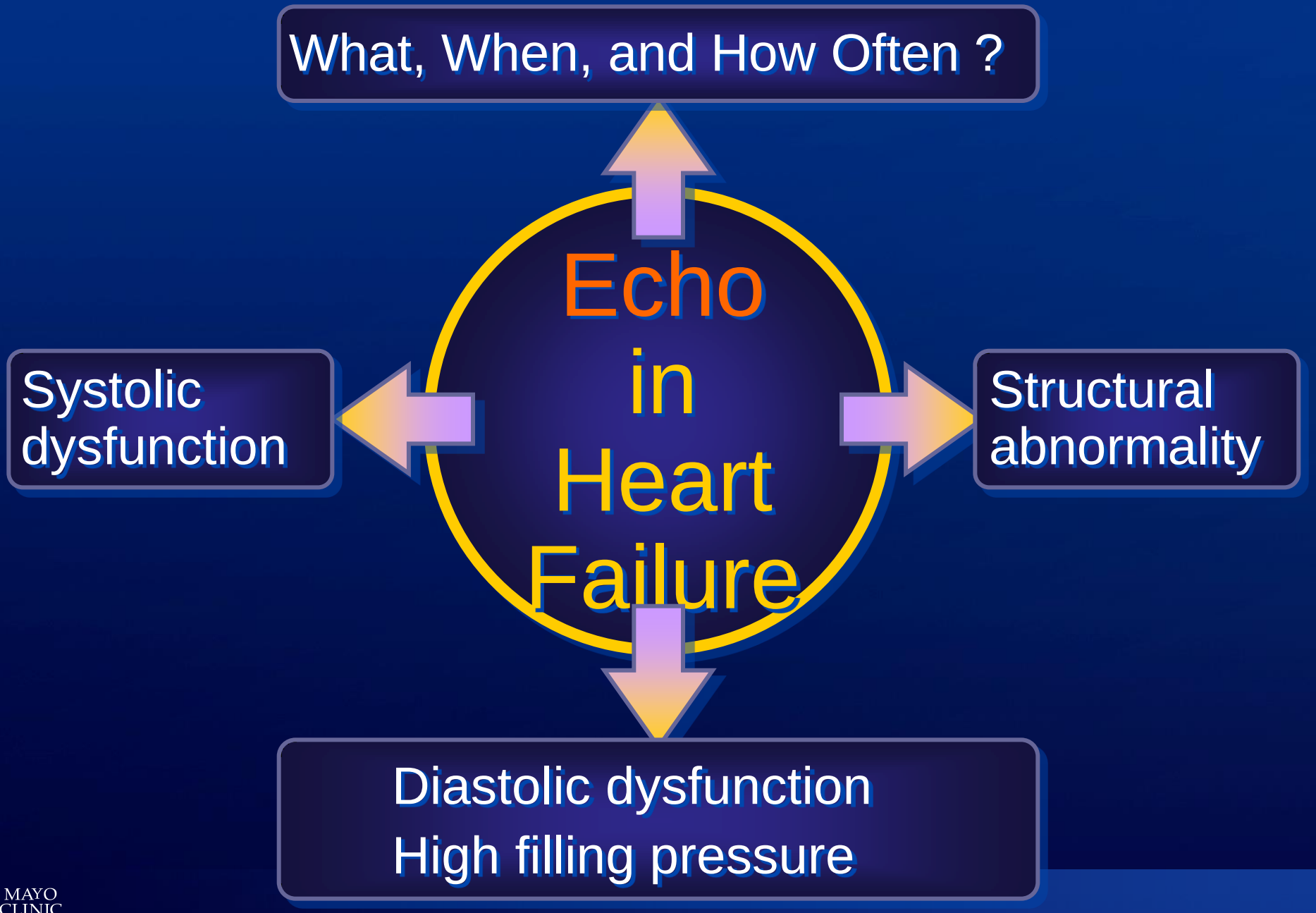

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2013 ACCF/AHA Guideline for the Management of Heart Failure

A Report of the American College of Cardiology Foundation/American Heart Association Task Force on Practice Guidelines

Developed in Collaboration With the American College of Chest Physicians, Heart Rhythm Society and International Society for Heart and Lung Transplantation

Endorsed by the American Association of Cardiovascular and Pulmonary Rehabilitation

"The single most useful diagnostic test in the evaluation of patients with HF is the comprehensive 2-dimensional echocardiogram coupled with Doppler flow studies…."

C. Yancy et al 2013

http://www.acc.org/clinical/guidelines/failure//index.pdf.

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Three fundamental questions must be addressed

1. Is the LVEF preserved or reduced ?
2. Is the structure of the LV normal or abnormal?
3. Are there other structural abnormalities

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http://www.acc.org/clinical/guidelines/failure//index.pdf.

Six fundamental questions must be addressed

1. Is the LVEF preserved or reduced ?
2. Is the structure of the LV normal or abnormal?
3. Are there other structural and/or hemodynamic abnormalities ?
4. Is diastolic function or filling pressure normal or abnormal ?
5. Is strain normal or abnormal ?
6. How Echo can help in managing HF ?

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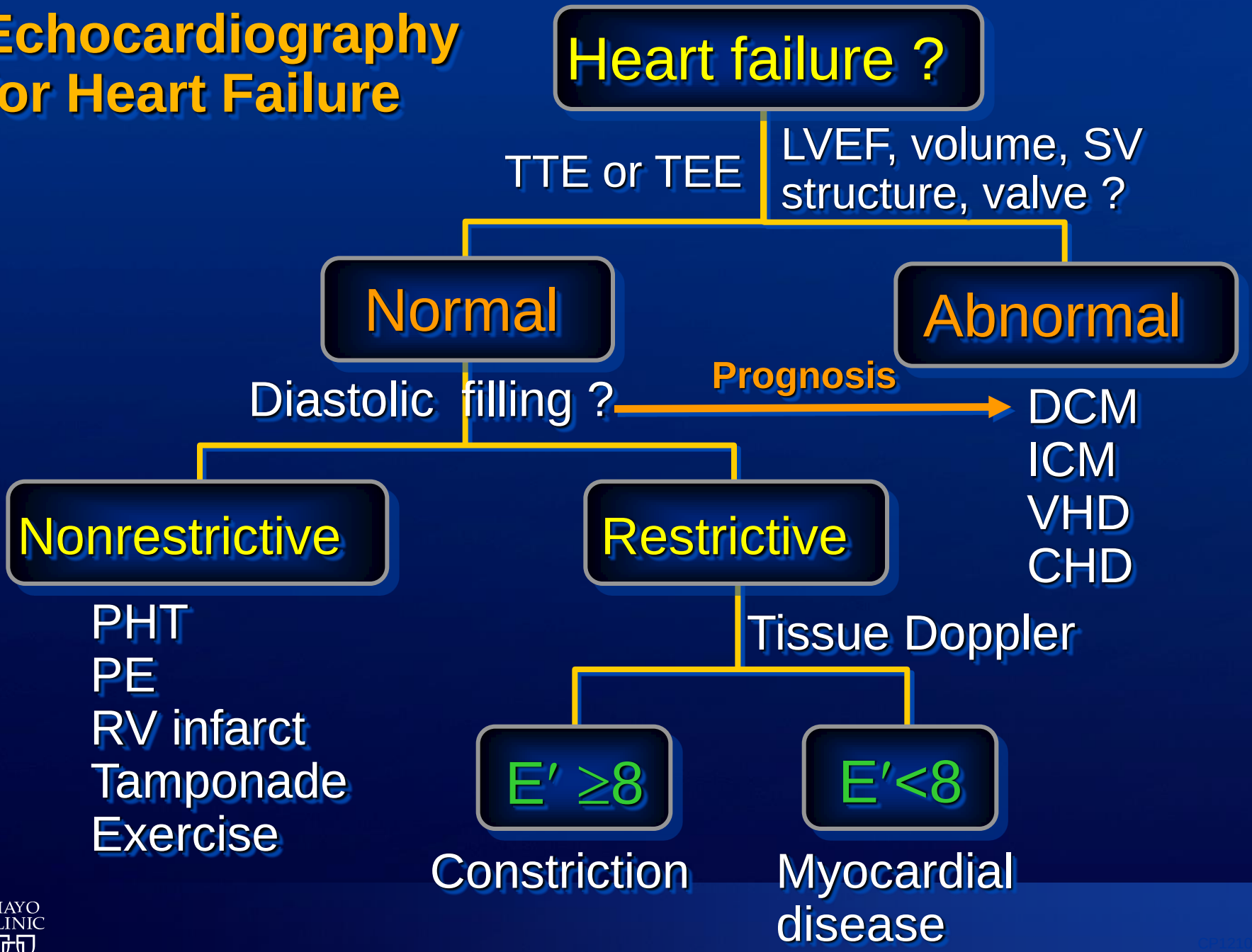
Echocardiography for Heart Failure



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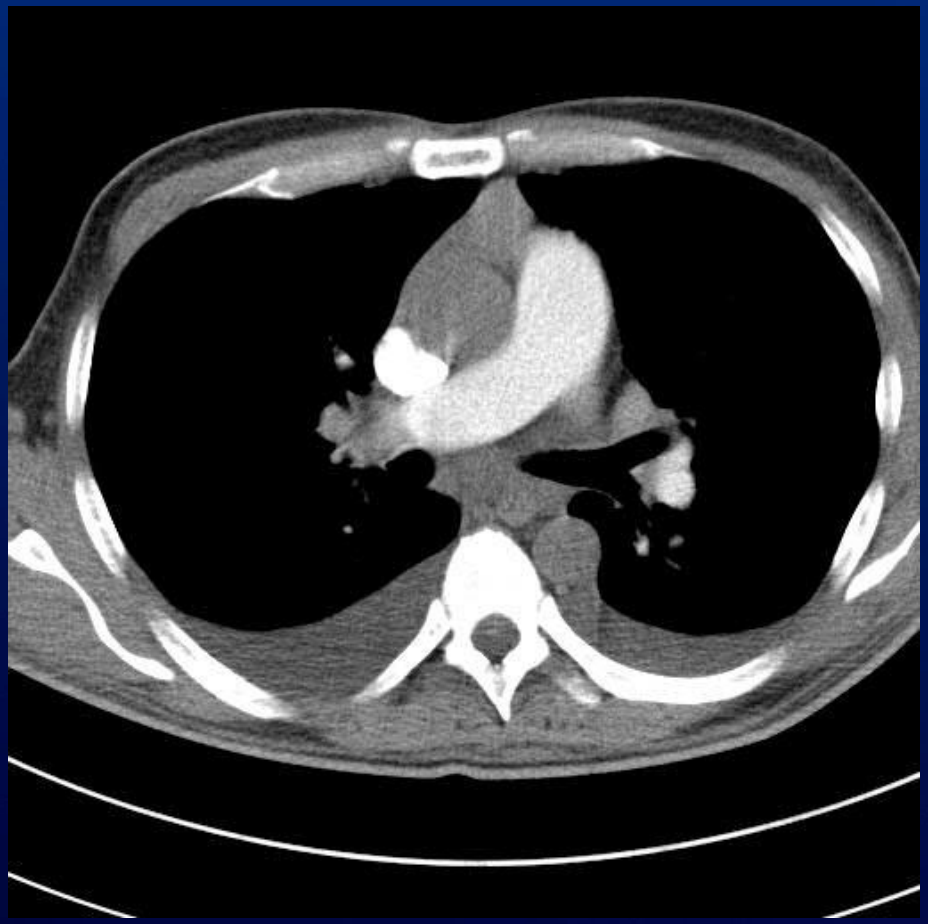
42 year old man with dyspnea

- Gradual onset of chest tightness and dyspnea
- Seen in the ED
- Chest CT negative except for bilateral pleural effusion
- Sent for cardiology evaluation
- Physical Examination
  - HR 90 BPM, JVP 7 cm
  - Increased S2 intensity with GR 1/6 systolic murmur
  - Mild pitting edema

42 year old man with dyspnea



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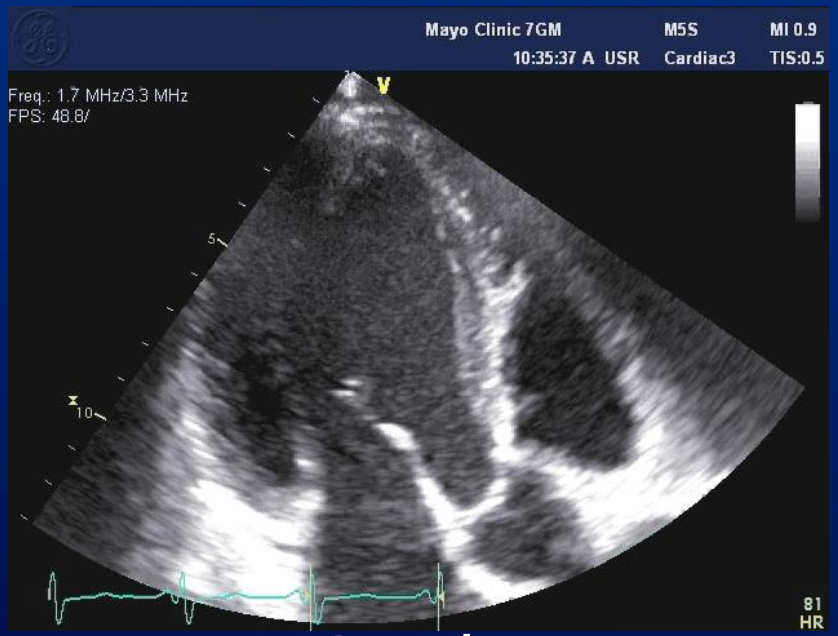
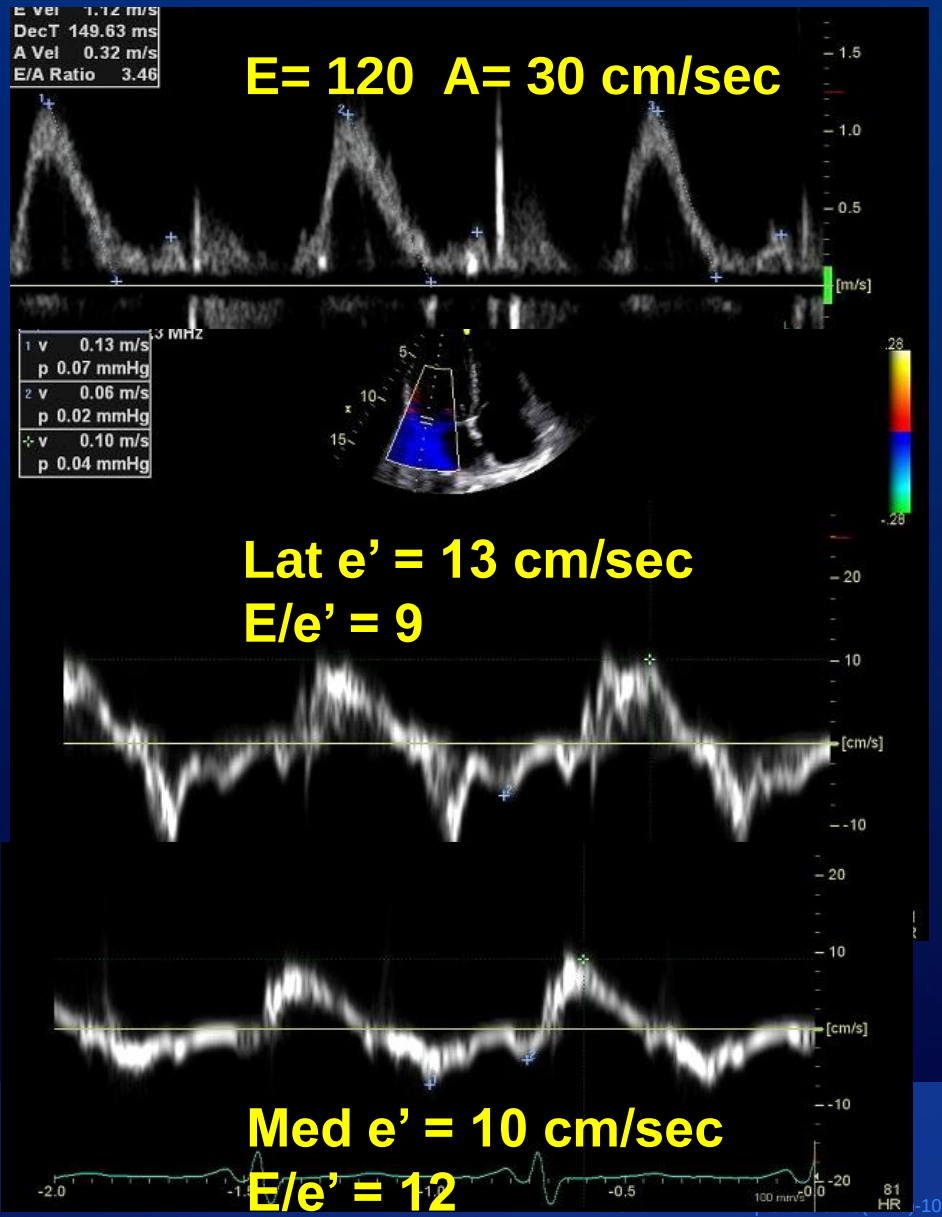
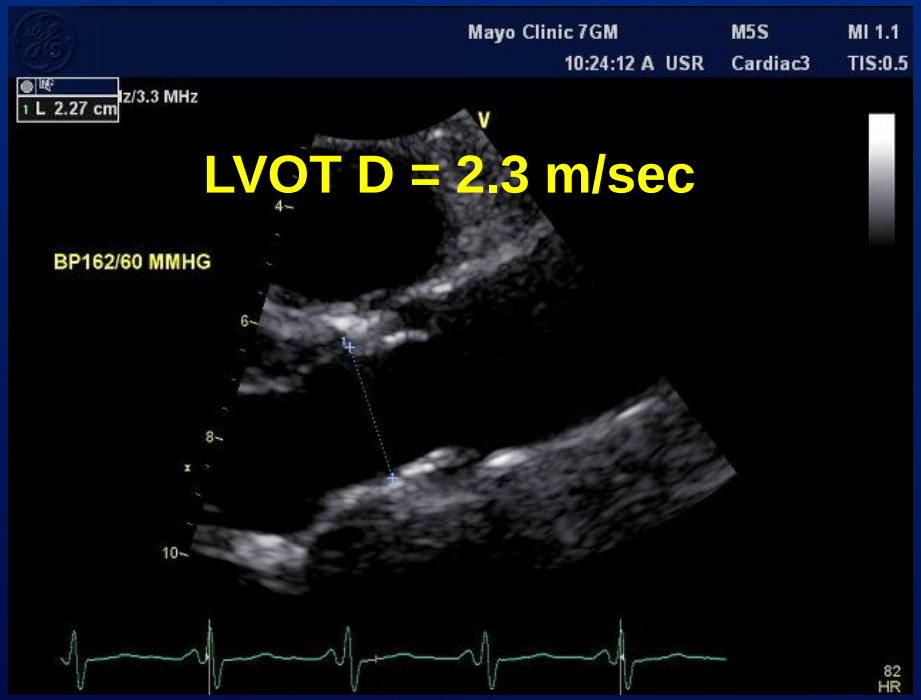
42 year old man with dyspnea
What is his diastolic function?



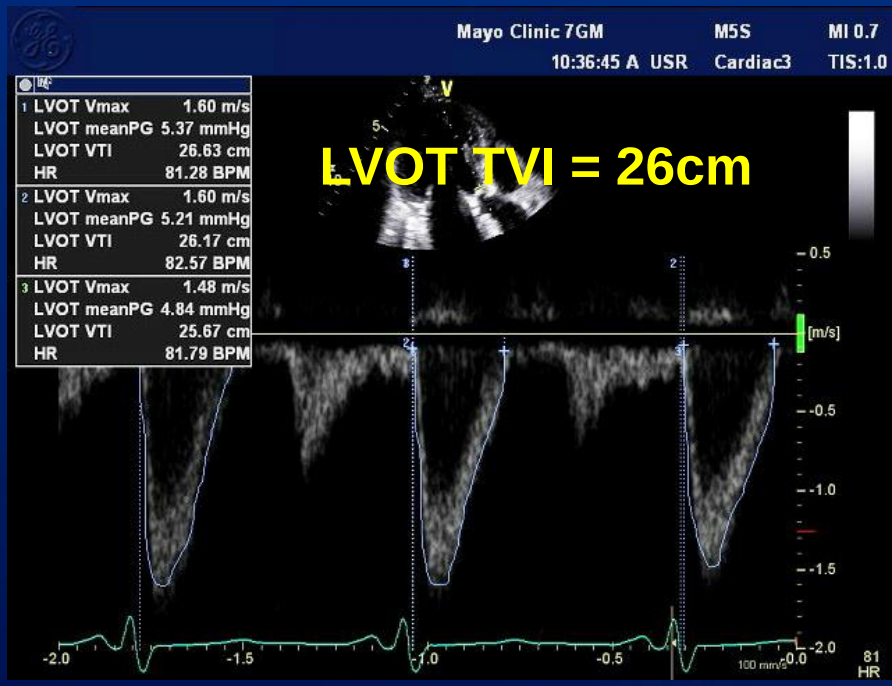
1. Grade 1
2. Grade 2
3. Grade 3
4. Normal
5. Constriction



42 year old man with dyspnea



LVOT D = 2.3 m/sec



LVOT TVI = 26cm

$SV = (2.3)^2 \times 0.785 \times 26 = 108$ mL

$CO = SV \times HR = 108 \times 80 = 8.6$ L

$CI = CO/BSA = 8.6 / 1.93 = 4.48$ L/m^2

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What is the most common cause of HF seen in this 42 year old man?

