Echocardiographic Evaluation of Diastolic Function

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Disclosure: nothing to disclose

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Practical Approach to Grade Diastolic Dysfunction

Recommendations for the Evaluation of Left Ventricular Diastolic Function by Echocardiography

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Keywords: Diastole, Echocardiography, Doppler, Heart failure

Diastolic Function

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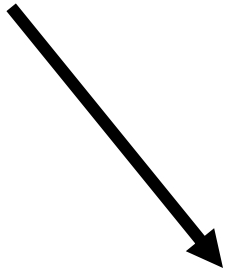
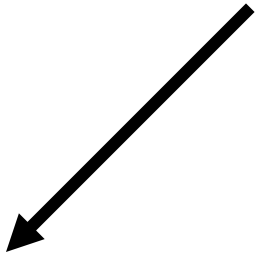
Cardiac Dyspnea

SYSTOLIC
HEART FAILURE

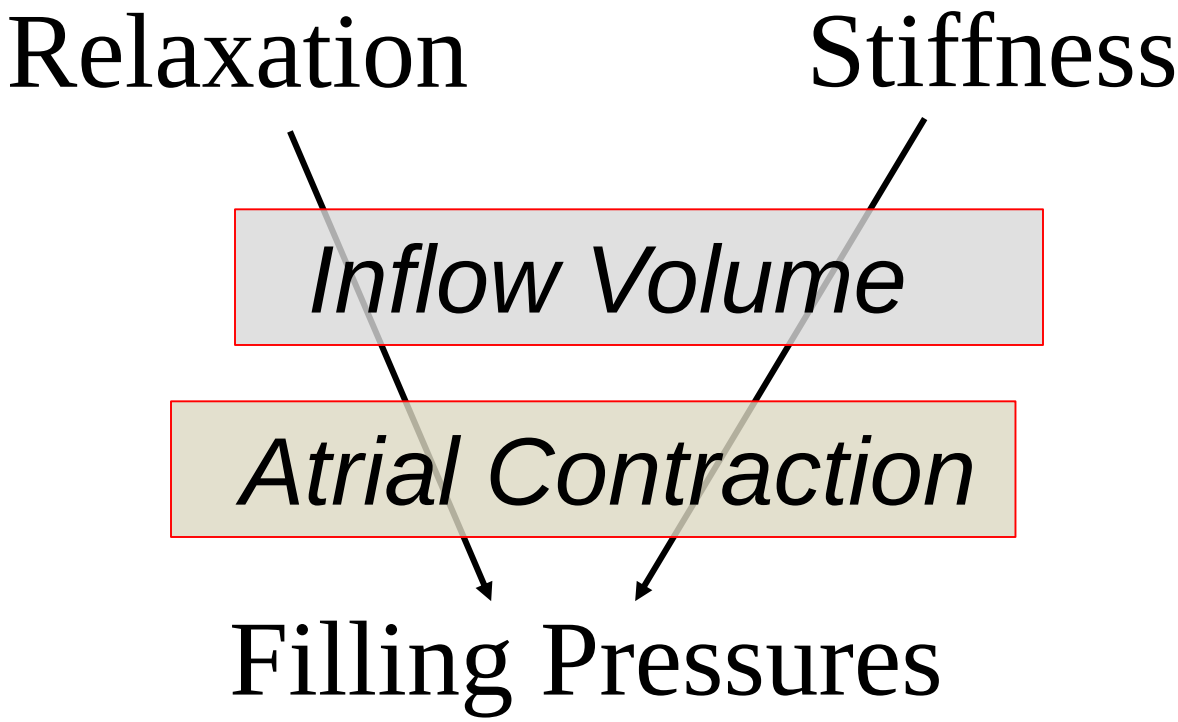
DIASTOLIC
HEART FAILURE



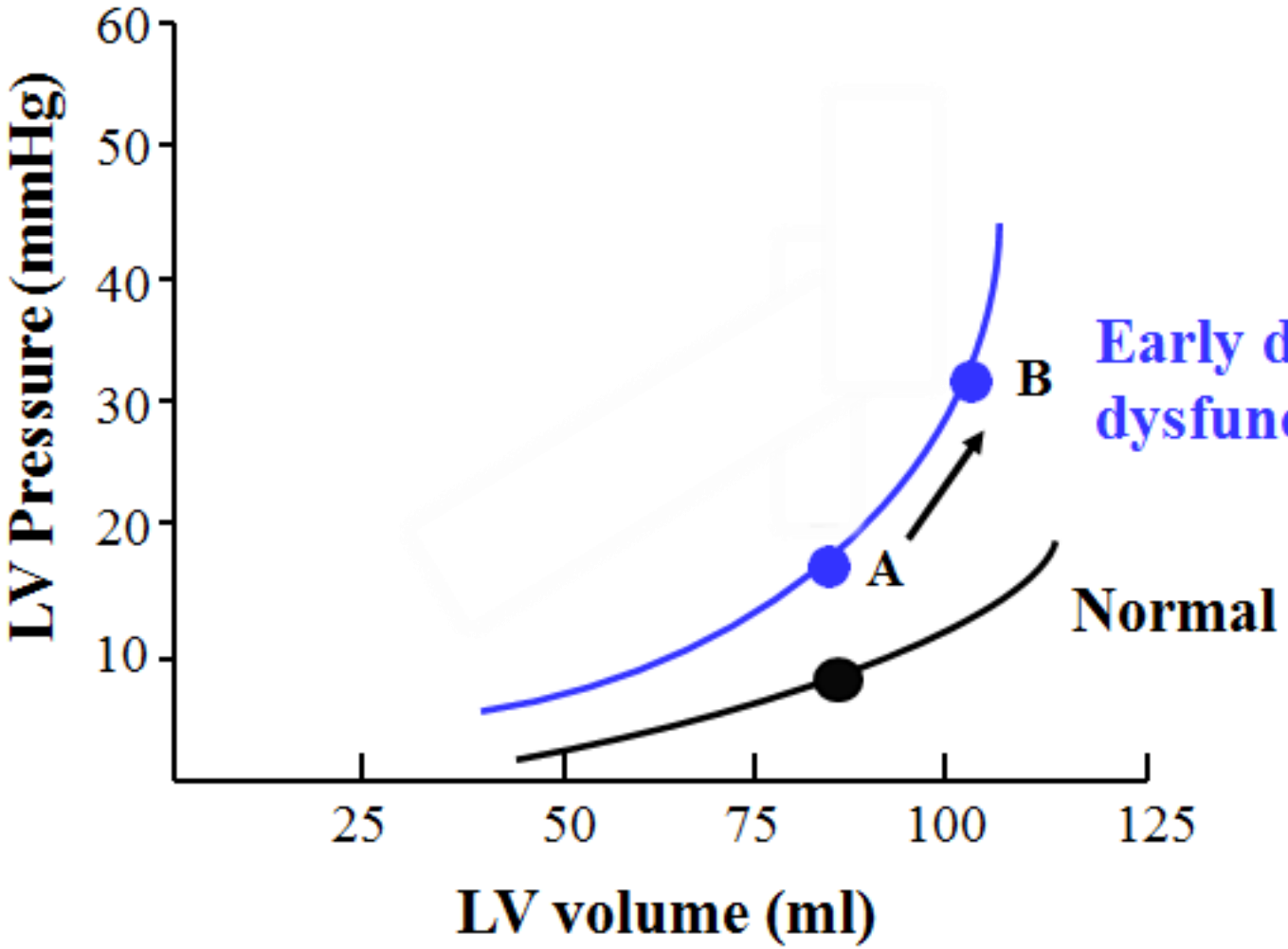


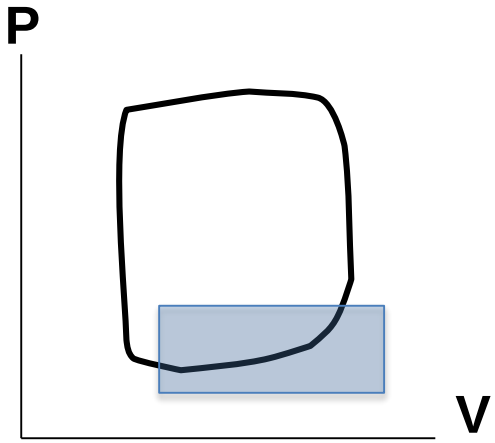
High Filling Pressures
2ary to abnormal diastolic function

Determinants of Diastolic Function



Diastolic Pressure-Volume Relations





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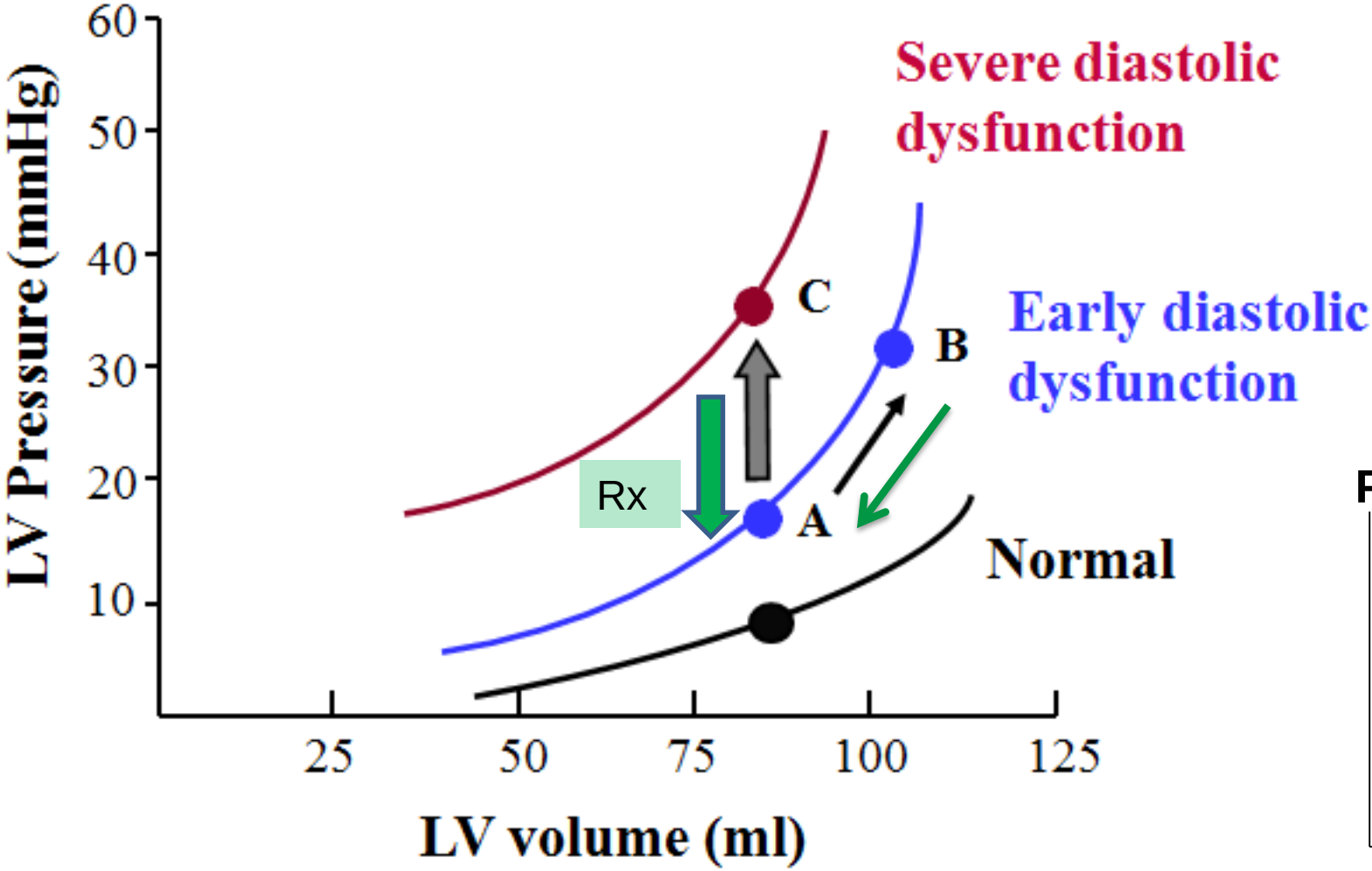