$SV = (2.3)^2 \times 0.785 \times 26 = 108$ mL

$CO = SV \times HR = 108 \times 80 = 8.6$ L

$CI = CO/BSA = 8.6 / 1.93 = 4.48$ L/m^2

1. Shunt
2. Obesity
3. Liver Disease
4. Pheochromocytoma

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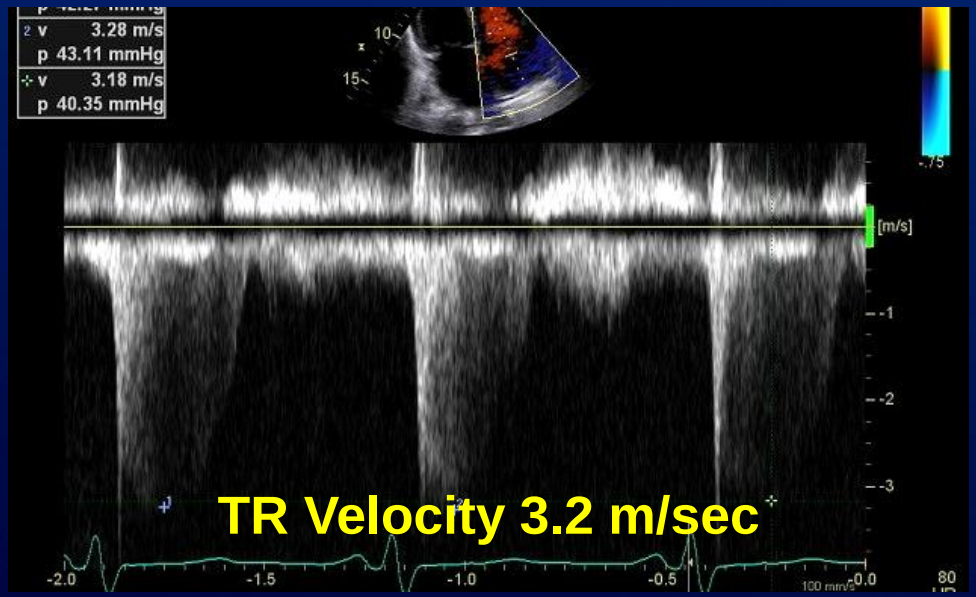
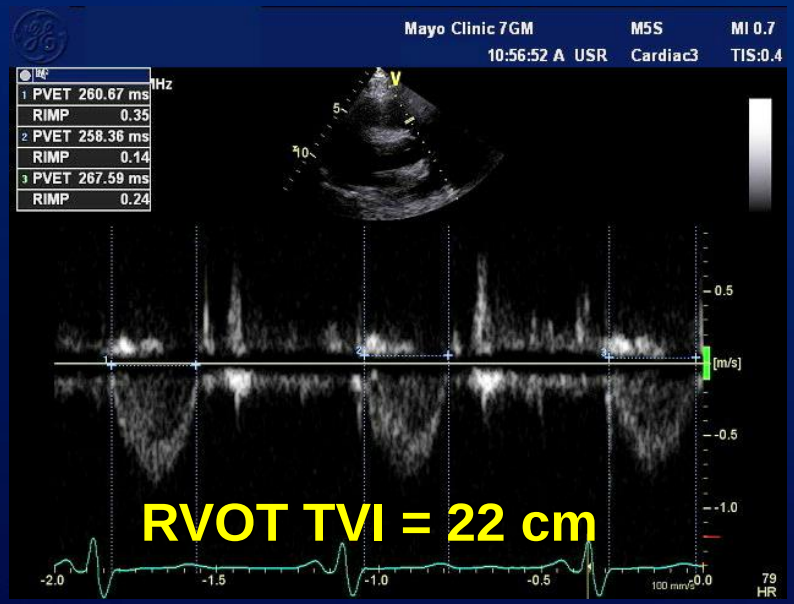
What is PA vascular resistance (PAVR) by Echo measurement?

SV= $(2.3)^2$ x 0.785 x 26 = 108 mL
CO = SV x HR = 108 x 80 = 8.6 L
CI = CO/BSA = 8.6 /1.93 = 4.48 L/m^2





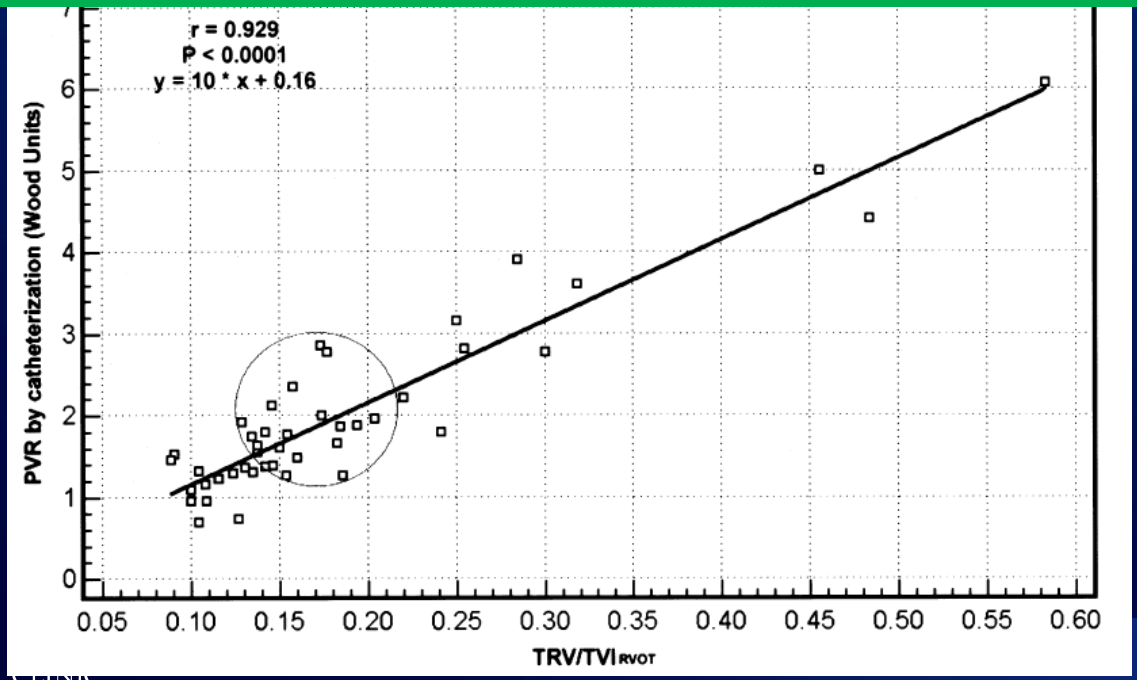
1= Mildly increased 2= Moderately increased
3= Severely increased 4= Normal

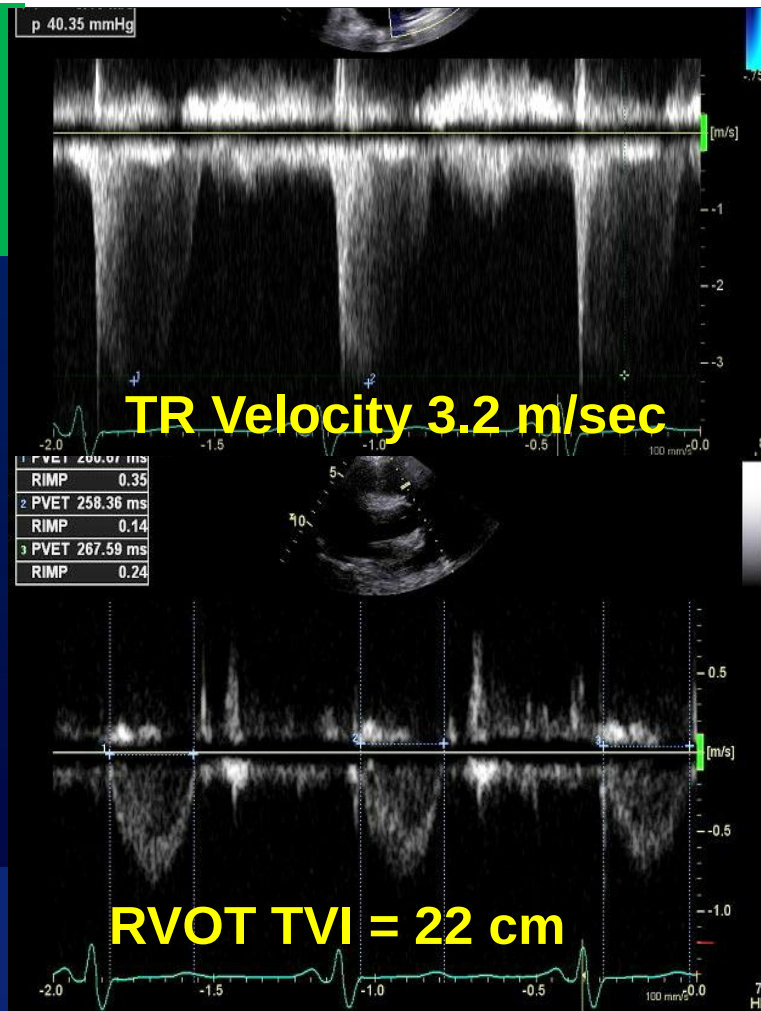
J Am Coll Cardiol 2003;41:1021–7

A Simple Method for Noninvasive Estimation of Pulmonary Vascular Resistance

Amr E. Abbas, MD,* F. David Fortuin, MD,* Nelson B. Schiller, MD, FACC,†
Christopher P. Appleton, MD, FACC,* Carlos A. Moreno, BS,* Steven J. Lester, MD, FACC*
San Francisco, California; and Scottsdale, Arizona

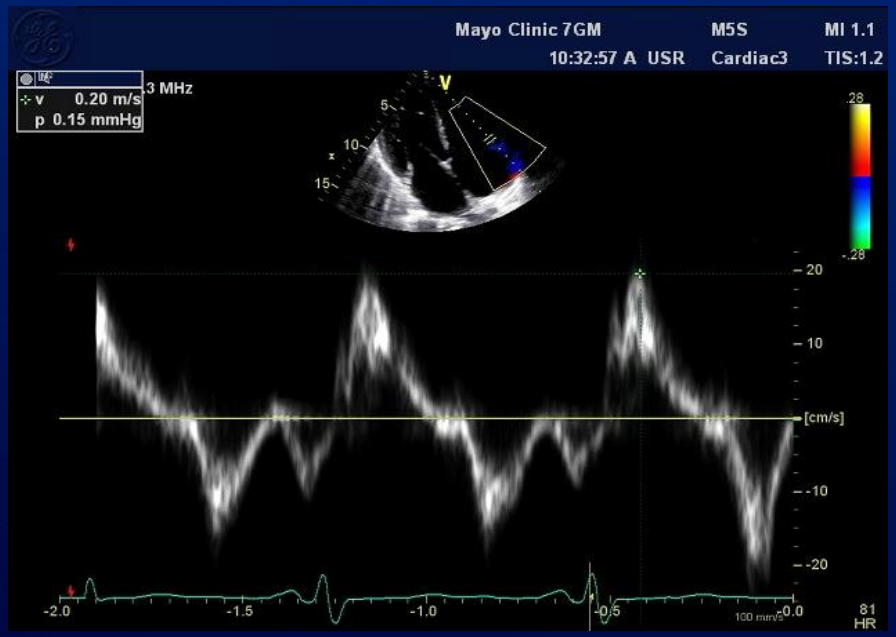
PVR = (TR Vel/ RVOT TVI) x 10 + 0.16
= (3.2/22) x10 + 0.16 = 1.42 + 0.16



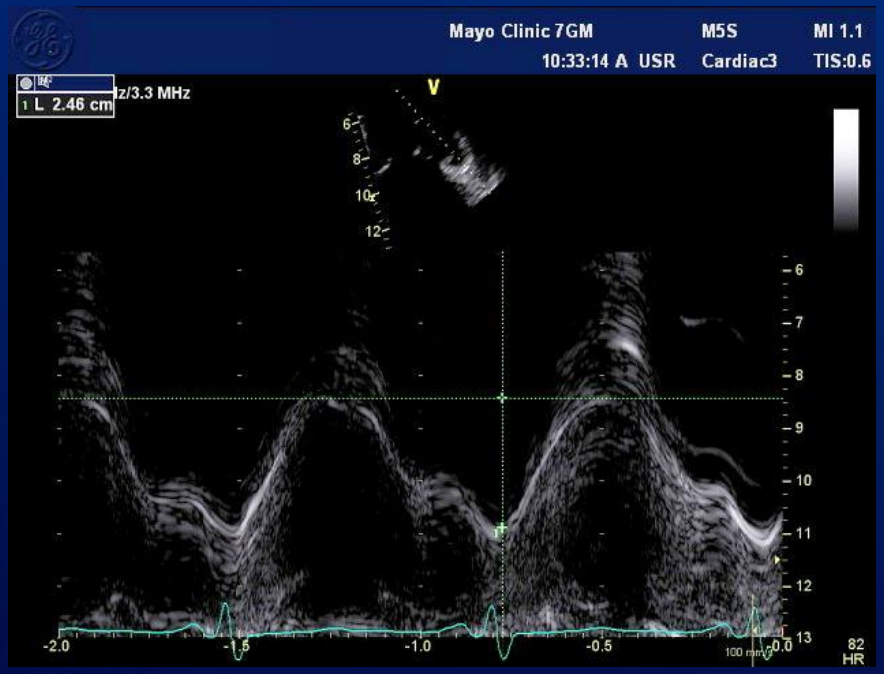


RV Function

TV S' = 20 cm/sec



TAPSE = 25 cm



His LVEDD=55, VST=13 and PWT =11mm
LV mass index = 150 gm/m^2
What is the type of his LV remodeling?

1. Normal
2. Concentric remodeling
3. Concentric hypertrophy
4. Eccentric hypertrophy

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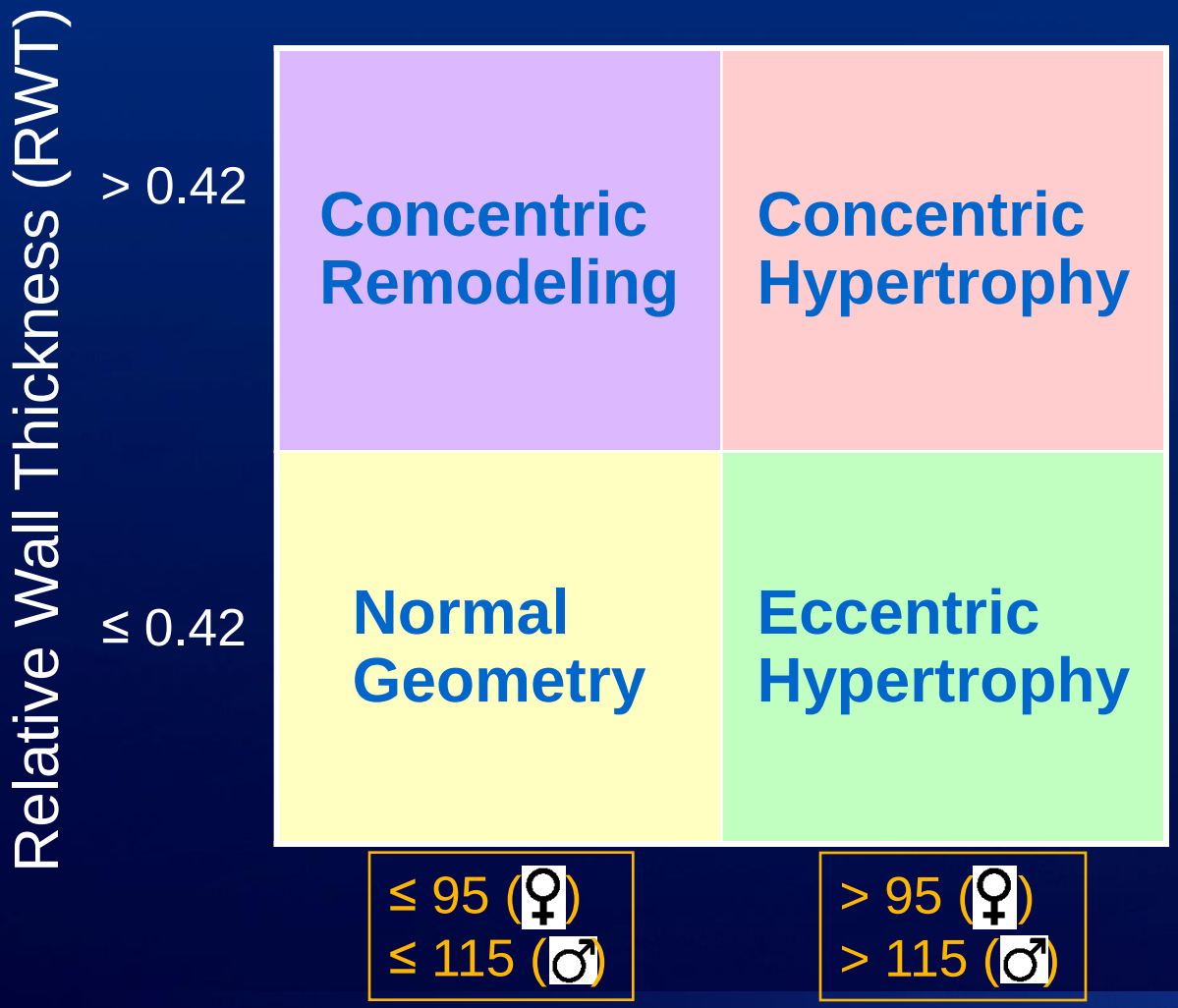
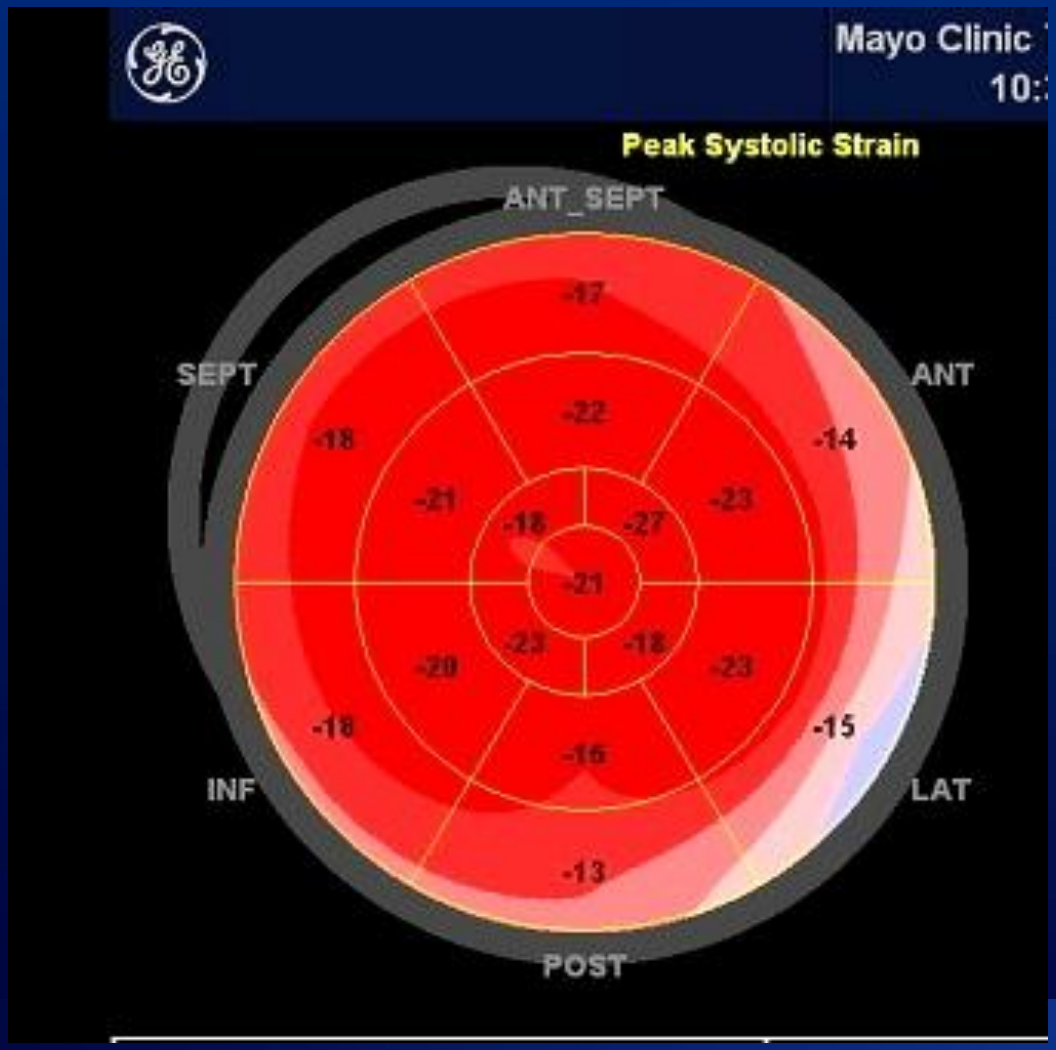
LV Geometry or Remodeling Type



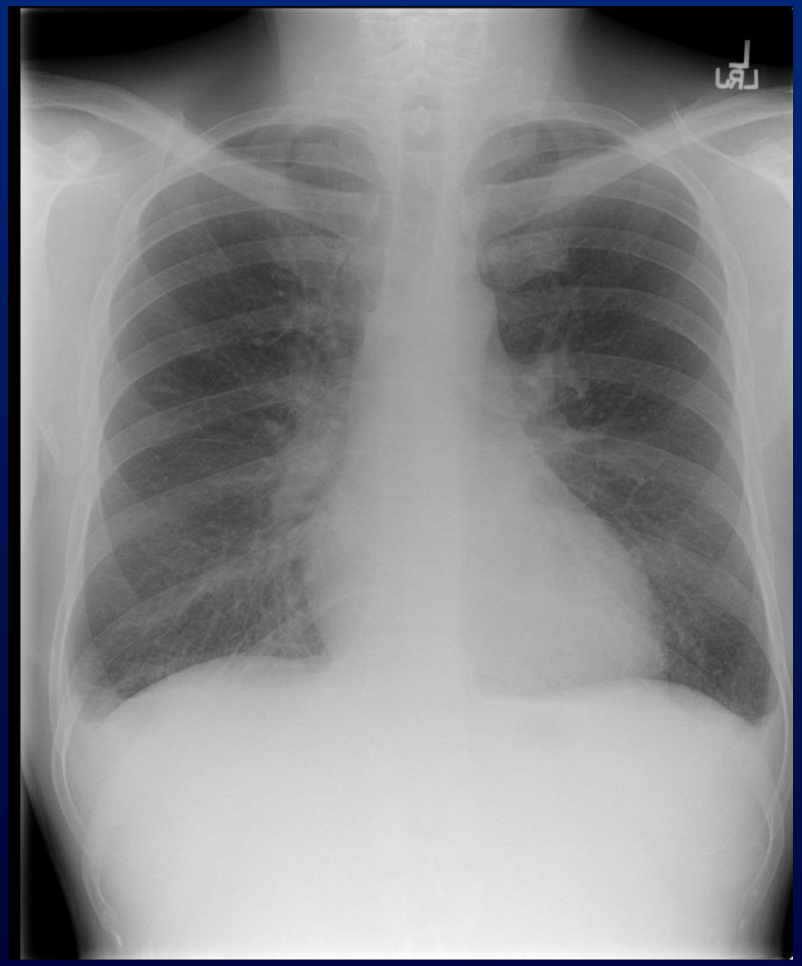
$$RWT = \frac{2 \times PWT_d}{LVID_d}$$

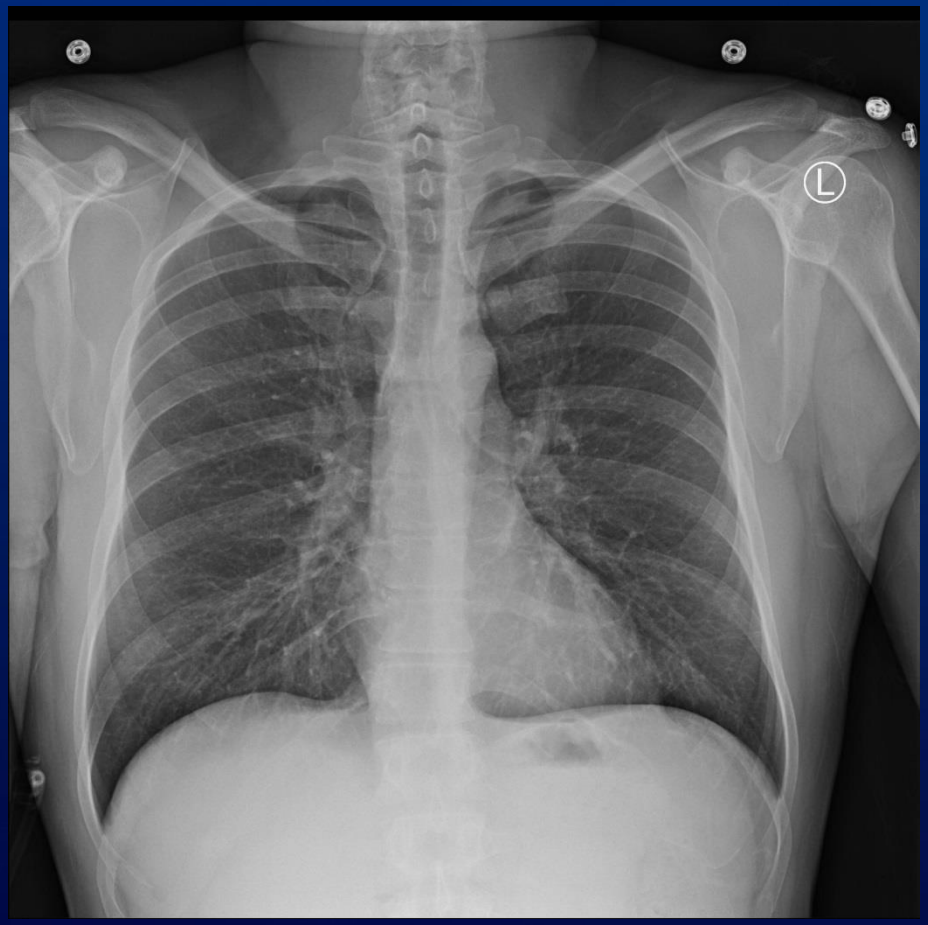
RWT = 2 x 11 / 55 = 0.40

Normal Global Longitudinal Strain - 19%



42 year old man with high output HF
Before and after treatment (Thyrotoxicosis)





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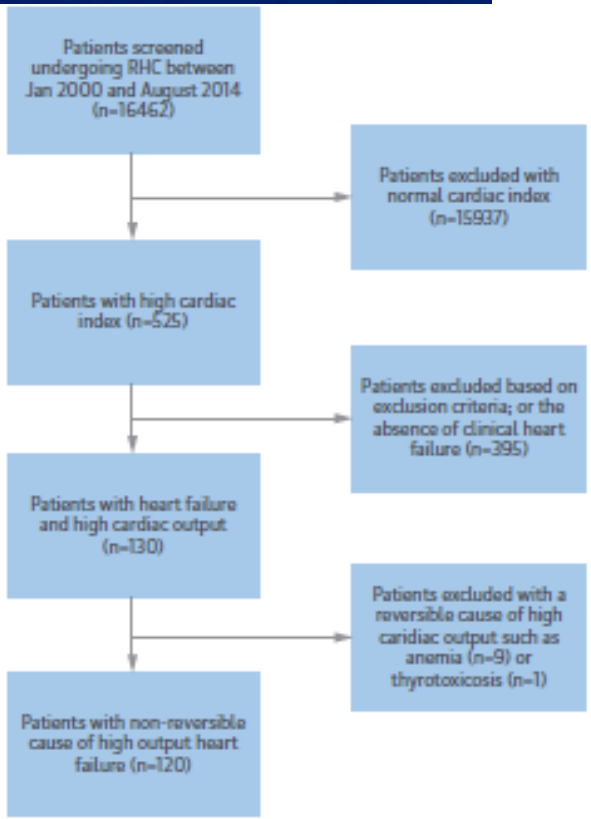
42 year old man with HF Summary

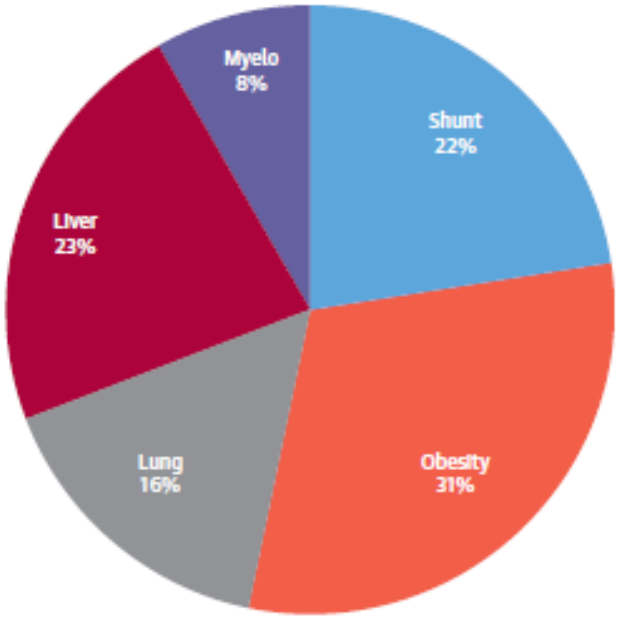
High-Output Heart Failure

A 15-Year Experience

JACC 2016

Yogesh N.V. Reddy, MD, Vojtech Melenovsky, MD, PhD, Margaret M. Redfield, MD, Rick A. Nishimura, MD, Barry A. Borlaug, MD





- CI > 4.0 L/m^2
- Obesity
- Shunt
- Liver Disease
- Diastolic function can be normal

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67 year old man with controlled hypertension and treated renal cell ca. presenting with progressive dyspnea.

- BP 120/80 mmHg
- HR 8o BPM
- JVP to the angle of the jaw
- Clear lung fields
- S3, but no murmur
- Hepatomegaly
- Pitting edema

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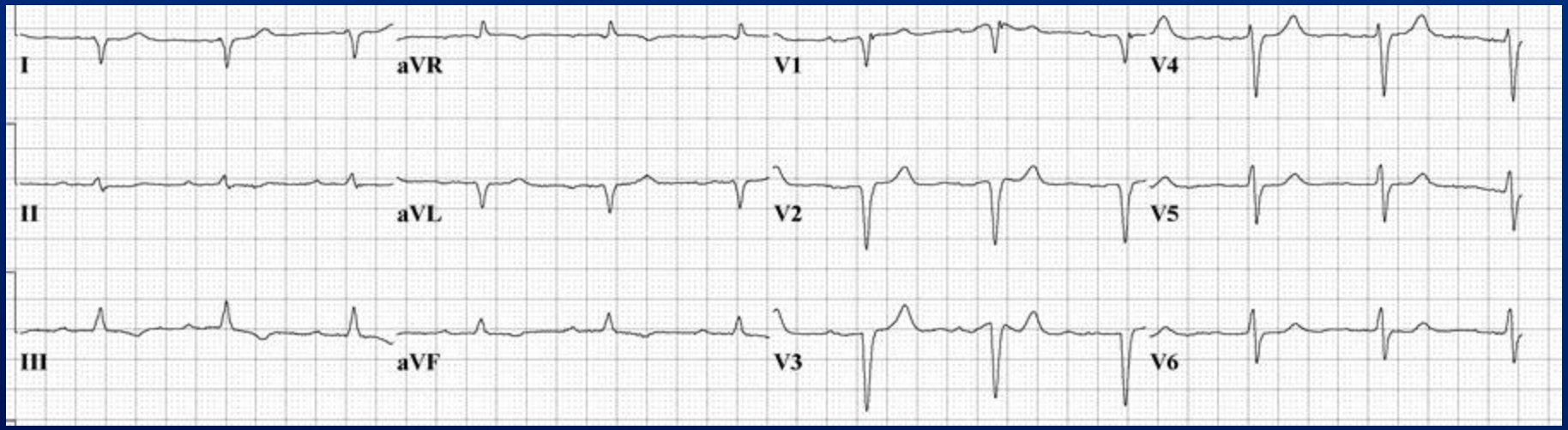
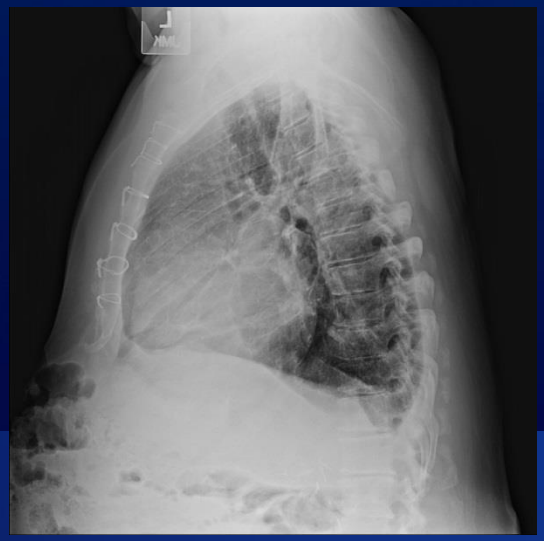
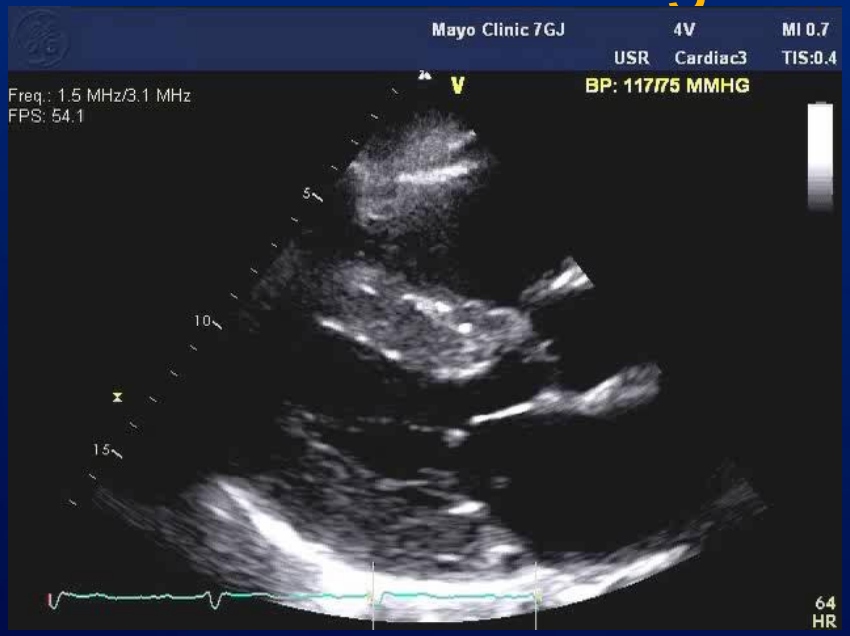
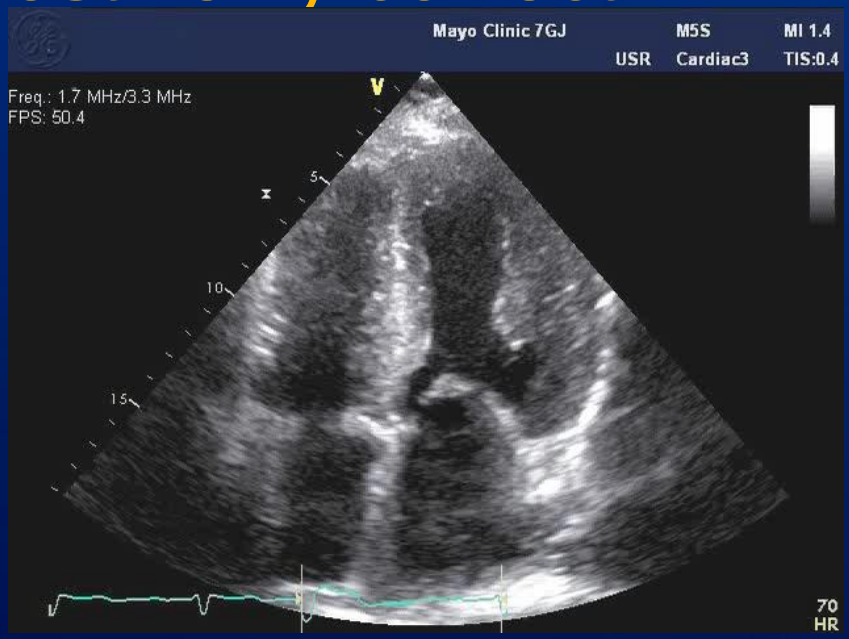
67 year old man with HF





67 year old man with HF
LVEDD 47 mm PW 18mm IVS 17 mm
LV mass index 188 gm/m^2
Which of following is most liekly correct?





1. Normal Athlete's heart
2. Hypertrophic CM
3. Concentric hypertrophy with hypertension
4. Concentric Infiltration

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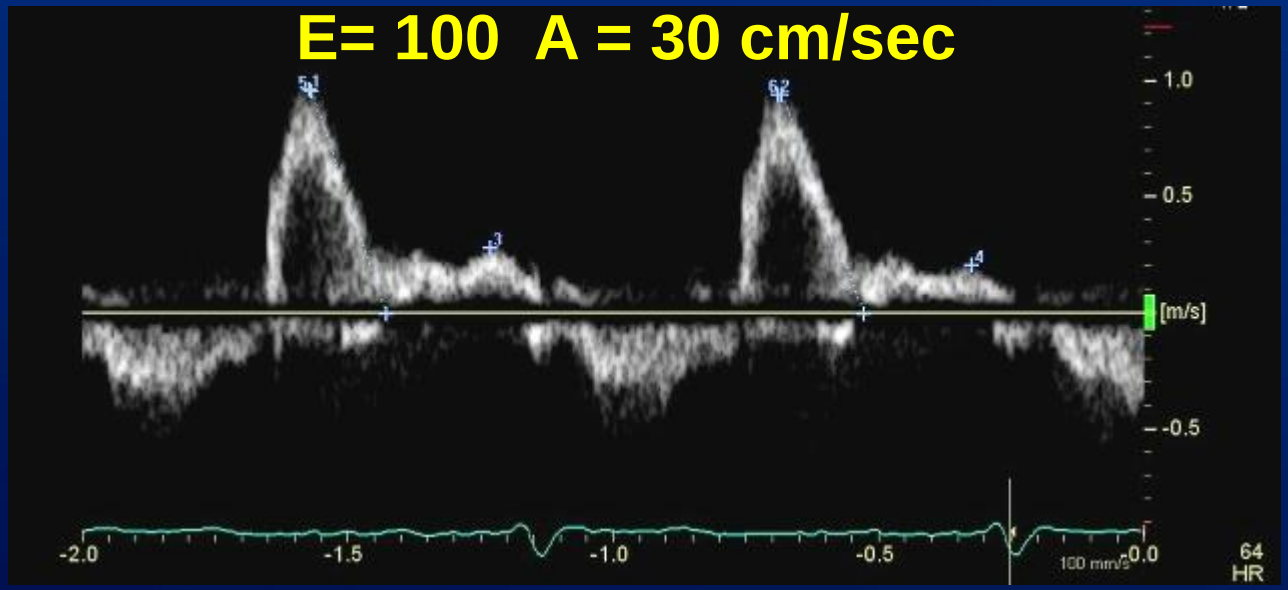
What is his diastolic function?



1. Need more information
2. Grade 2
3. Grade 3
4. Normal

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What would you expect for his mitral annulus velocities?

1. Medial e’ 4 cm/sec and lateral e’ 6 cm/sec
2. Medial e’ 6 cm/sec and lateral e’ 4 cm/sec
3. Medial e’ 8 cm/sec and lateral e’ 10 cm/sec
4. Medial e’ 10 cm/sec and lateral e’ 8 cm/sec

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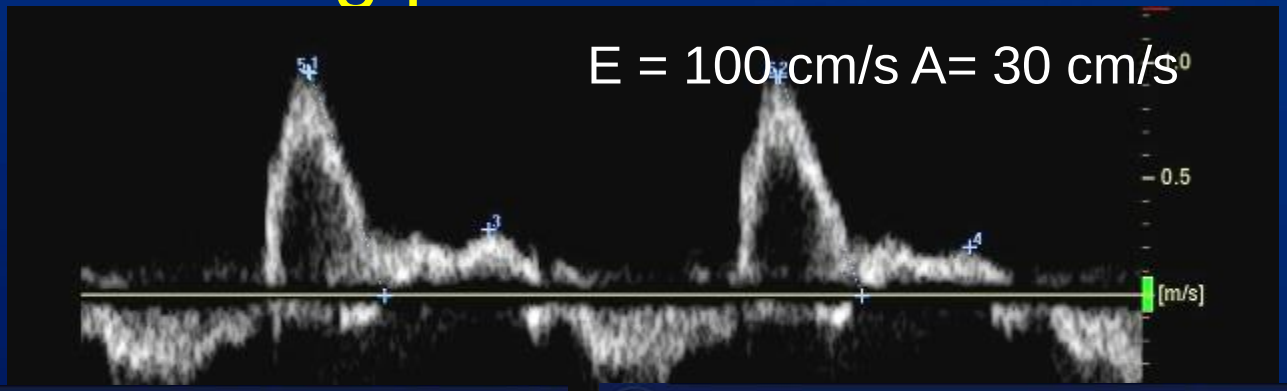
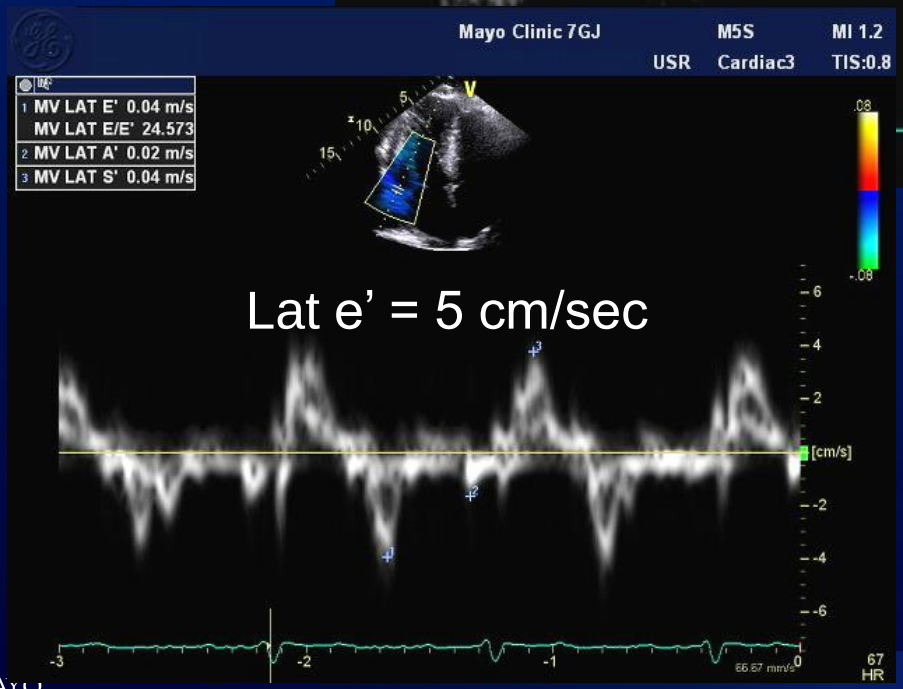
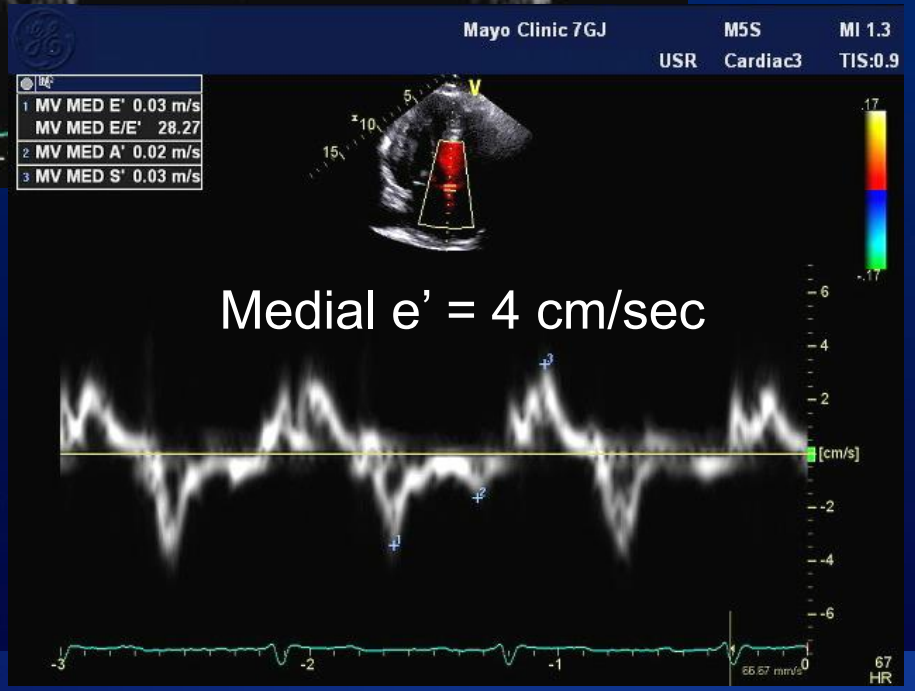
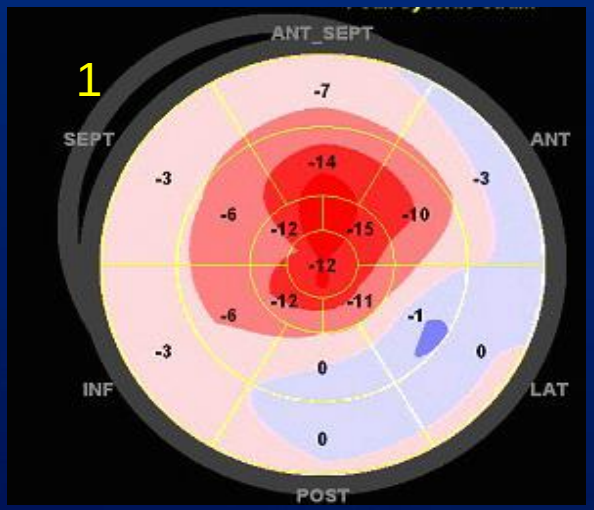
What is his filling pressure?