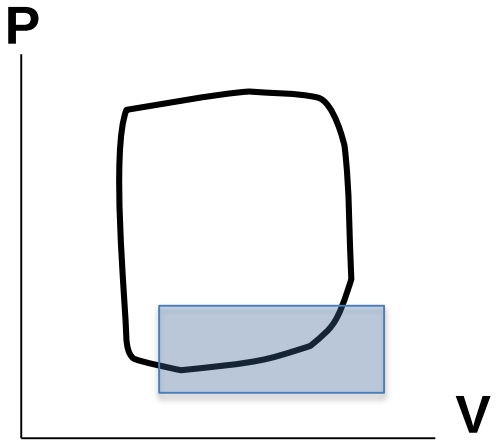

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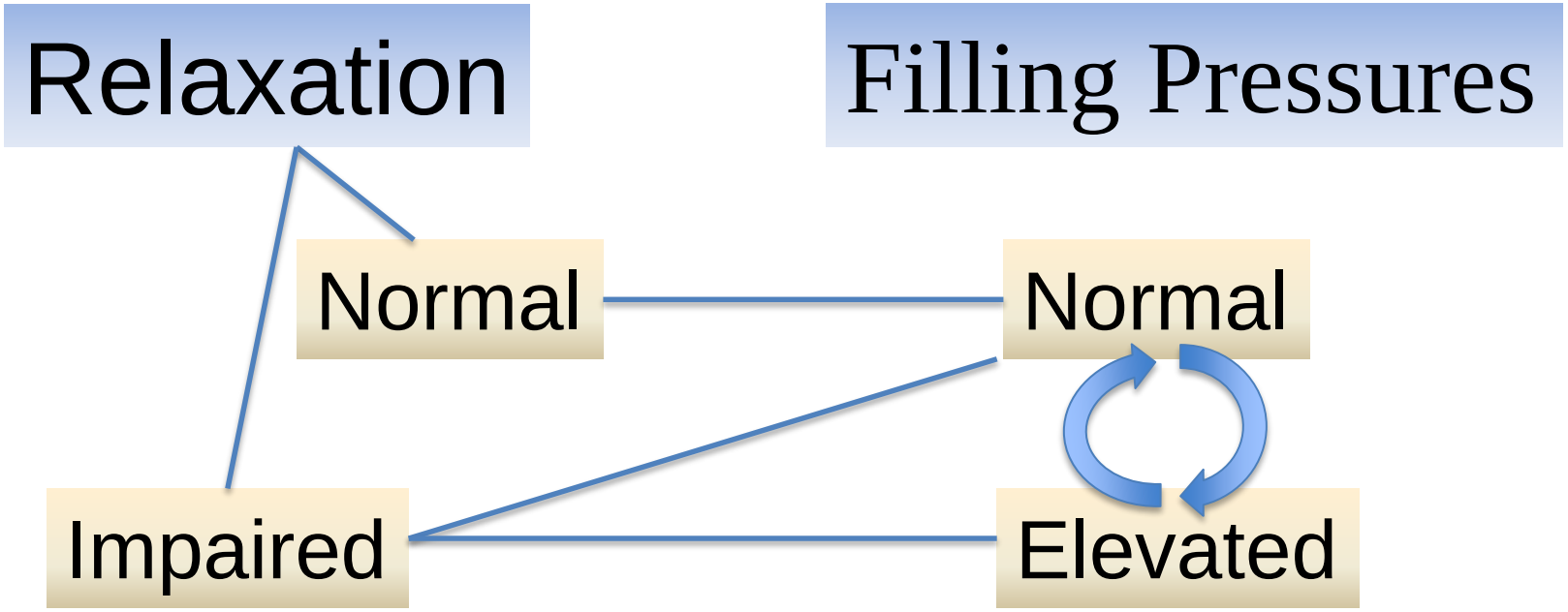
Echocardiographic Evaluation of Diastolic Function

Assess



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How To Assess Diastolic Function?