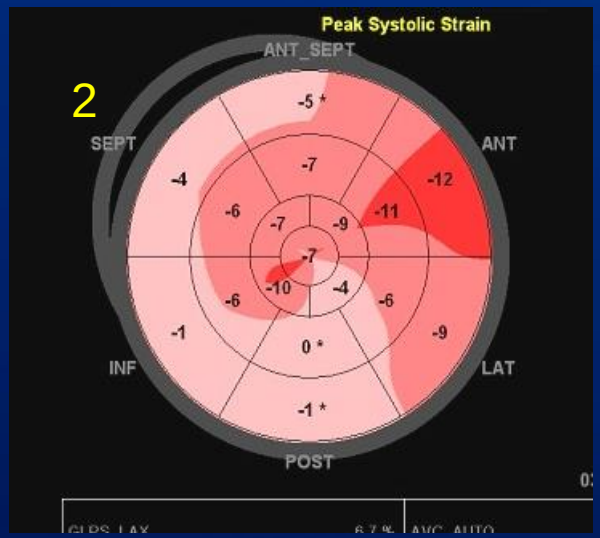


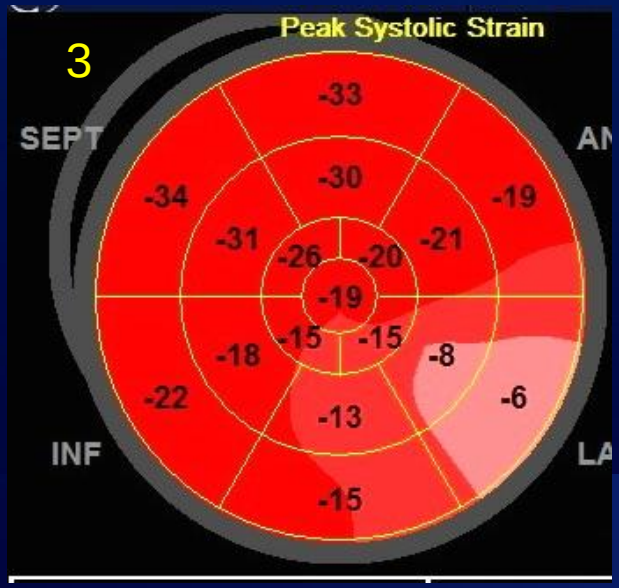


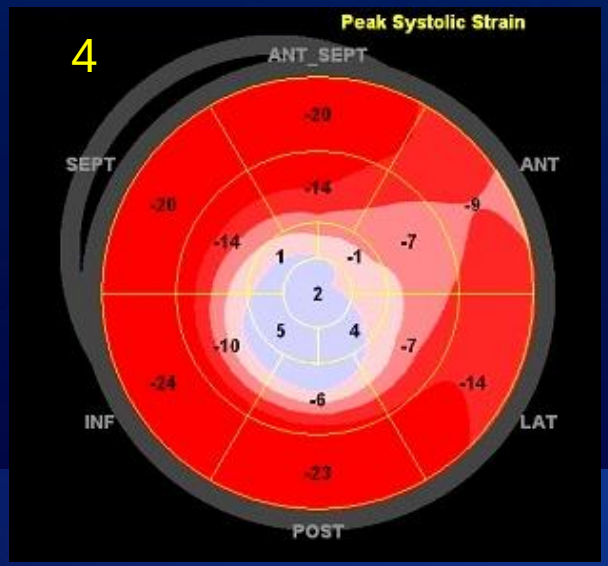


Which of following strain imaging patterns is expected in this patient









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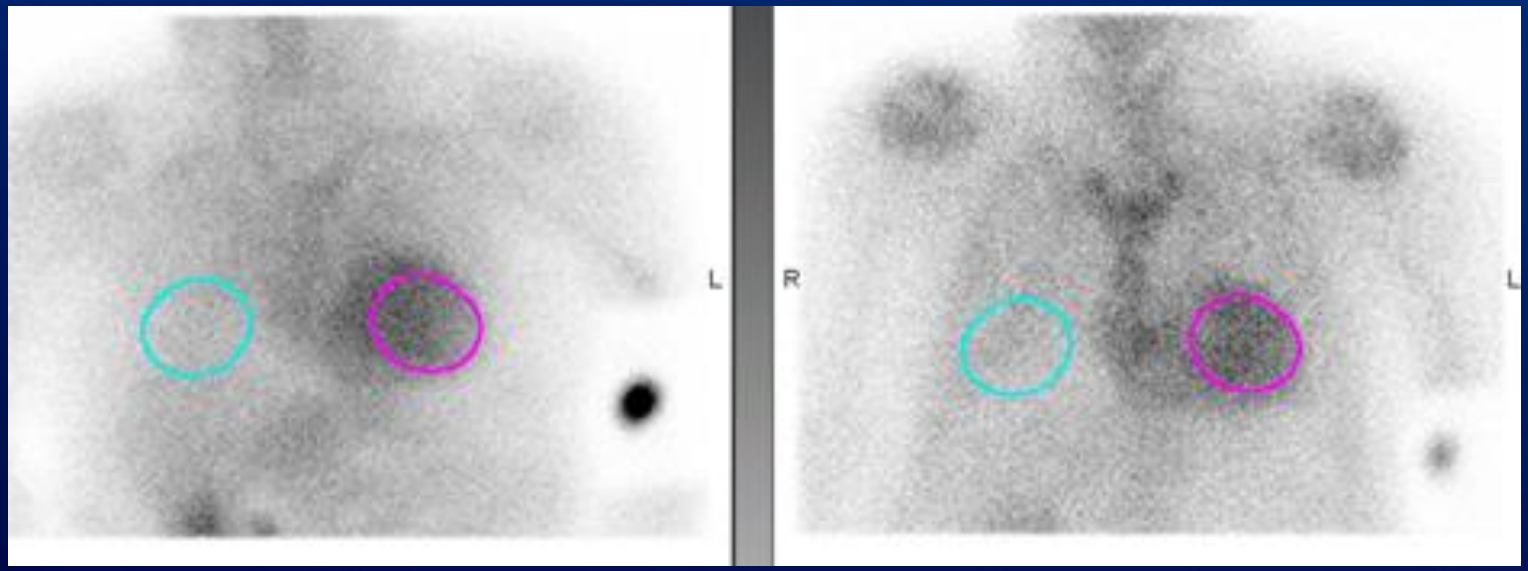
Further study (PYP –SPECT)
Transthyretin Cardiac Amyloidosis



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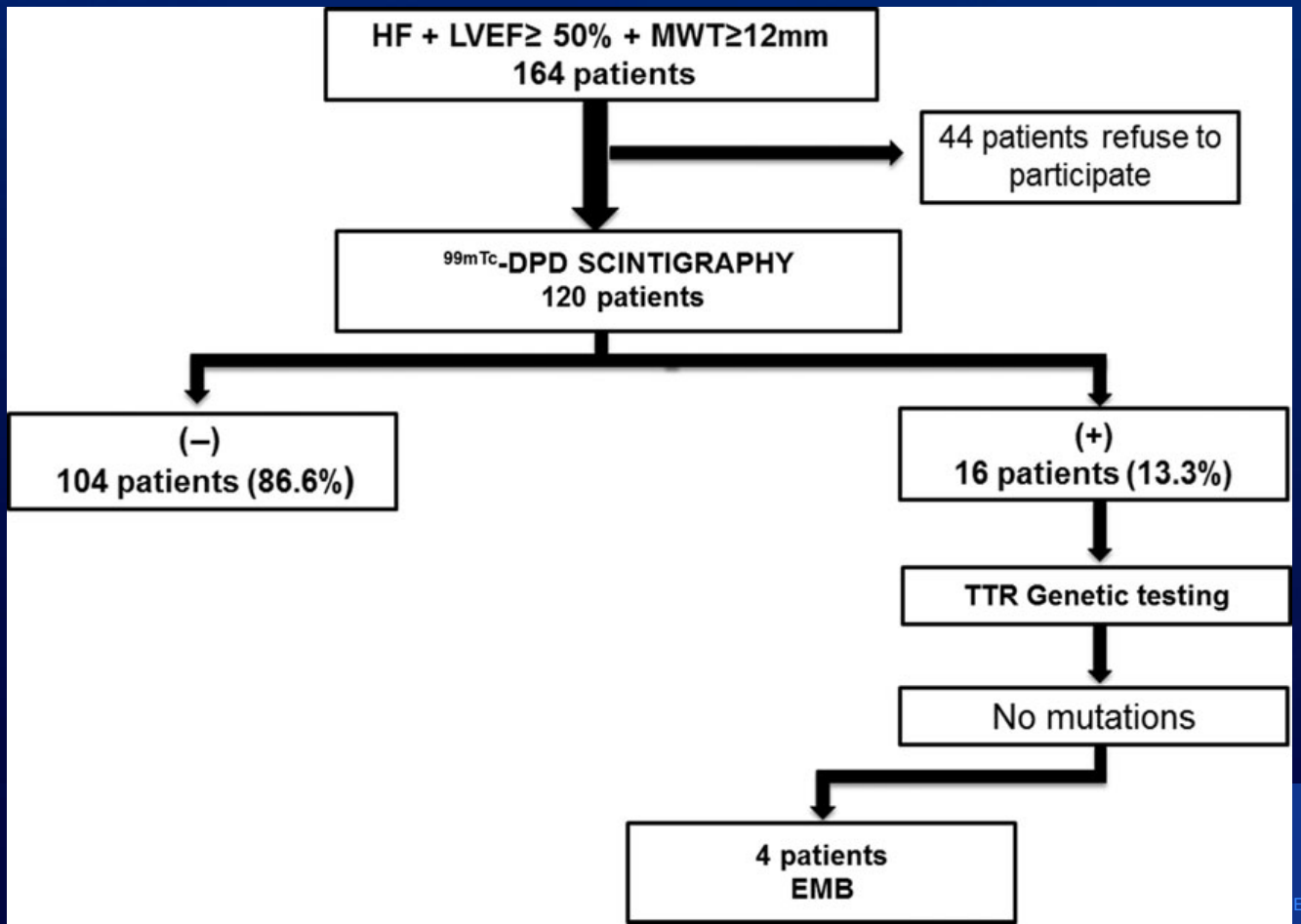
European Heart Journal (2015) 36, 2585–2594
doi:10.1093/eurheartj/ehv338

CLINICAL RESEARCH
Heart failure/cardiomyopathy

Wild-type transthyretin amyloidosis as a cause of heart failure with preserved ejection fraction

Esther González-López[1], Maria Gallego-Delgado[1], Gonzalo Guzzo-Merello[1], F. Javier de Haro-del Moral[2], Marta Cobo-Marcos[1], Carolina Robles[1], Belén Bornstein[3,4,5], Clara Salas[6], Enrique Lara-Pezzi[7], Luis Alonso-Pulpon[1], and Pablo Garcia-Pavia[1,7]*



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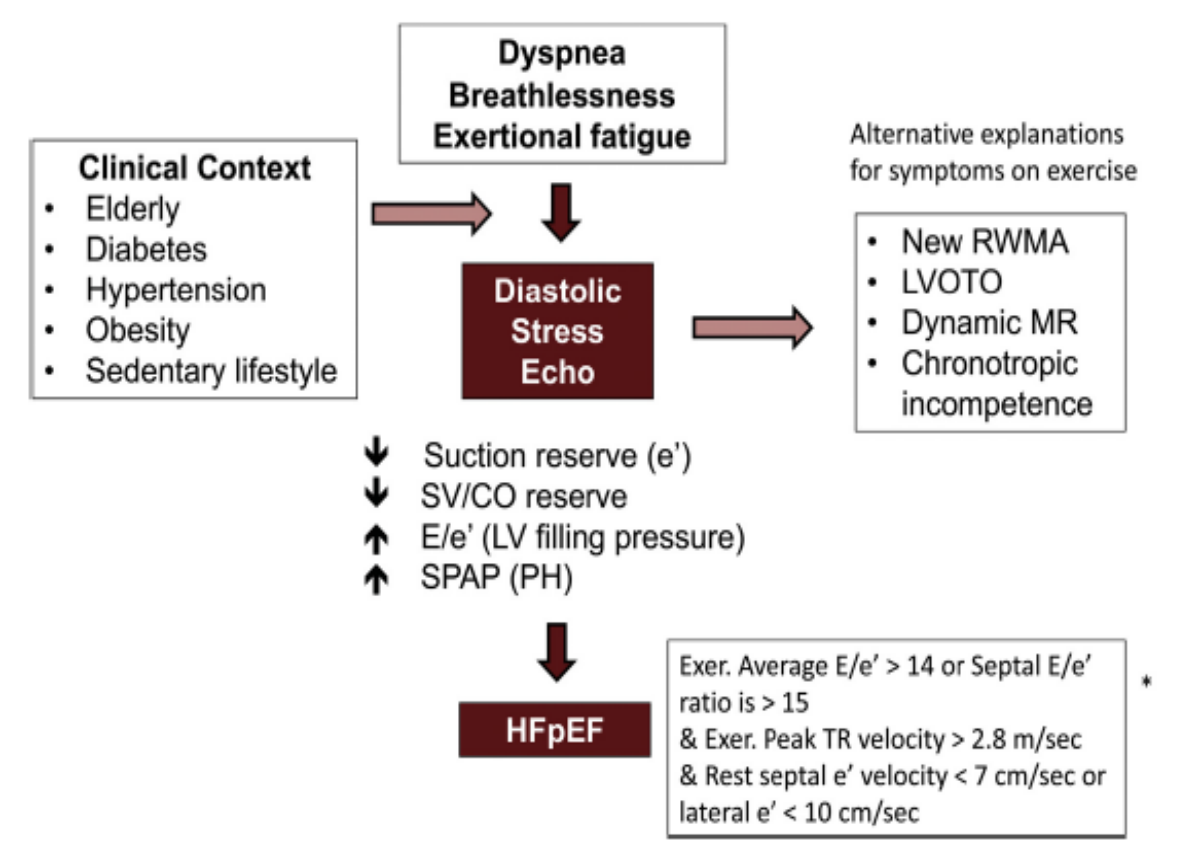
The Clinical Use of Stress Echocardiography in Non-Ischaemic Heart Disease: Recommendations from the European Association of Cardiovascular Imaging and the American Society of Echocardiography

- HFpEF by Echo
  - Grade 2-3 at rest
  - E/e' >15 at rest
  - Abnormal strain
- Stress Echo
  - Grade 1, ? 2
  - Indeterminate



Lancellotti et al. JASE 2017

Stages of Heart Failure

2013/14 HF Guideline

A	B	C	D
At high risk for HF W/O SHD or symptoms	Structural Heart Disease W/O symptoms or signs	Structural Heart Disease W/ symptoms or signs	Refractory Heart Failure

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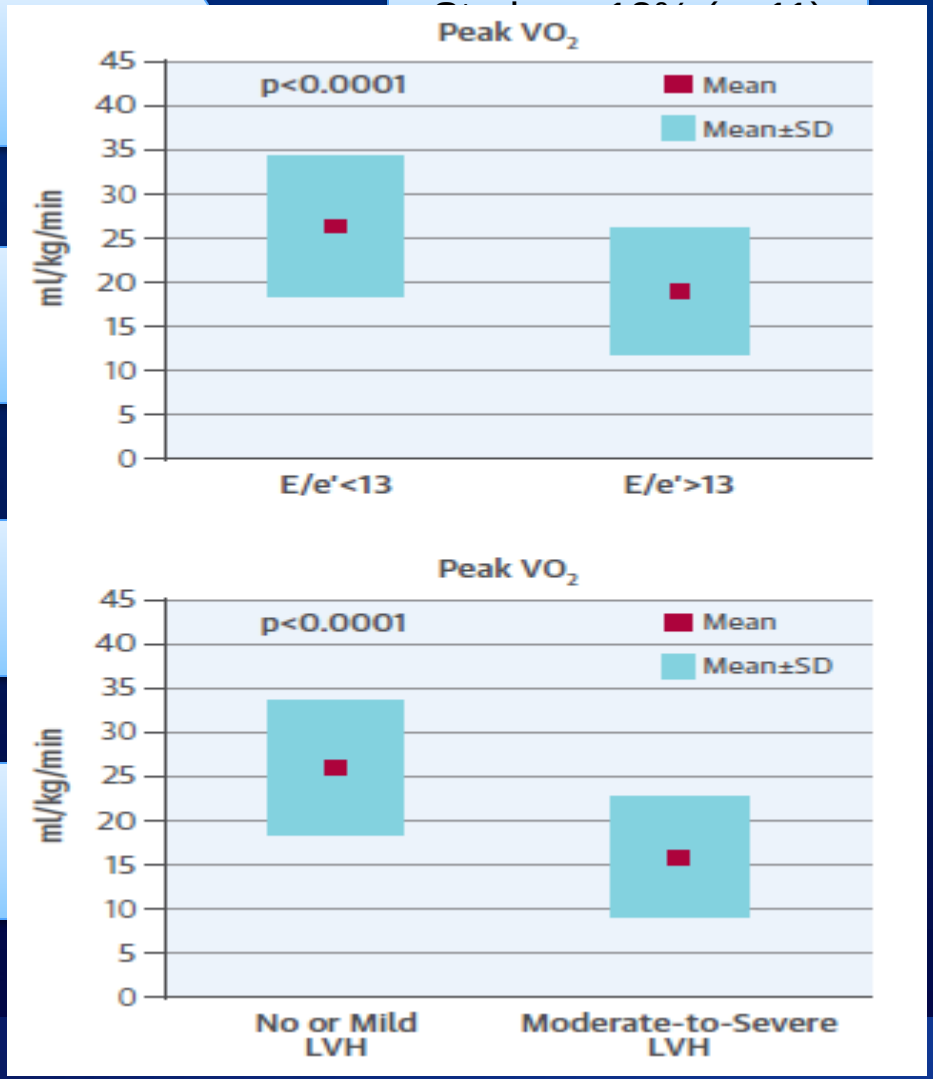
Exercise Limitation Associated With Asymptomatic Left Ventricular Impairment

Analogy With Stage B Heart Failure

Wojciech Kosmala, MD, PhD,*† Christine L. Jellis, MD, PhD,‡ Thomas H. Marwick, MBBS, PhD, MPH†

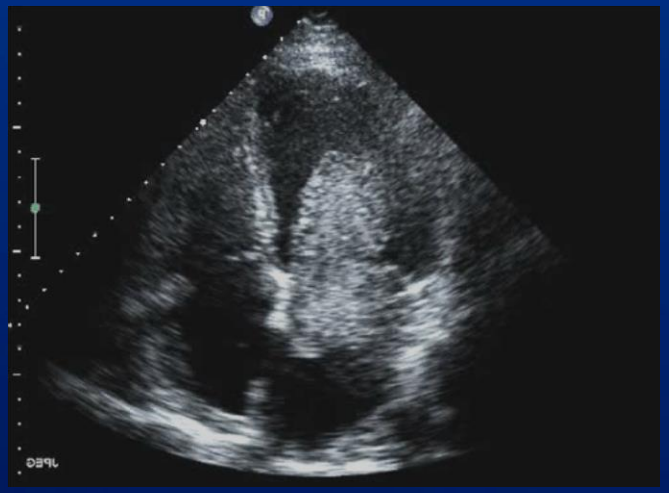
Moderate-to-severe LVH
n=123

No or mild LVH
n=387

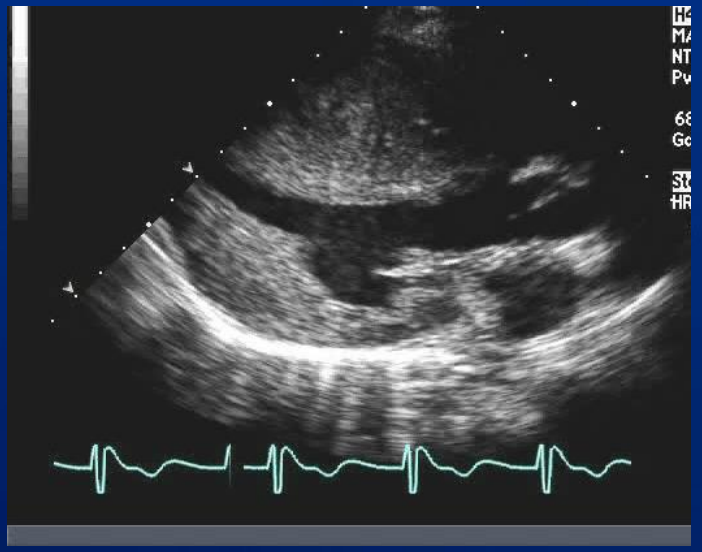


Kosmala W et al: JACC 65:257-266, 2015

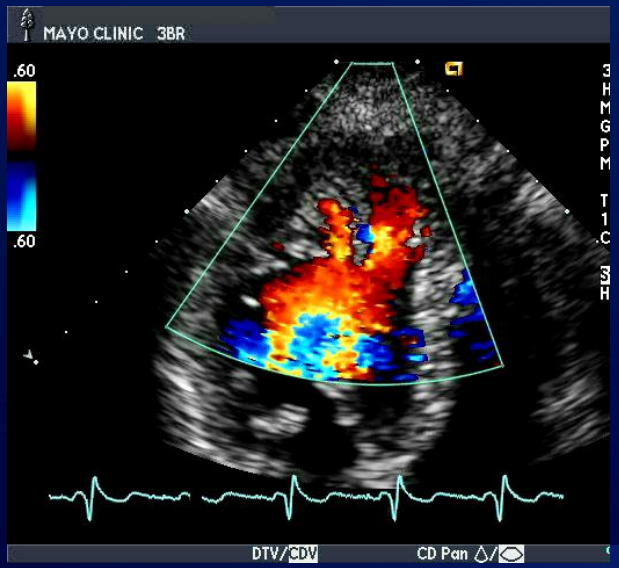
Structural Abnormalities by Echo



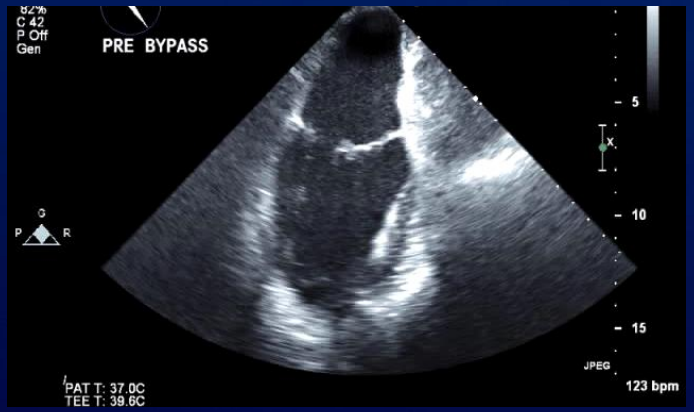
Myxoma



Hypertrophic CM



Noncompaction



Partial Rupture of PM

LV Ejection Fraction/Volume

- Classification of HF
  - HFrEF
  - HFpEF
- Prognosis
- Medical therapy
- Implantable Cardiac Defibrillator
- Cardiac Resynchronization Therapy
- Clinical Trials

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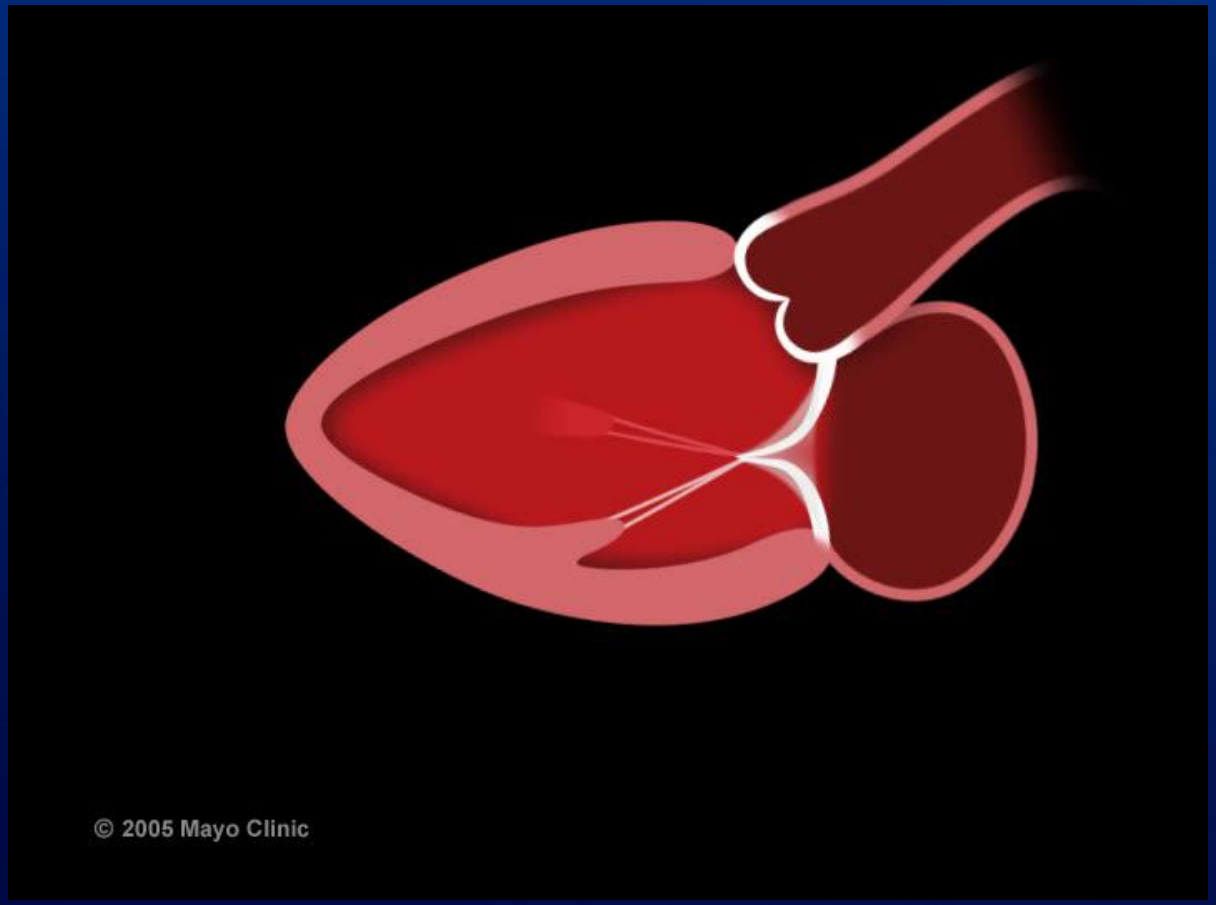
Dilated or Ischemic CM



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Echocardiography
Heart Failure with Reduced EF (HFREF)

- LV Volumes
- LV Ejection Fraction (EF)
- Sphericity
- Filling Pressures
- Mitral Regurgitation
- RV Function
- Pulmonary Artery Systolic Pressure
- LVAD Structure and Hemodynamics

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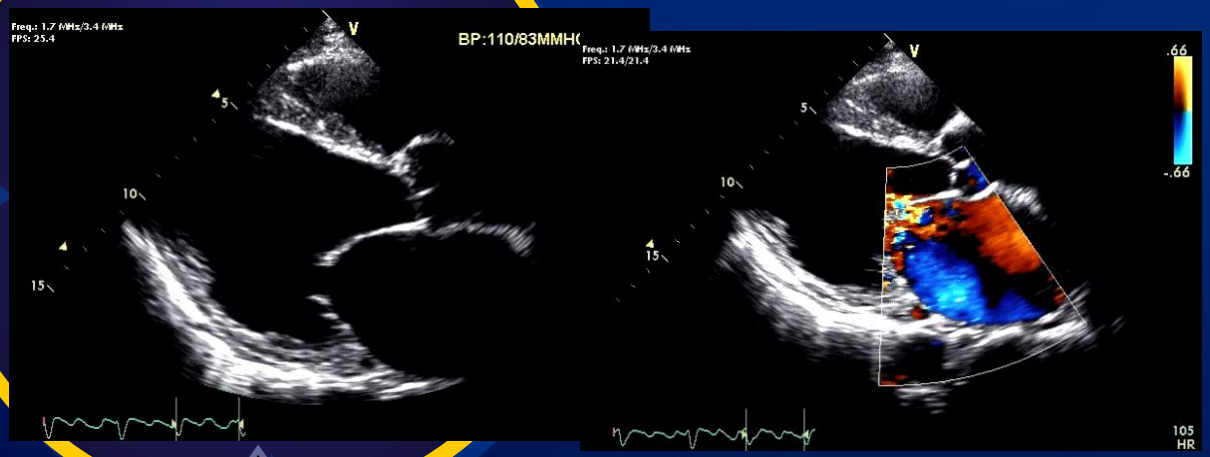
Echocardiography in HFrEF

Symptoms: Rest or exercise

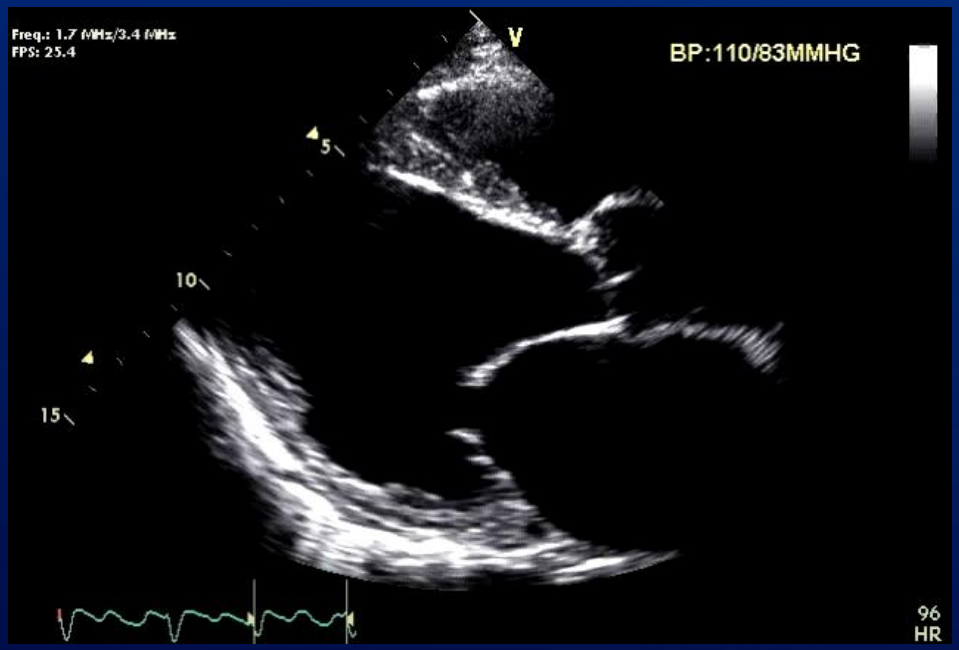
Systolic dysfunction



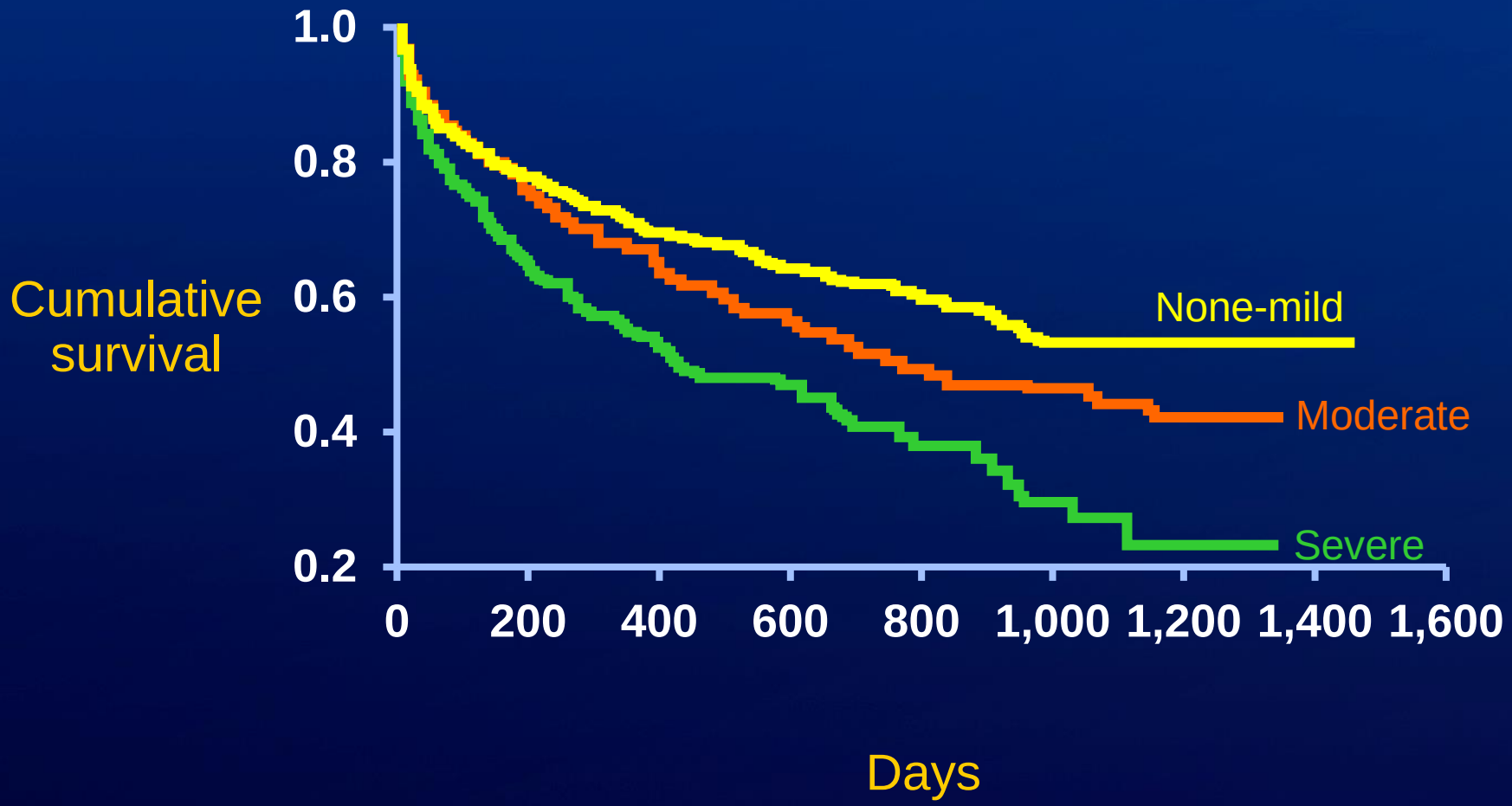
Diastolic dysfunction
High filling pressure

Which of following parameters is most predictive of clinical outcome?

1. Mitral Regurgitation
2. LVED volume index
3. Diastolic function
4. RV function



Survival of Patients with DCM Mitral Regurgitation

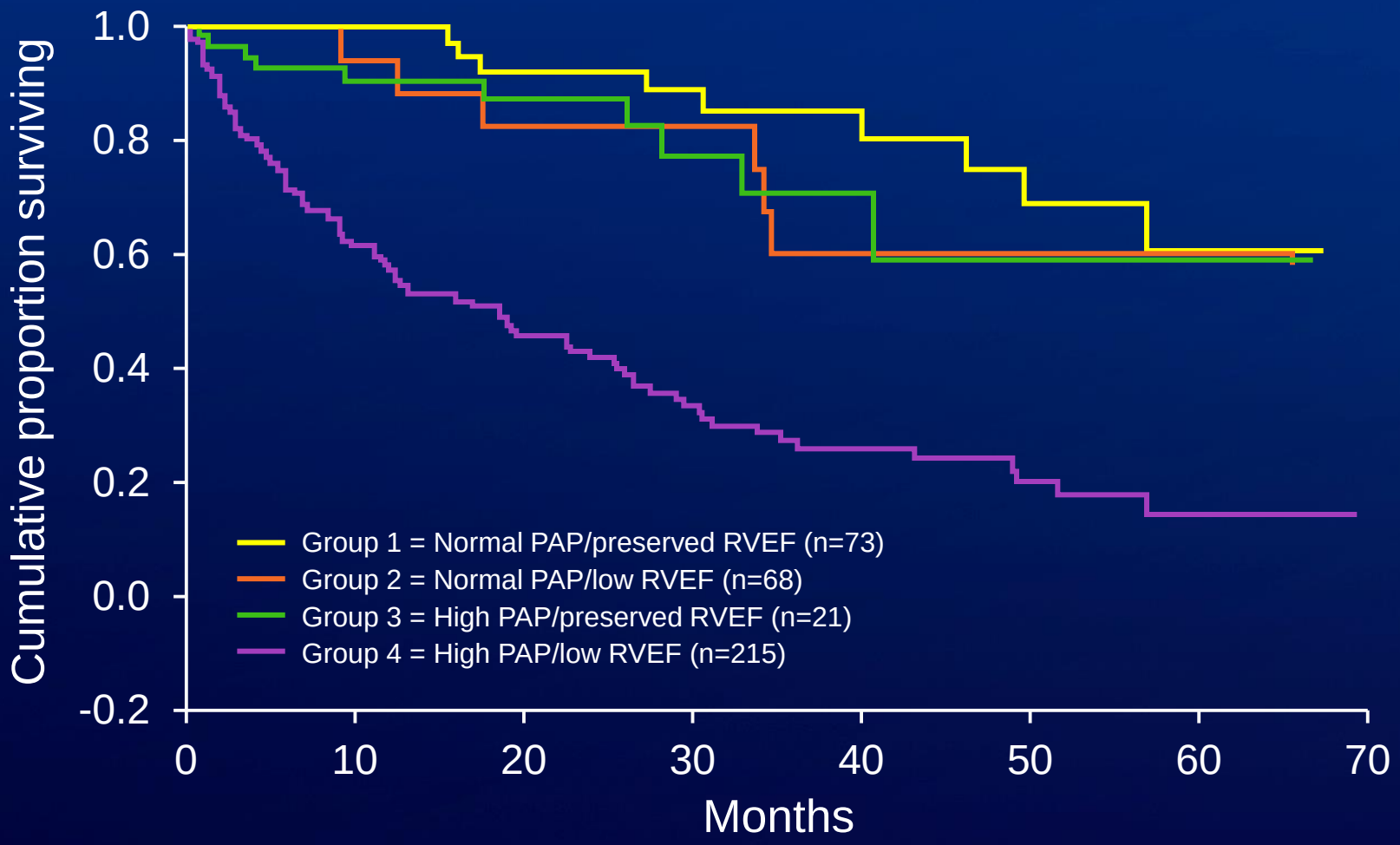


Koelling et al: Am Heart J 144:527, 2002

MAYO CLINIC

CP1155462-1

Survival of Patients with DCM RV function and Pulmonary HTN



Ghio et al: J Am Coll Cardiol 37:183, 2001

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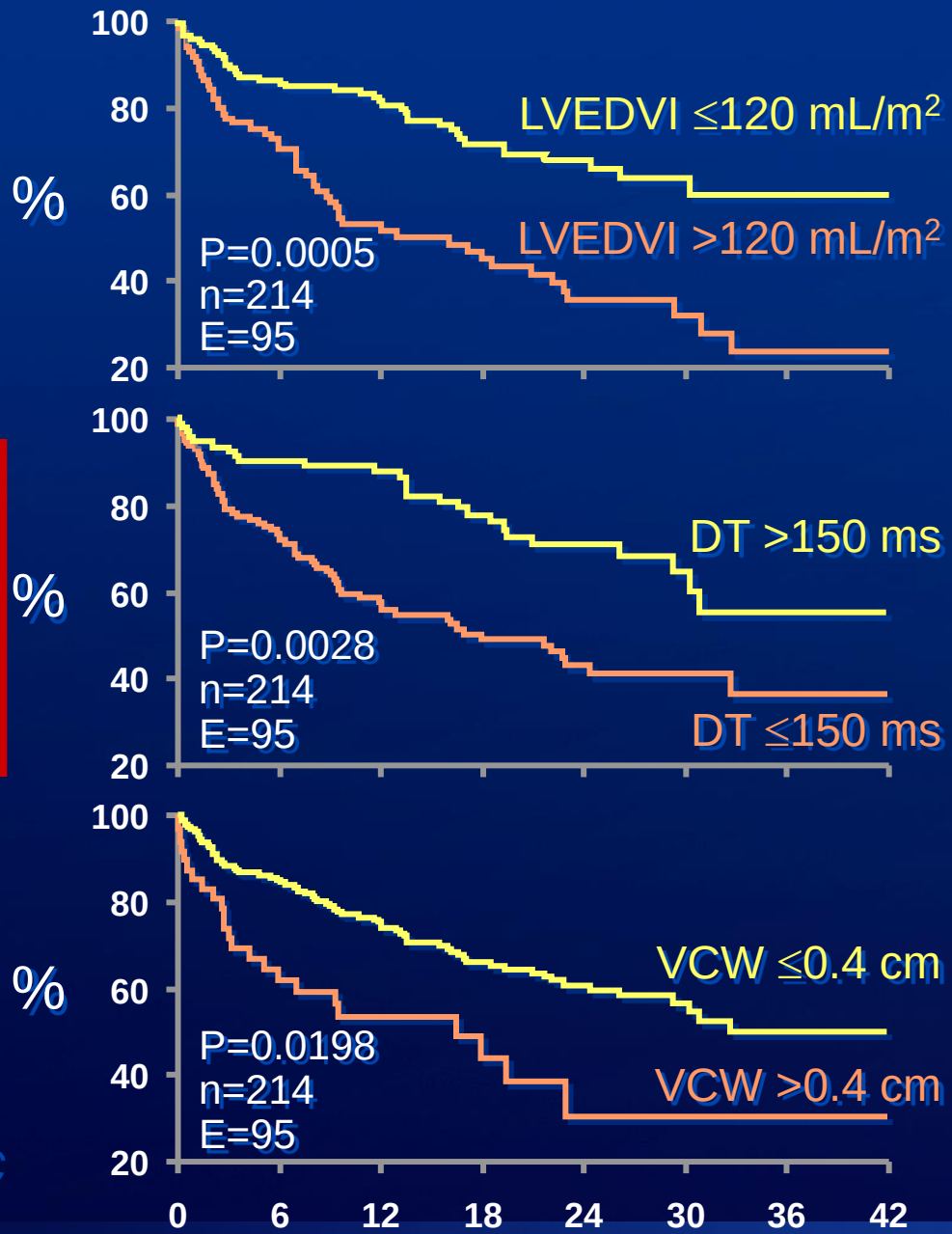
BEST

Survival Predictors

1. LV Volume
2. Diastolic FP
3. MR

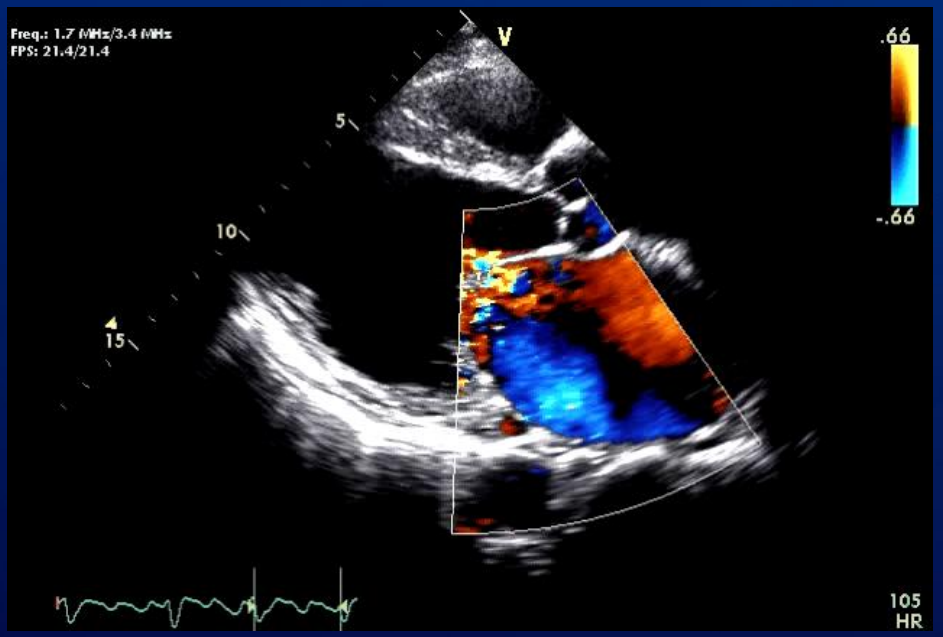


Grayburn et al: JACC 45(7):1064, 2005

MAYO CLINIC

PISA calculation in this patient showed following data: ERO= 0.3 cm^2 and RV =45mL What is MR severity ?

1. Mild
2. Moderate
3. Moderately severe
4. Severe



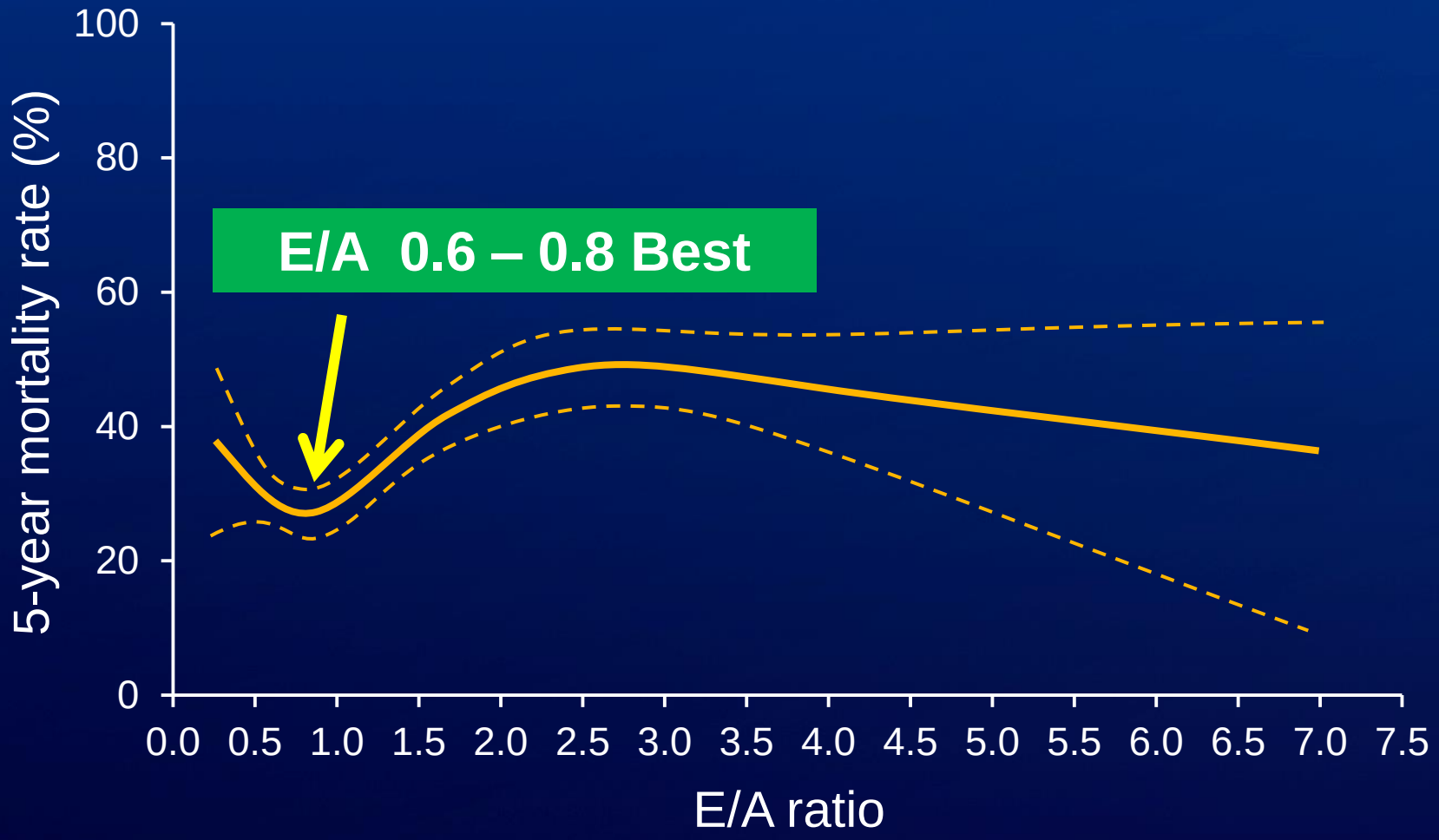
Predictors of Clinical Outcome in Ischemic CM STICH Trial