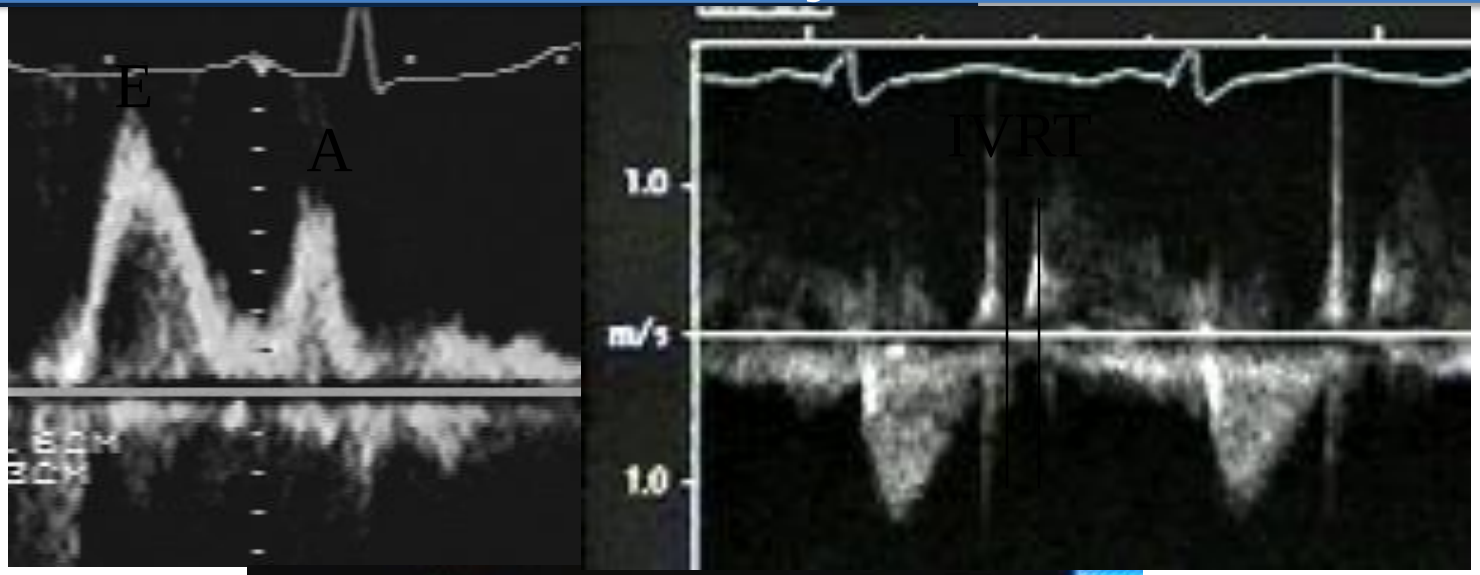
What do I use?

1. Clinical Sx's and age
2. 2D echo findings
   a. LV size; EF; RMWA
   b. LVH
   c. LA size
3. Doppler findings
   a. transmitral velocity; IVRT; PV vel
   b. Lat and sep e'
   c. TR vel->PASP

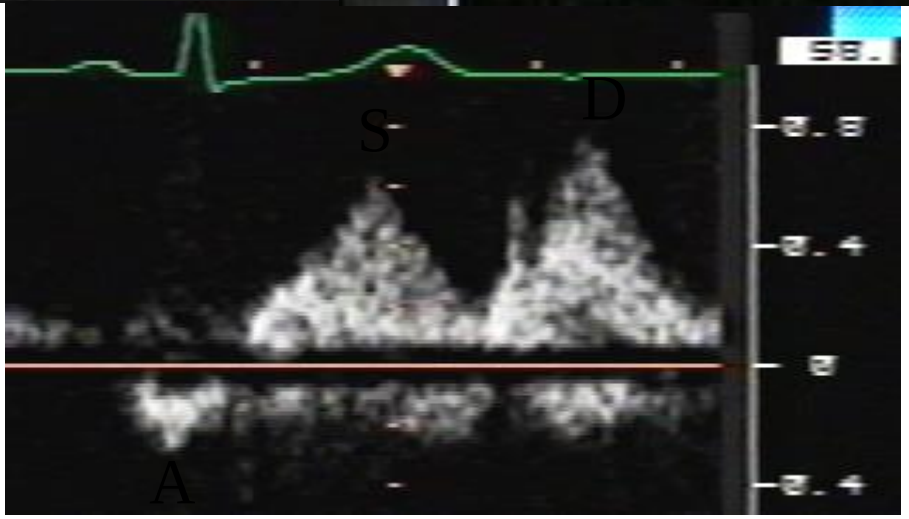
Doppler Assessment of Diastolic Function