	Chi-Square	P-value
Creatinine	30.0	< 0.001
ESVI (& EF) by echo	27.3	<0.001
Age	20.3	<0.001
Received CABG	13.1	<0.001
E/A ratio by echo	12.5	<0.001
MR severity by echo	6.0	0.014

MAYO CLINIC

Lin et al. In Submission

Prognosis in STICH Patients with ICM 1511 patients



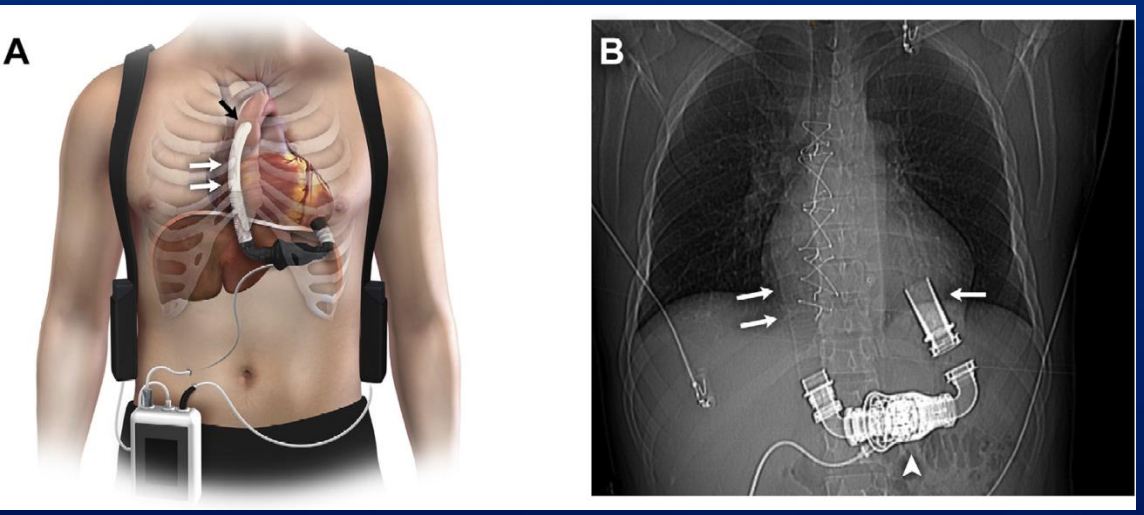
MAYO CLINIC

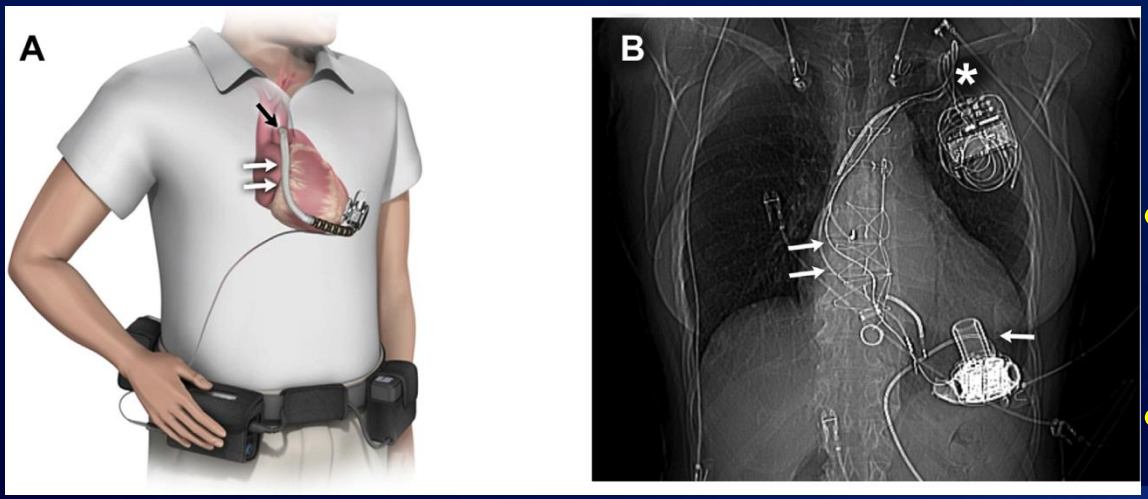
Echo Guidance: LVAD, Transplant, CRT

- LVAD
  - *Understand LVAD Hemodynamics*
- Cardiac Transplantation
  - *Identify signs of rejection*
- Cardiac resynchronization therapy
  - *Recognize the role of Echo in CRT*

MAYO CLINIC

LVAD
Heartmate and Heartware





- Continuous Flow
- Impeller and housing above diaphragm for HM
- Impeller and housing within pericardial sac for HW
- Outlet cannula in the ascending aorta
- Hemodynamics are similar

MAYO CLINIC

Stainback et al. JASE 2015

Which of following conditions becomes worse after LVAD ?

1. Aortic stenosis
2. Aortic regurgitation
3. Mitral stenosis
4. Mitral regurgitation

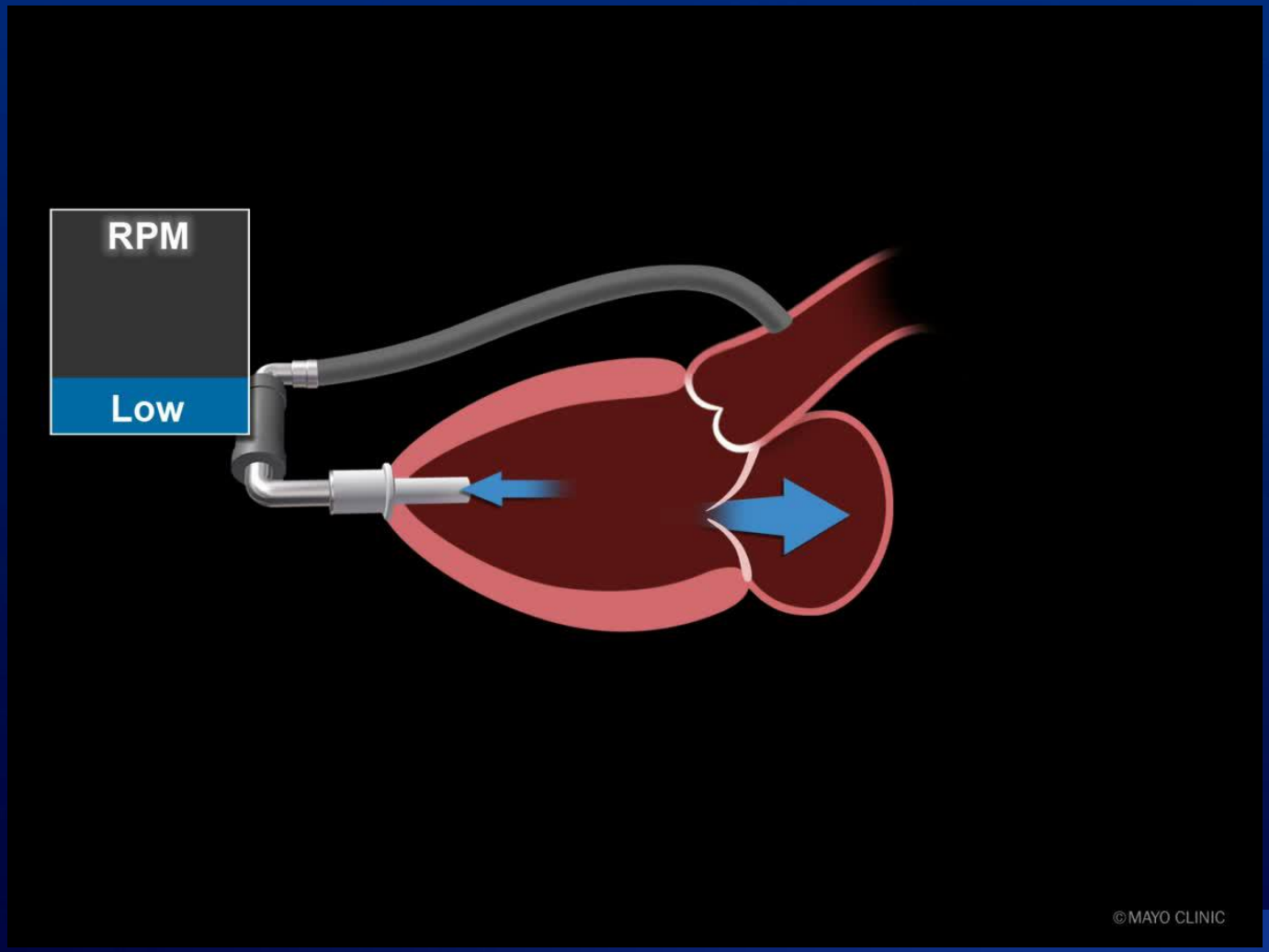
MAYO CLINIC

Which of following conditions fits best for LVAD?

1. LVEF < 35%
2. LVEDD > 63 mm
3. Diastolic dysfunction ≥ grade 2-3
4. Mitral regurgitation ≥ grade 3-4

MAYO CLINIC

AV motion in LVAD



Advanced HF Therapies: LVAD and Transplant

Patient Selection

Advanced HF EF <25%
Optimal medical management
CRT if QRS >120 msec

- NYHA III-IV
- 6-minute walk <300 m
- Peak VO2 <14 mL/kg/min
- Frequent hospital admissions

CMS criteria for Destination Therapy LVAD

Not eligible for transplant

- Too old
- High BMI
- High PVR
- Recent malignancy
- HIV
- Renal insufficiency

Advanced HF EF <25%
Optimal medical management CRT if QRS >120 msec

- NYHA III-IV
- 6-minute walk <300 m
- Peak VO2 <14 mL/kg/min
- Frequent hospital admissions

Better outcomes with LV enlargement
↑ 30 day mortality if LVEDD <63mm

Heart transplant

LVAD as a bridge to transplant

Consider LVAD

Miller JACC 2013, Topilsky JACC 2011

ASE GUIDELINES & STANDARDS

Echocardiography in the Management of Patients with Left Ventricular Assist Devices: Recommendations from the American Society of Echocardiography

Raymond F. Stainback, MD, FASE, Chair, Jerry D. Estep, MD, FASE, Co-Chair, Deborah A. Agler, RCT, RDCS, FASE, Emma J. Birks, MD, PhD, Merri Bremer, RN, RDCS, EdD, FASE, Judy Hung, MD, FASE, James N. Kirkpatrick, MD, FASE, Joseph G. Rogers, MD, and Nishant R. Shah, MD, MSc, *Houston, Texas; Cleveland, Ohio; Louisville, Kentucky; Rochester, Minnesota; Boston, Massachusetts; Philadelphia, Pennsylvania; and Durham, North Carolina*

(J Am Soc Echocardiogr 2015;28:853-909.)

Keywords: Echocardiography, mechanical circulatory support, left ventricular assist devices, comprehensive examination

MAYO CLINIC

Stainback et al JASE 2015

Role of Pre-operative Assessment for LVAD: Patient Selection

- High risk for complications
- Biventricular vs Univentricular support
  - LV size and EF
  - Right ventricular function
  - Shunts (PFO or ASD)
  - Valve disease
  - Intra-cardiac thrombi

MAYO CLINIC

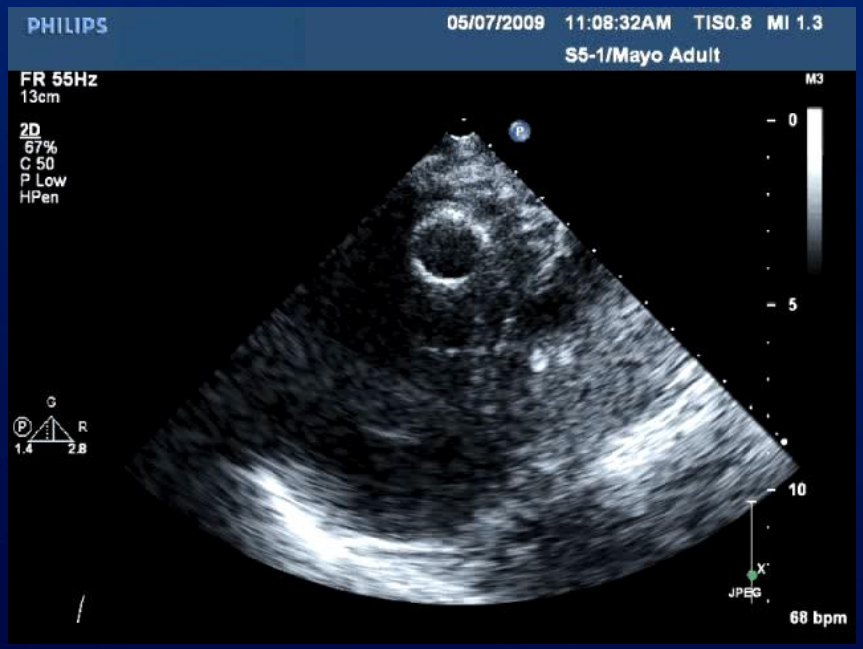
Courtesy Dr. G Lin

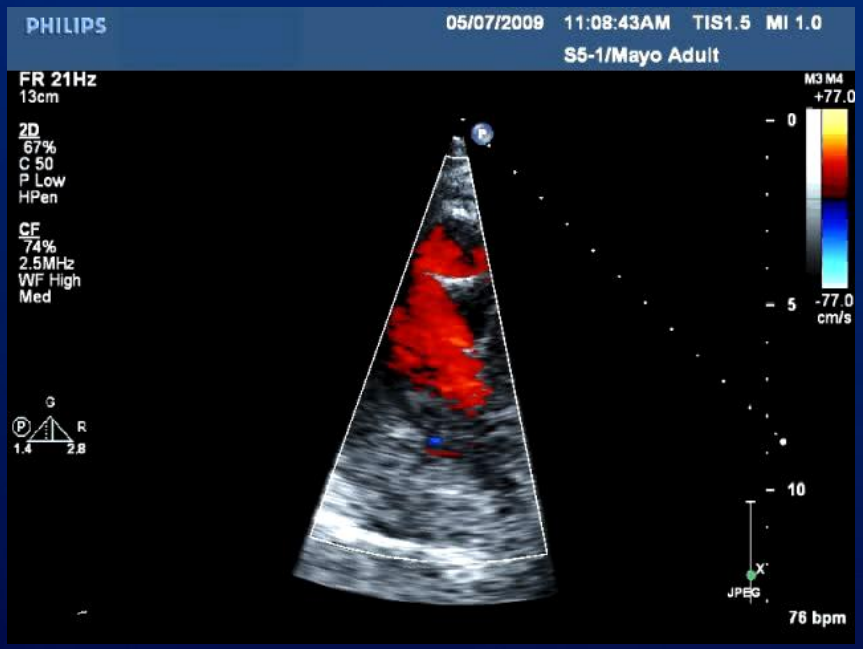
Pre-LVAD Valve assessment

Valve	Post-LVAD	Replace/ Repair	Considerations
Aortic regurgitation	Worsens Continuous	Yes	Repair or patch closure
Aortic stenosis	LVAD inflow not affected	No	Not involved in VAD circuit
Mitral regurgitation	May improve	No	↓MR due to↓ LV size and LVP post-LVAD
Mitral stenosis	Impairs LVAD inflow	Yes	Results ↓ flow to VAD circuit
Tricuspid regurgitation	Worsens	Yes	Could indicate RV dysfunction
Mechanical Aortic Valve	Risk of thrombosis due to ↓flow across valve	Yes	Replace with bioprosthetic or patch closure
Mechanical Mitral valve	MR improves, MS impedes flow	Yes, for MS No, for MR	↑forward flow across MV post-LVAD

MAYO CLINIC

LVAD Normal Images
Inflow Cannula

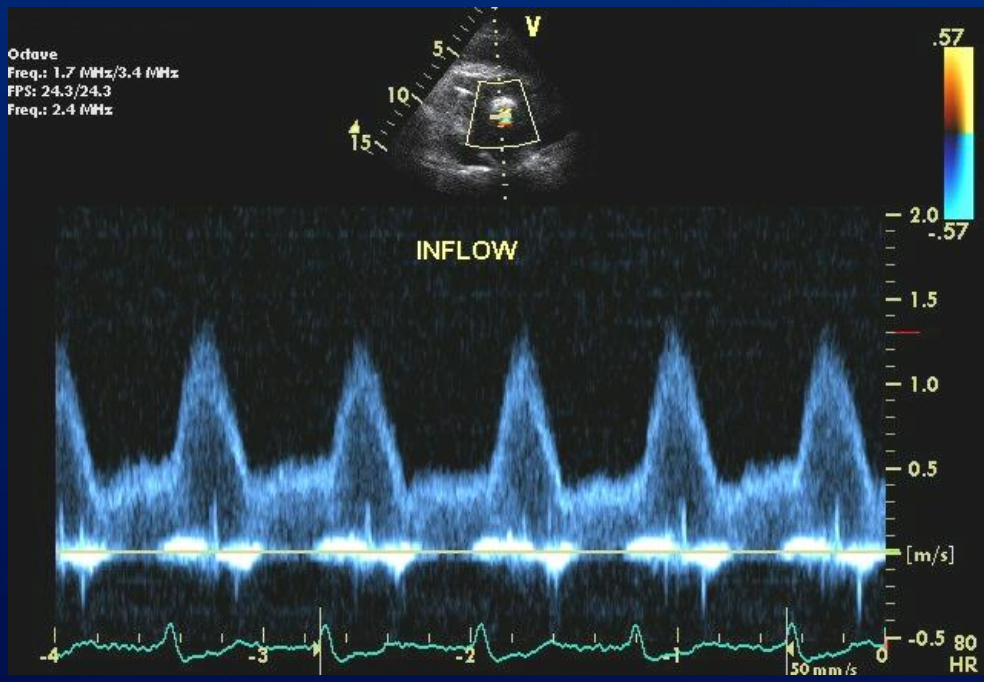




Courtesy Dr. Borgeson

LVAD Normal Velocity at Inflow Cannula

- Velocity influenced by angle of interrogation
- Velocities are typically < 1.5 m/sec
- Velocities >2 m/s are suspicious for obstruction (cannula abuts ventricular wall, thrombus) or hypovolemia

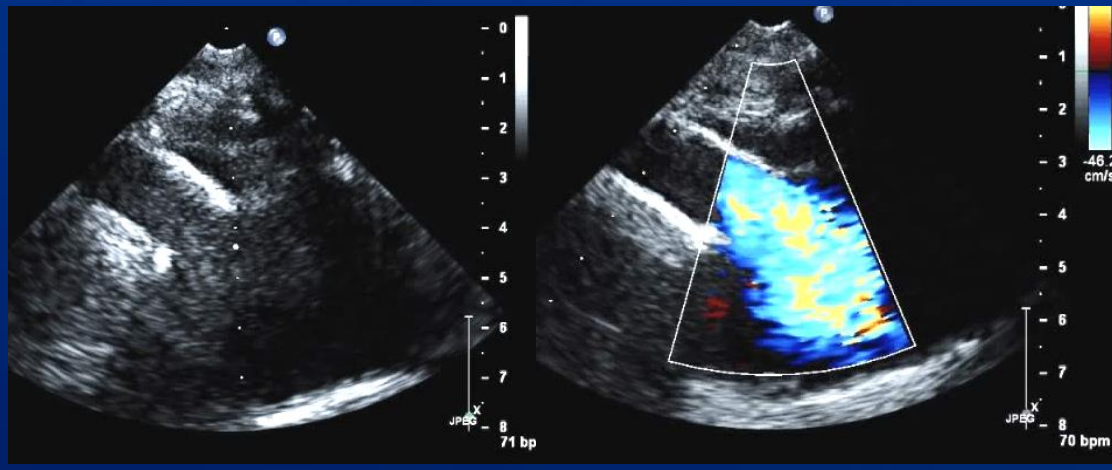


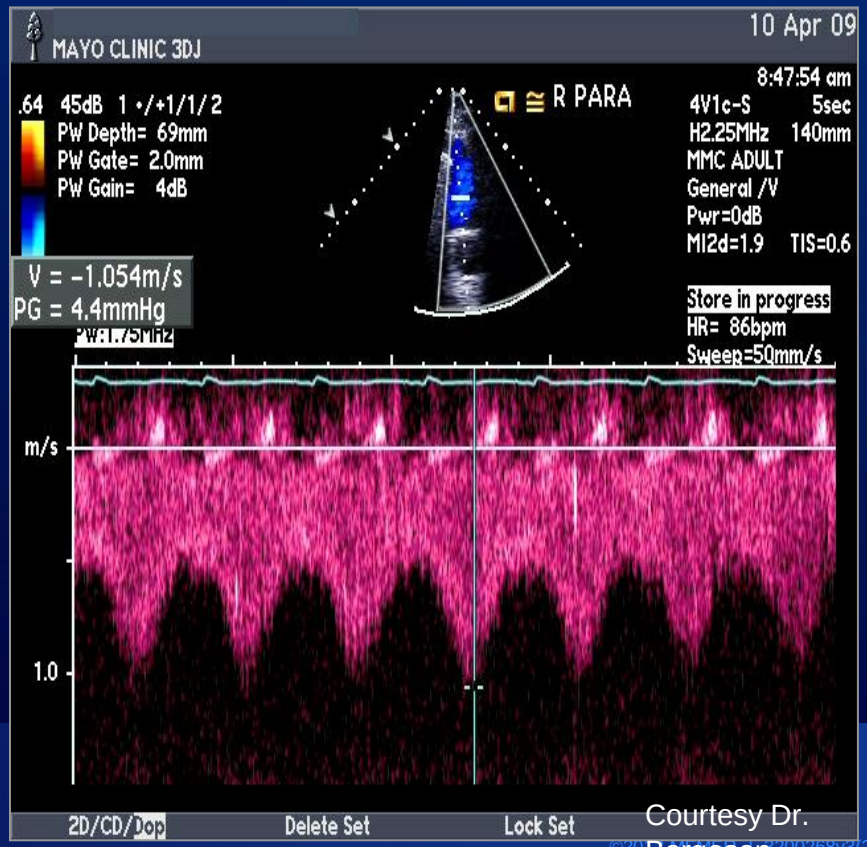
MAYO CLINIC

Courtesy Dr. Borgeson

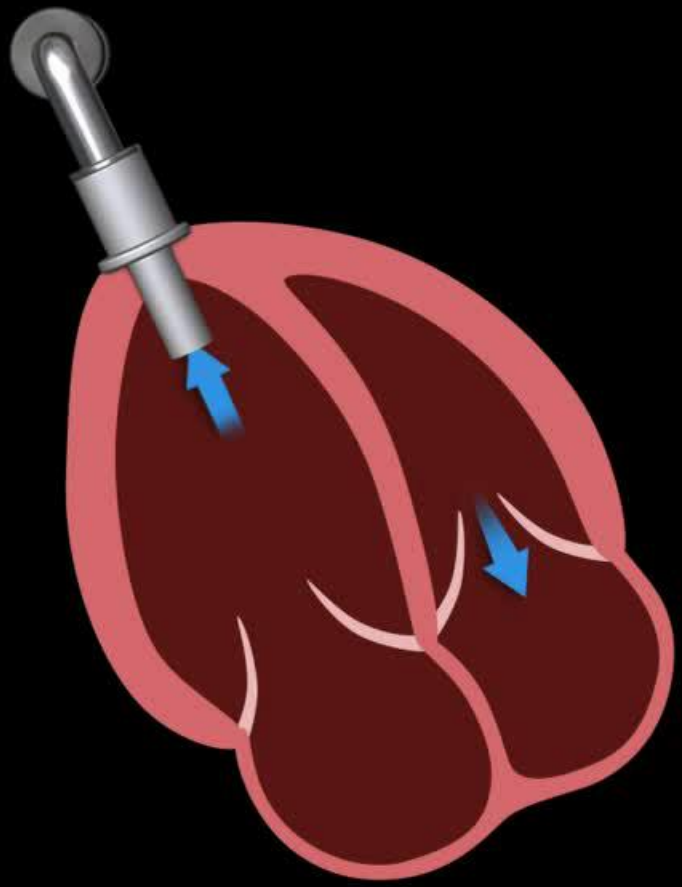
Outflow Cannula

- Usually into the ascending thoracic aorta
- Right parasternal imaging
- Variable angle of entry, need to move probe up and down looking for cannula. (color flow imaging)
- "Normal" velocity again difficult to define due to angle issues
  - Typically <1.5 but >2 m/sec usually abnormal.





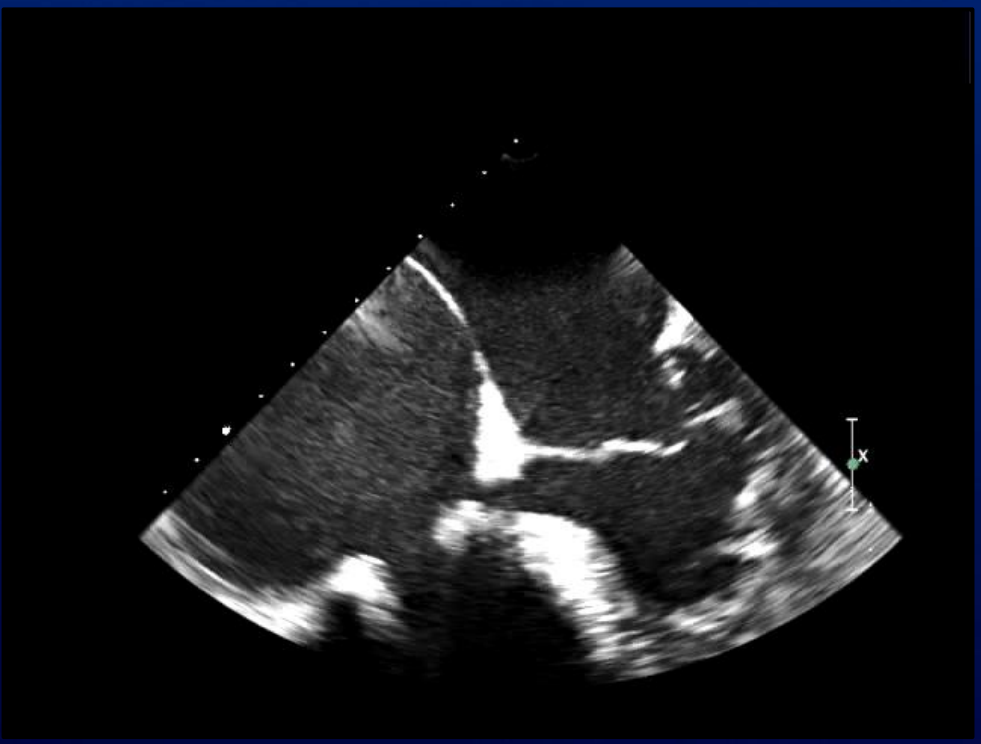
Courtesy Dr. Borgeson



RPM

Low

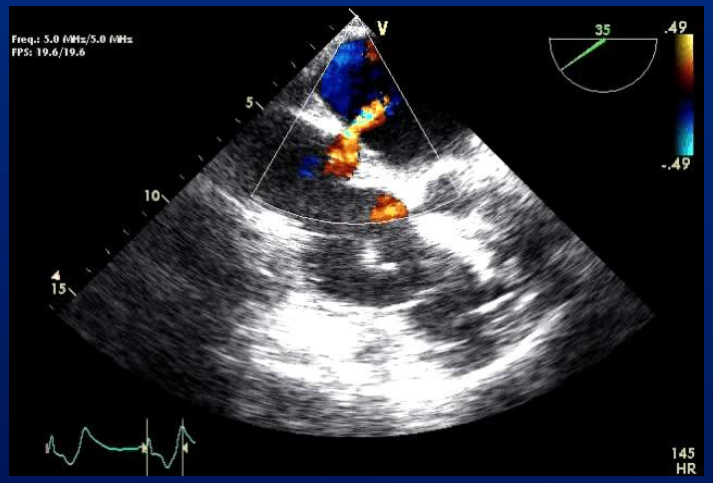
67 yo male with DCM S/P implantation of Heart Mate II LVAD Which of followings is most likely expected?

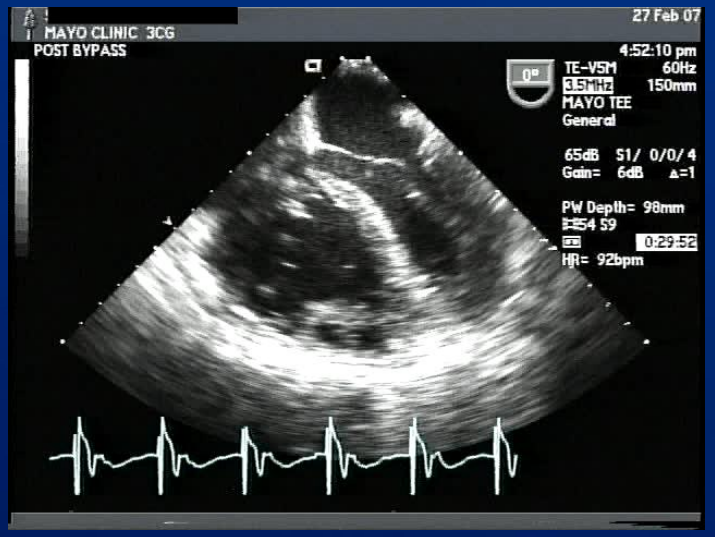


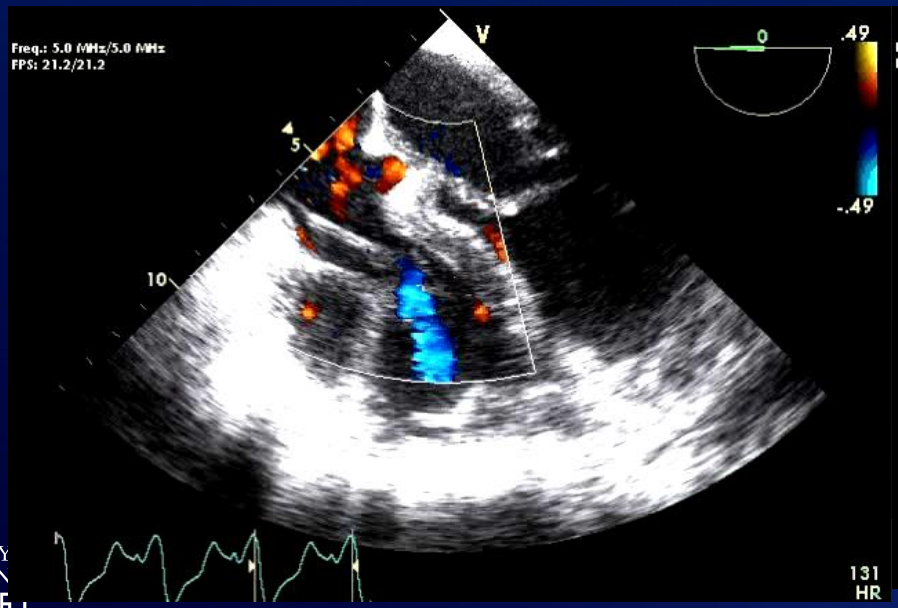
1. Increased FP
2. Severe hypoxemia
3. ↑ MR severity
4. LV thrombus

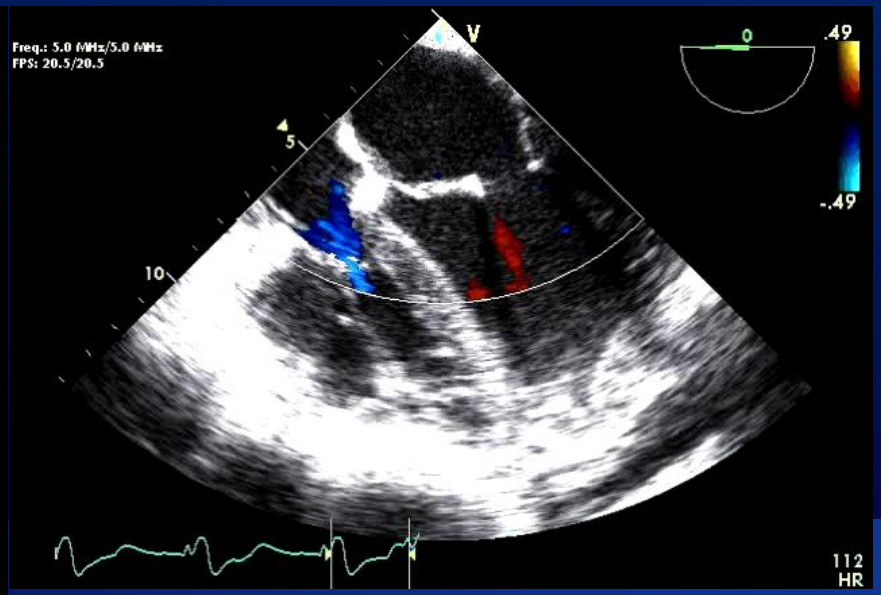
MAYO CLINIC

TEE in LVAD with too high RPM

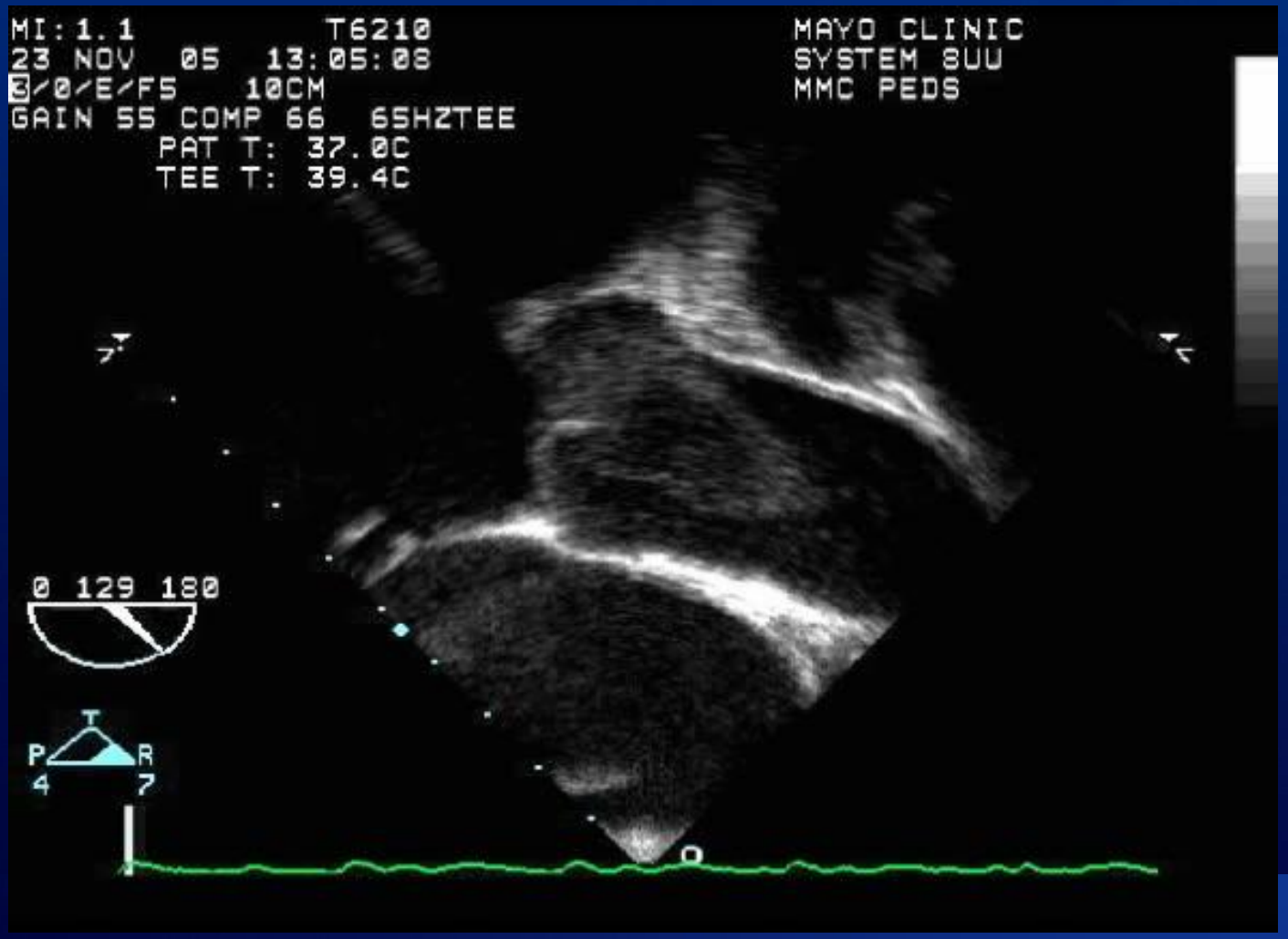




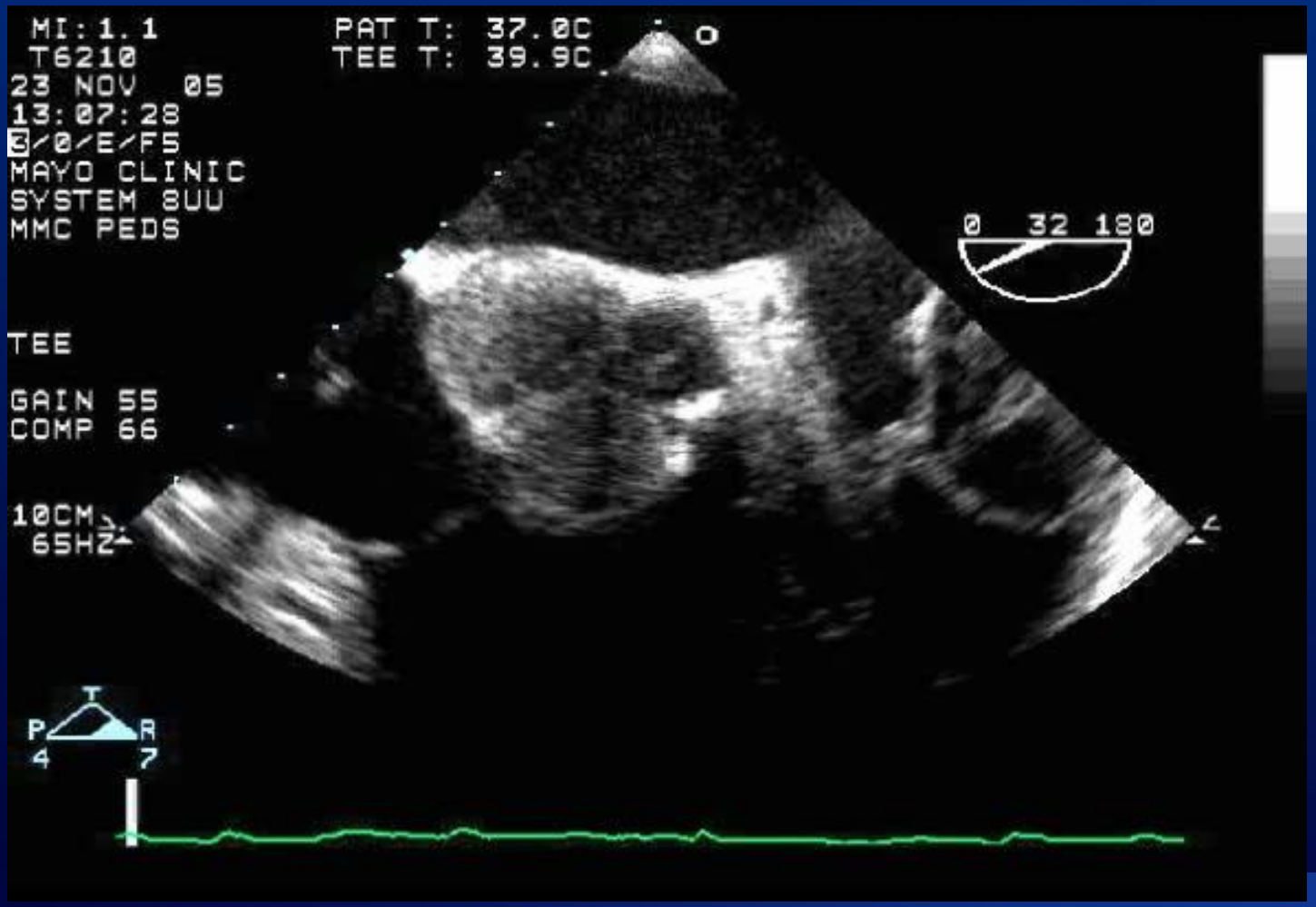




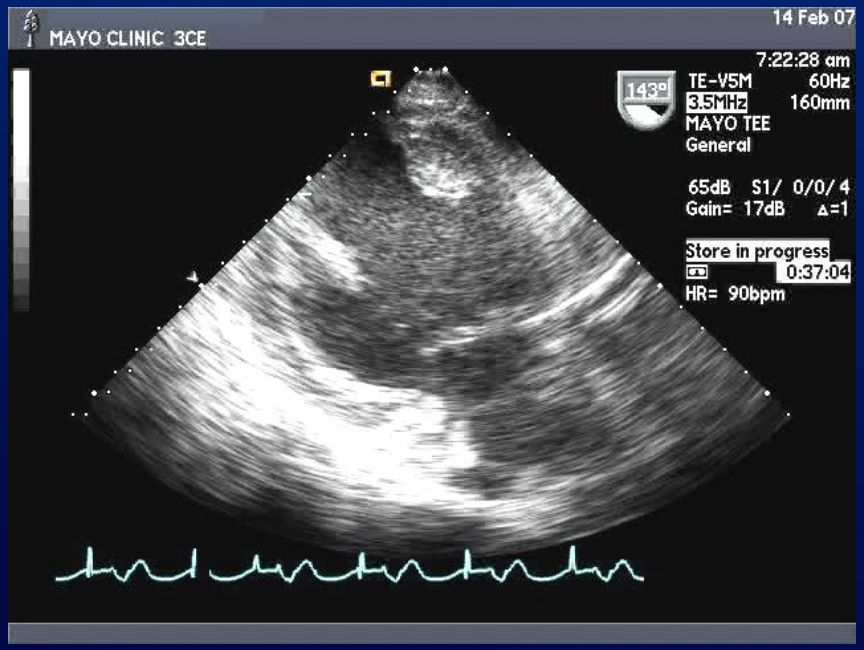
VAD Abnormalities: Stagnant Flow in Aortic Root