Transmitral and Pulmonary Vein Velocities

MITRAL



PULMONARY VEIN



Sweep speed at 100mm/s

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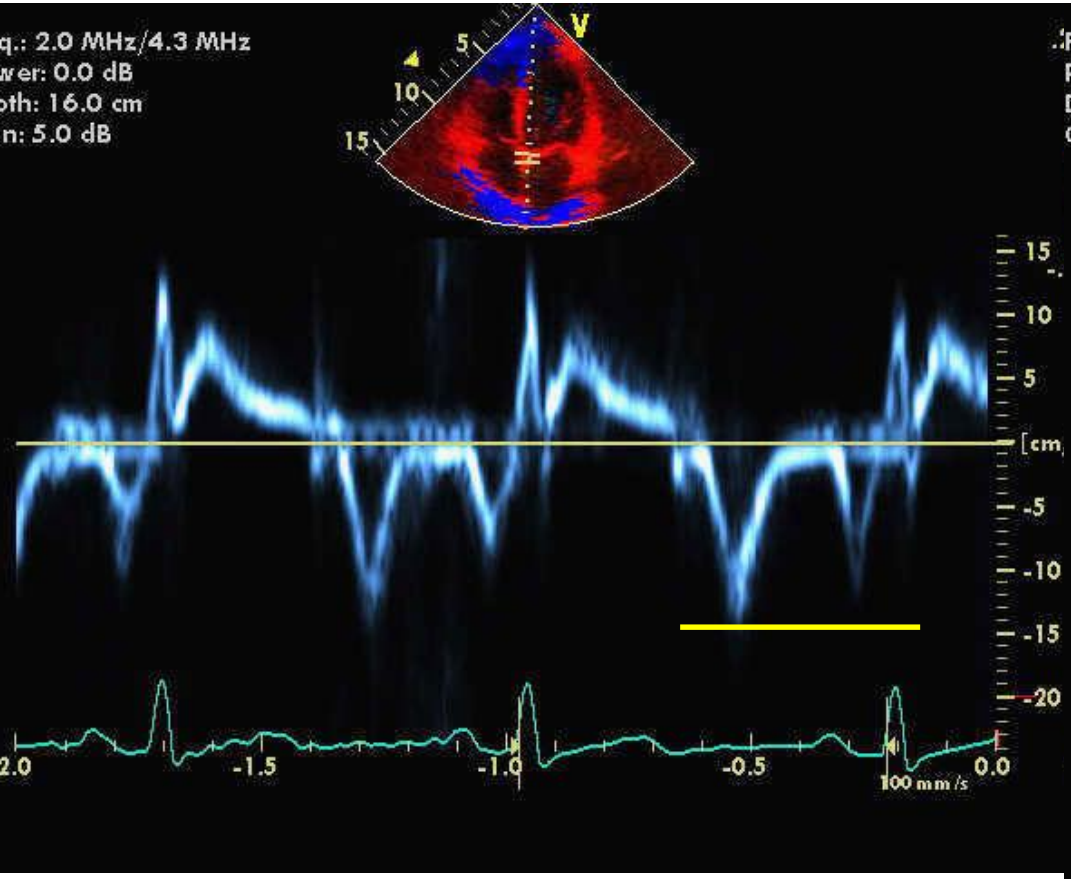
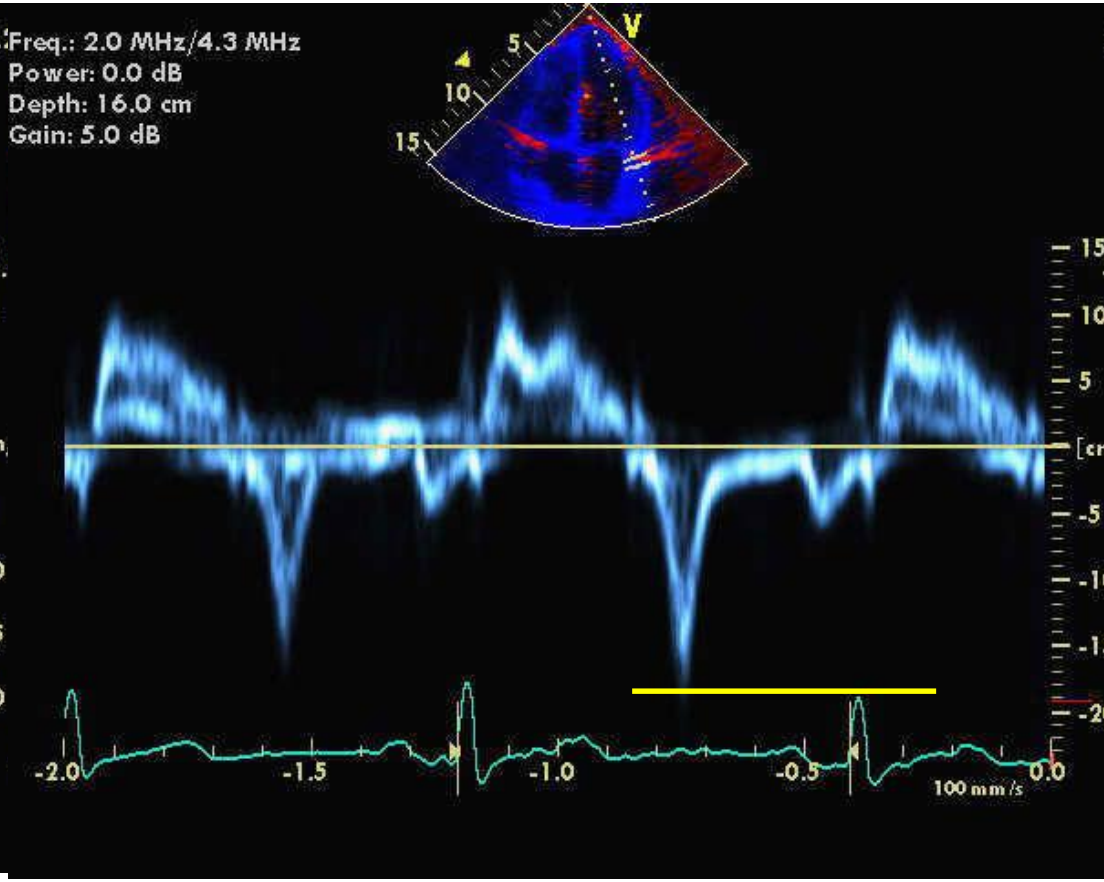
Myocardial (or annular) Velocity by Tissue Doppler