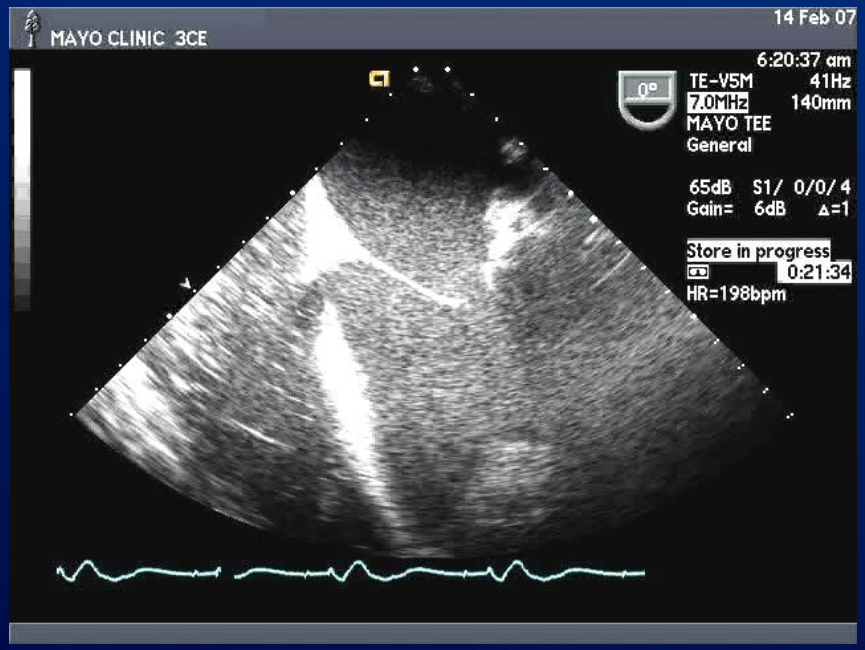


VAD Abnormalities: Stagnant Flow in Aortic Root

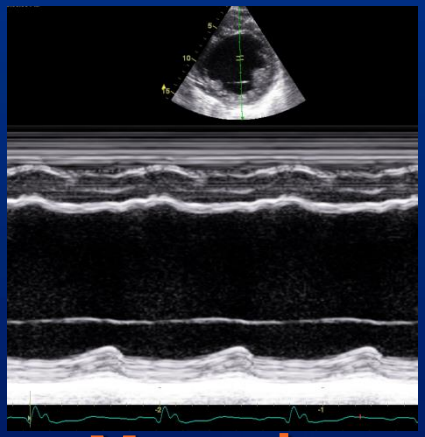


VAD Abnormalities Intracardiac clots

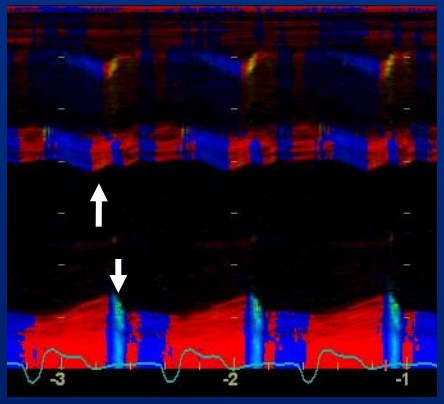




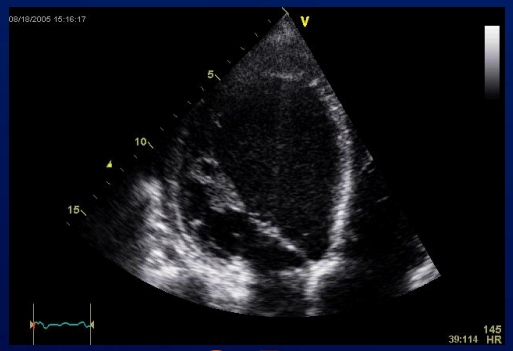
Echo for Dyssynchrony



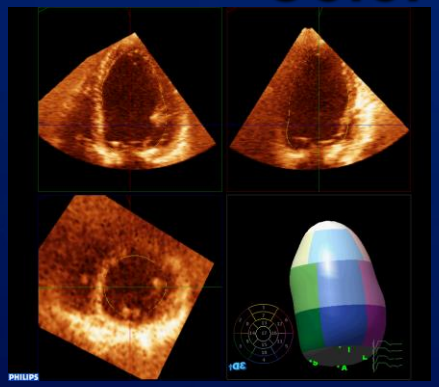
M mode



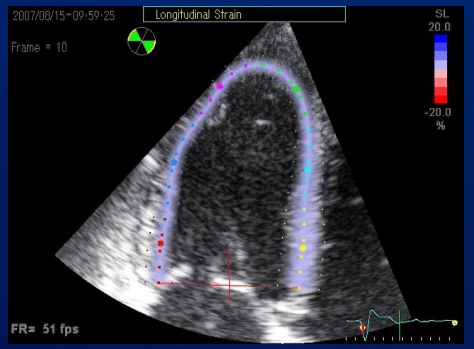
Color M mode



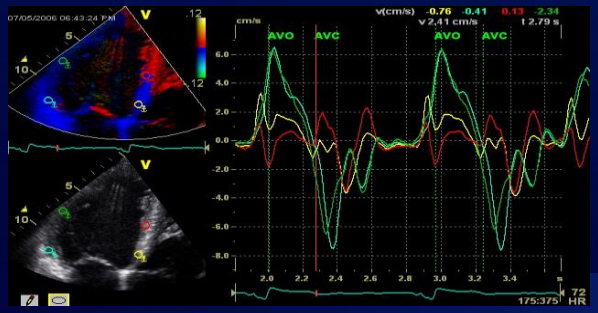
2-D



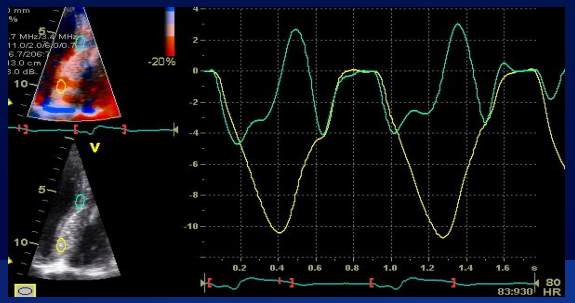
3-D



2-D Speckle



Tissue Velocity

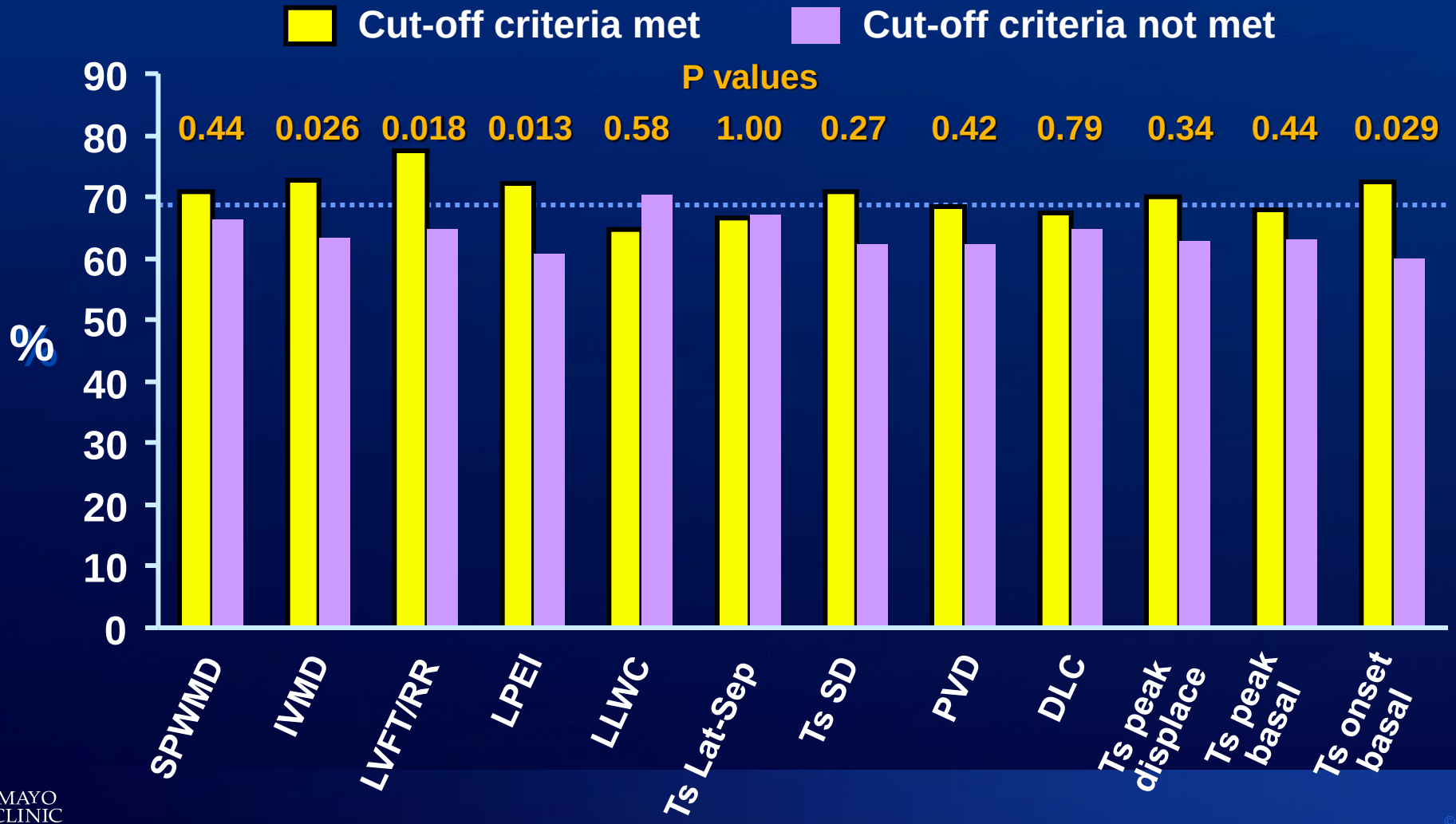


Strain

PROSPECT

Predictive Value of Echo Dyssynchrony Measures

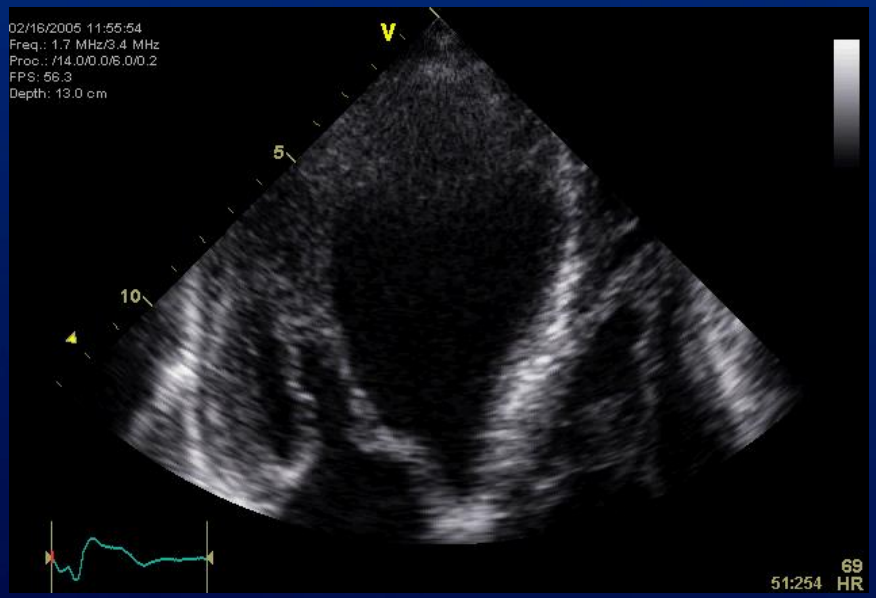
Improved Clinical Composite Score

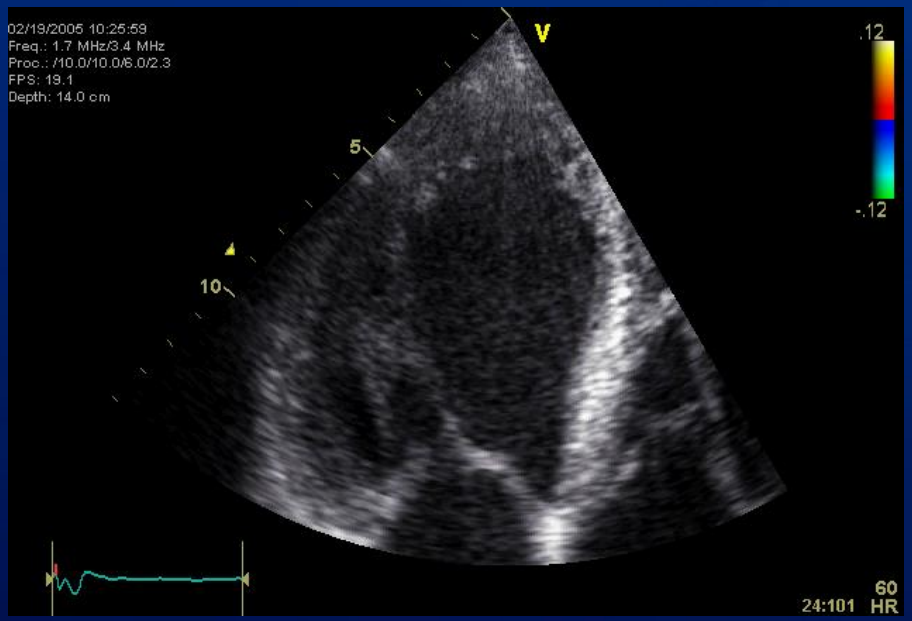


MAYO CLINIC

Chung et al. Circ 2008

Case presentation for CRT
Apical rocking for postive response



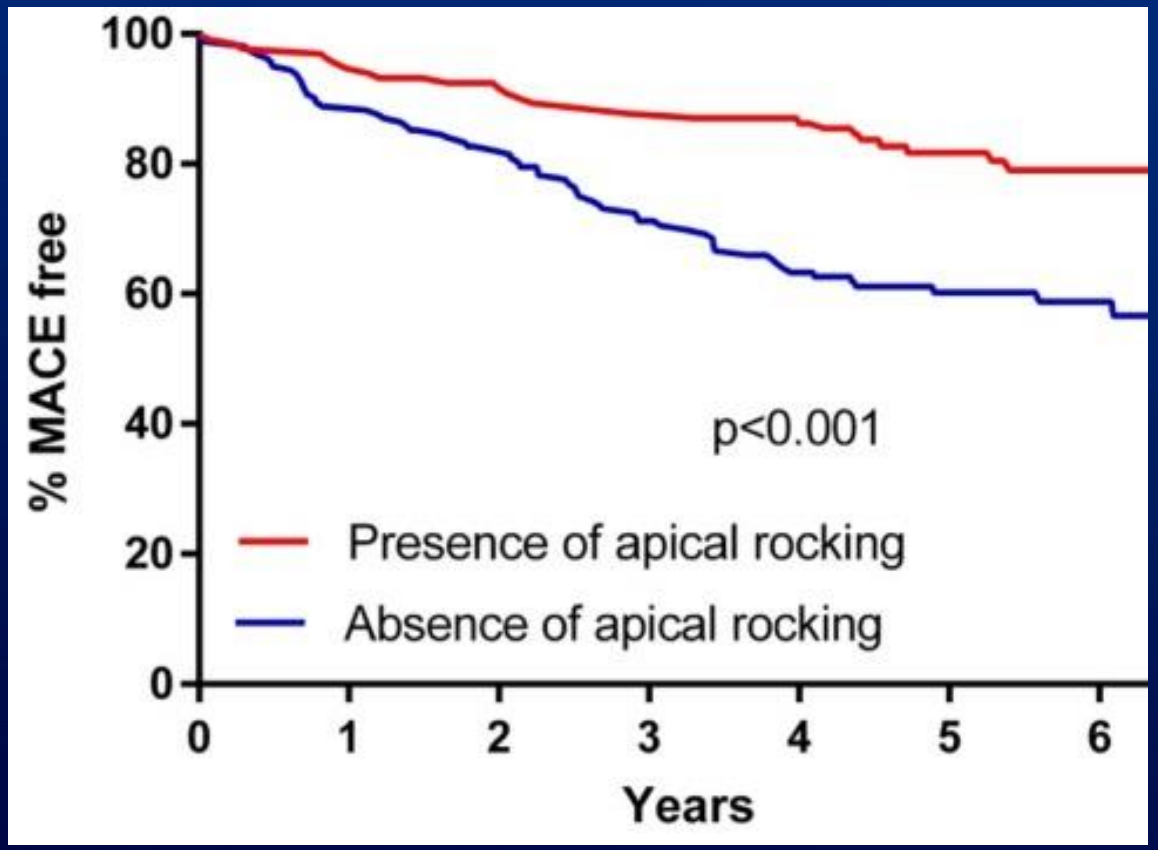


Baseline EDV: 231 ml ESV: 177 ml EF: 23%

1 day after CRT
EDV: 207 ml
ESV: 150 ml
EF: 28 %

MAYO CLINIC

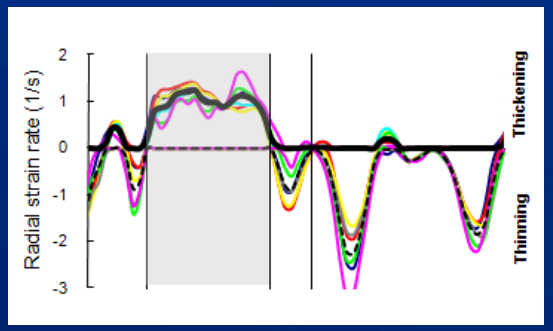
Association of apical rocking with long-term major adverse cardiac events in patients undergoing cardiac resynchronization therapy



Ghani et al EJ CVI 2016

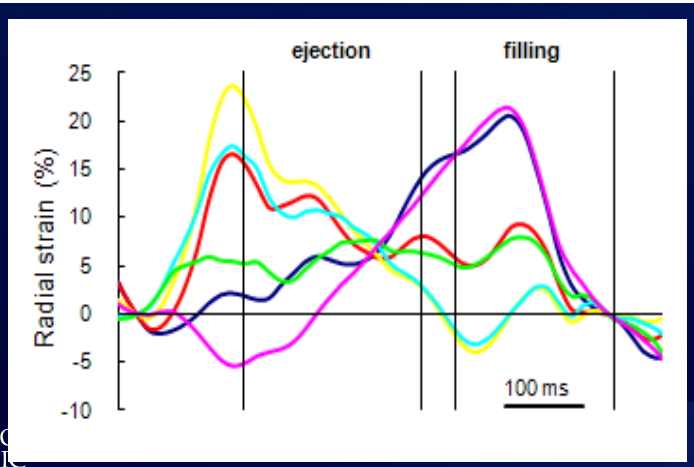
Discoordination of LV Mechanics

LBBB and Low EF

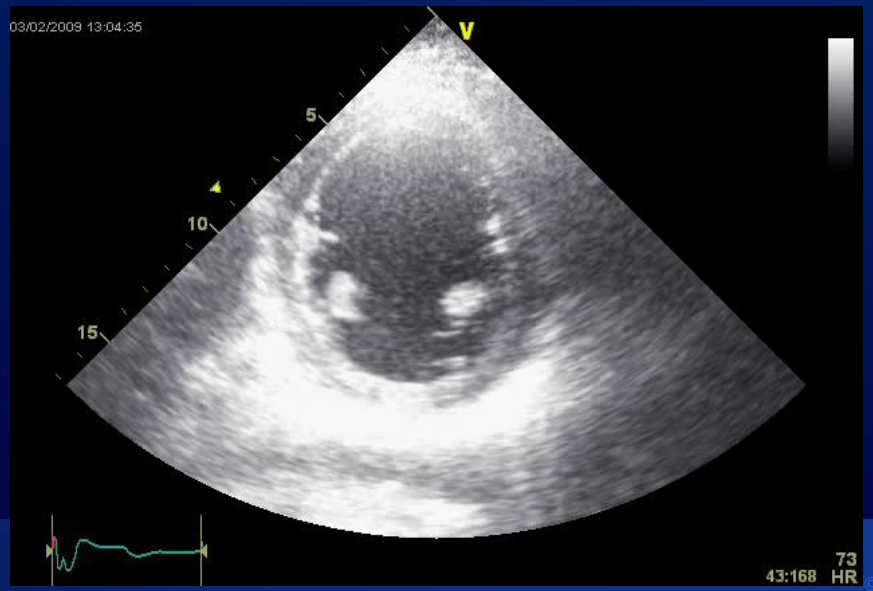


Normal

Discoordination
"Stretch/shortening"



Radial Strain

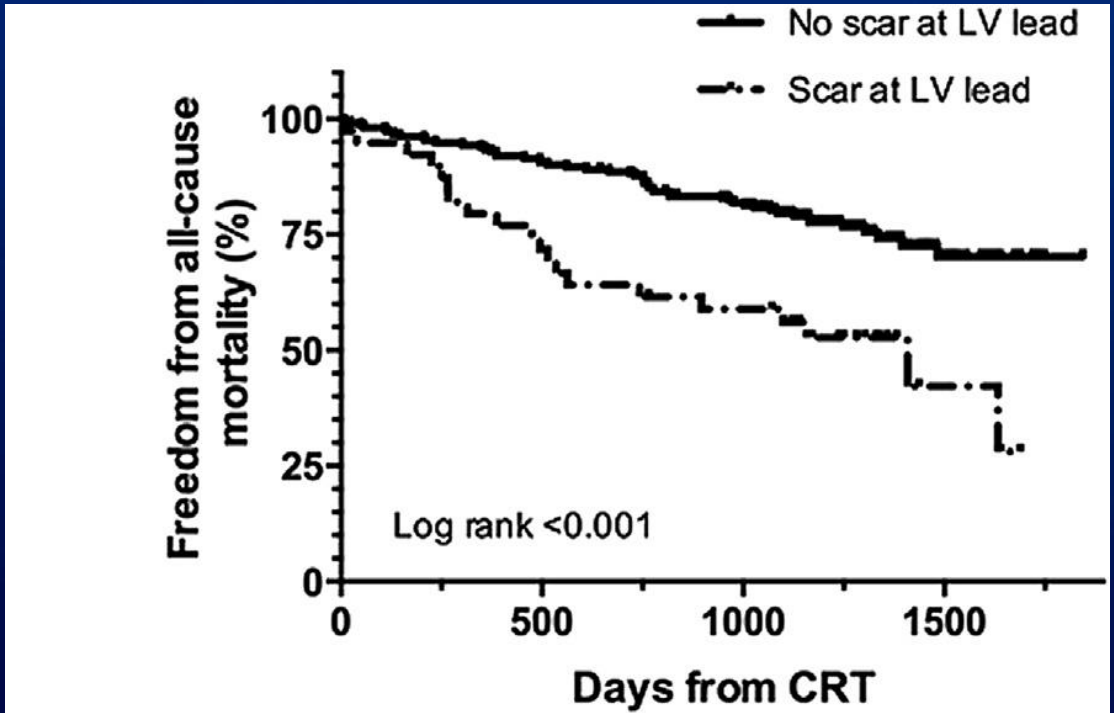


Prognostic Benefit of Optimum Left Ventricular Lead Position in Cardiac Resynchronization Therapy

Follow-Up of the TARGET Study Cohort (Targeted Left Ventricular Lead Placement to guide Cardiac Resynchronization Therapy)

Anna C. Kydd, MD,* Fakhar Z. Khan, MD,* William D. Watson, MD,* Peter J. Pugh, MD,* Munmohan S. Virdee, MD,† David P. Dutka, DM*

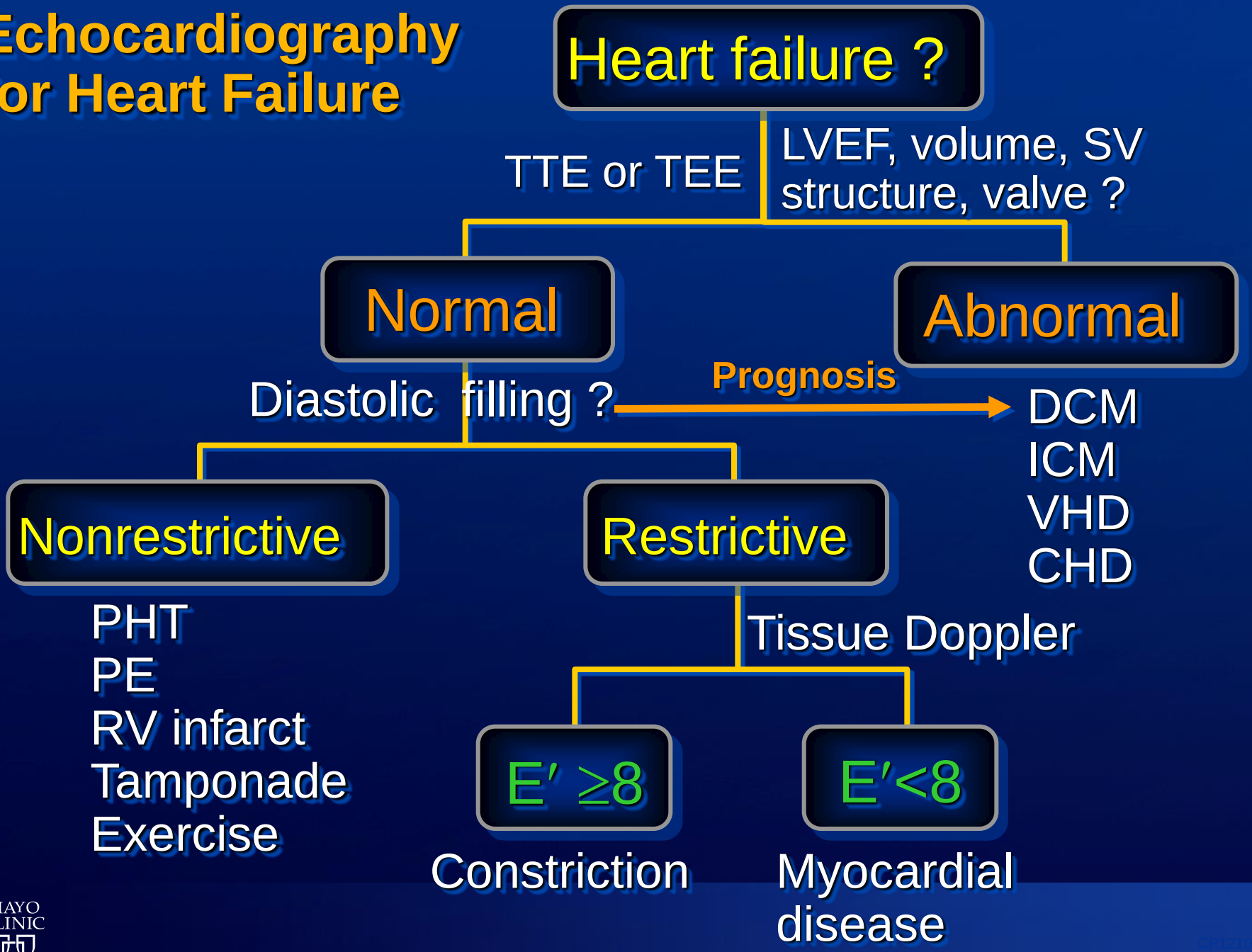
Cambridge, United Kingdom



No. at risk				
No scar	211	190	165	30
Scar	39	29	23	4

JACC HF 2014

Echocardiography for Heart Failure



MAYO CLINIC

Thank You!

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