Septal



Lateral

Spectral Tissue Doppler Technical Issues

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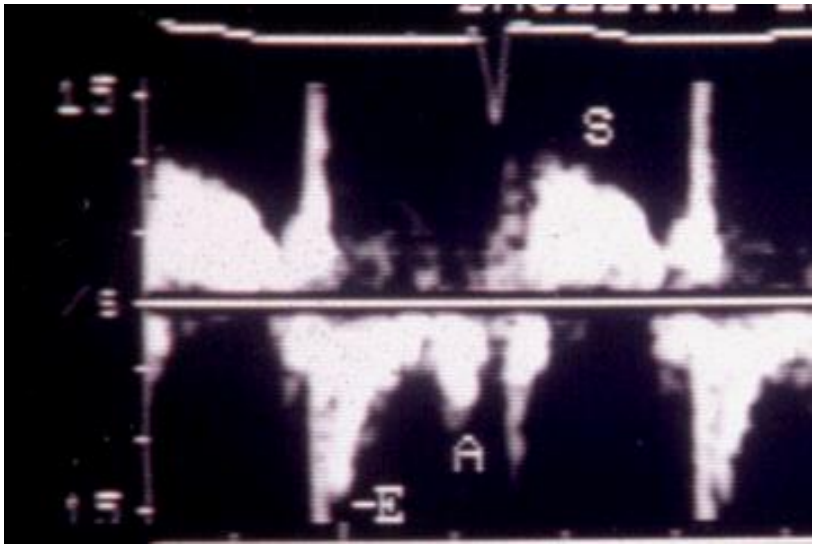

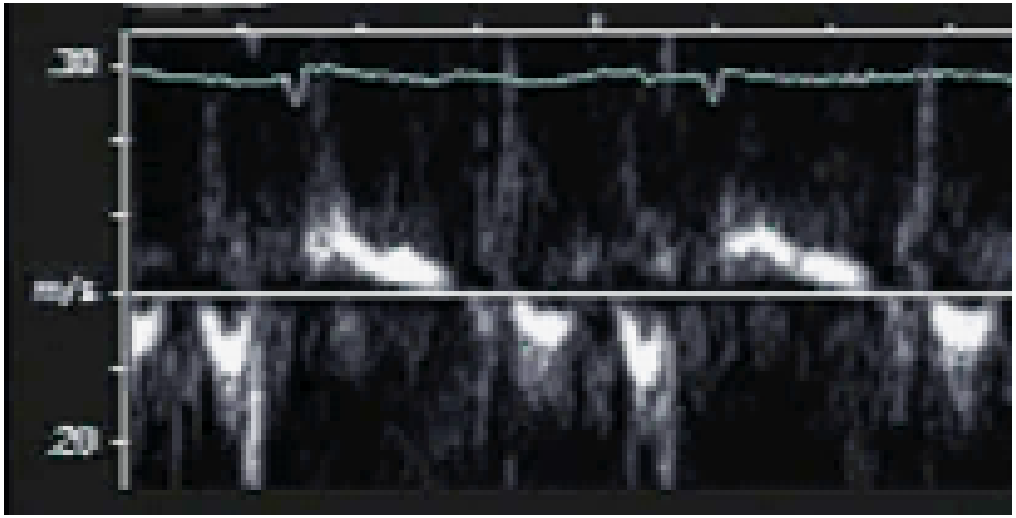

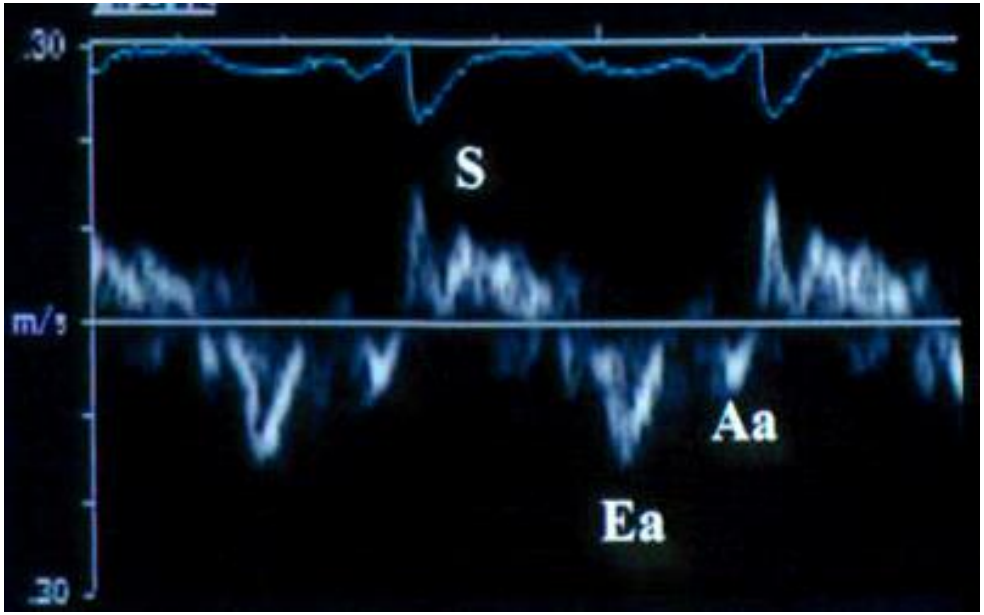

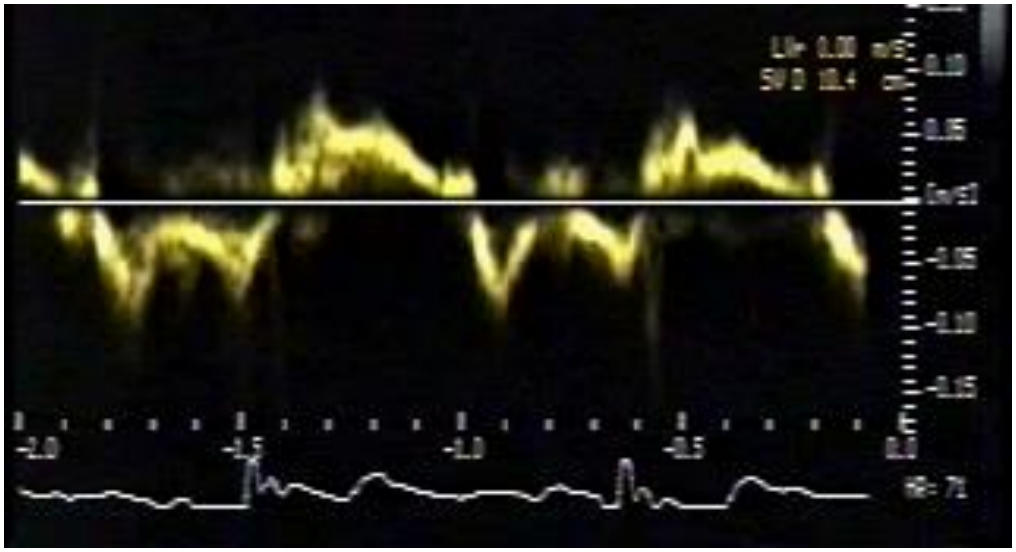

Systolic Heart Failure

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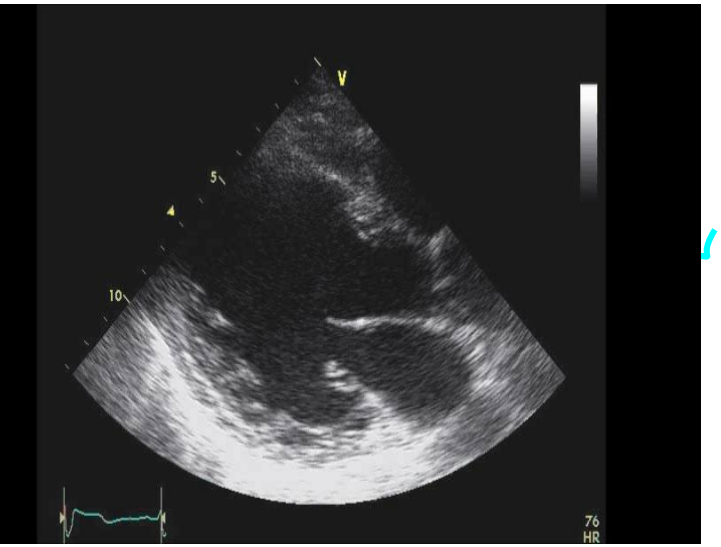
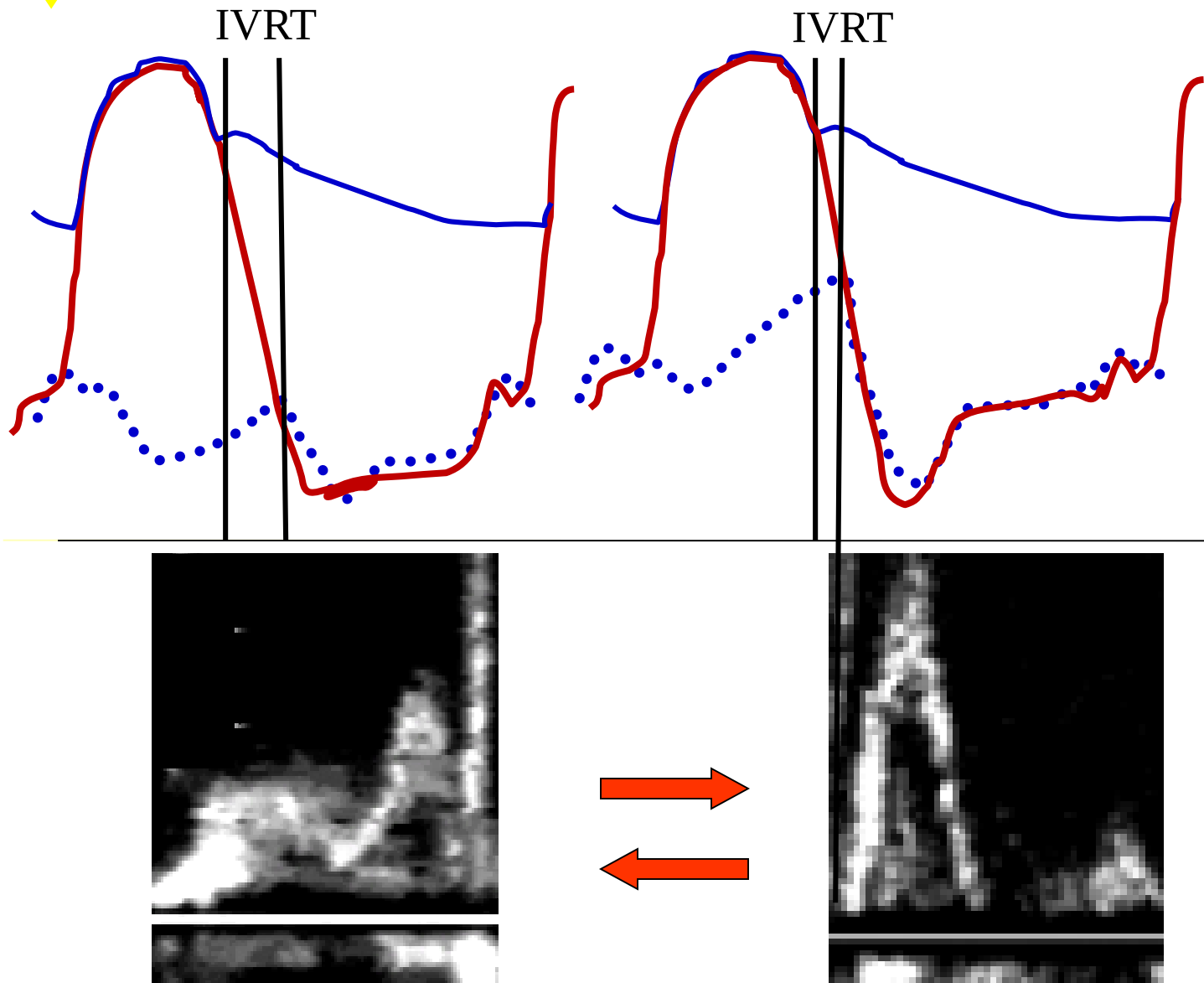
RELAXATION

SYSTOLIC HF





Diastolic Dysfunction

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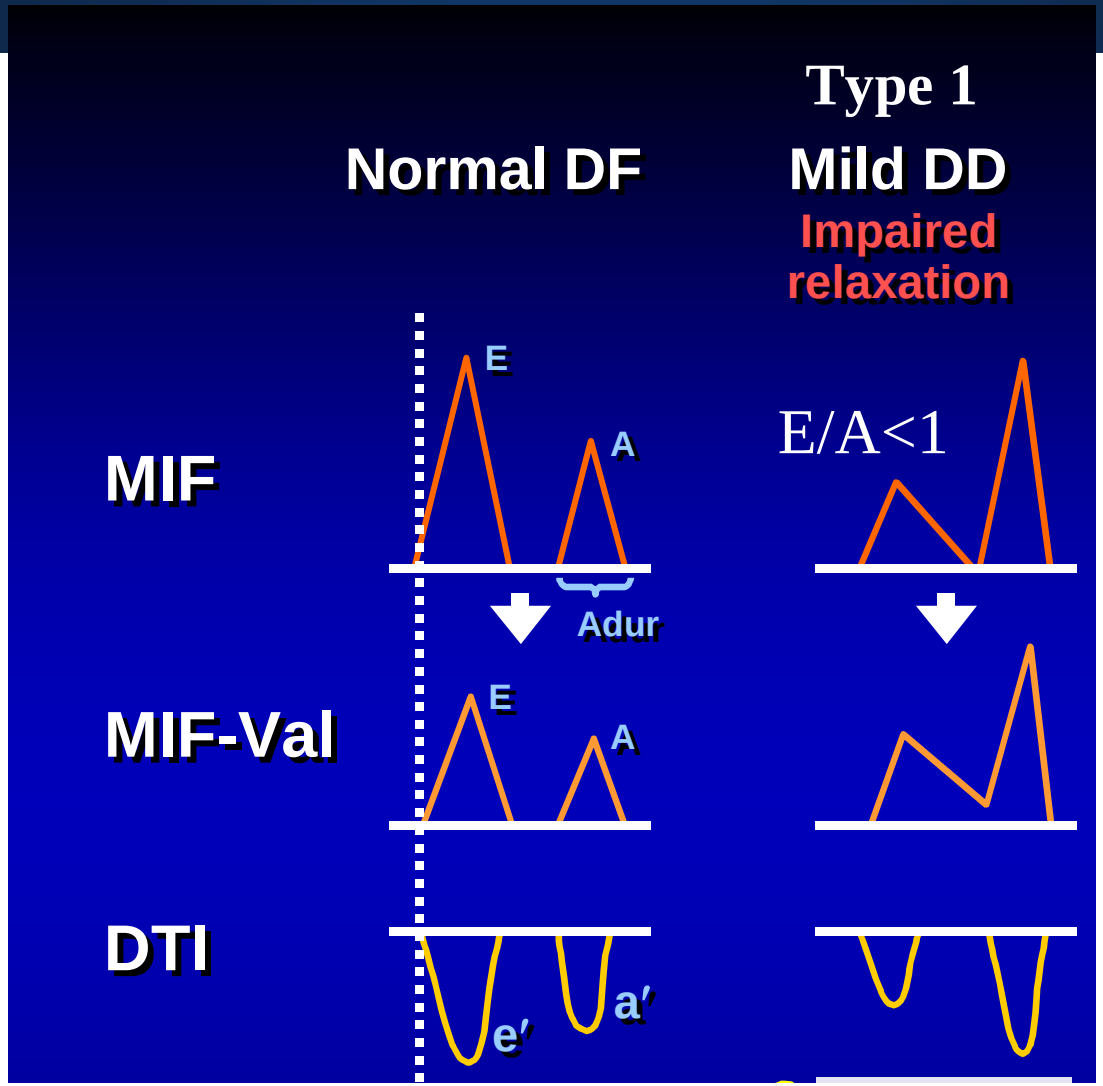
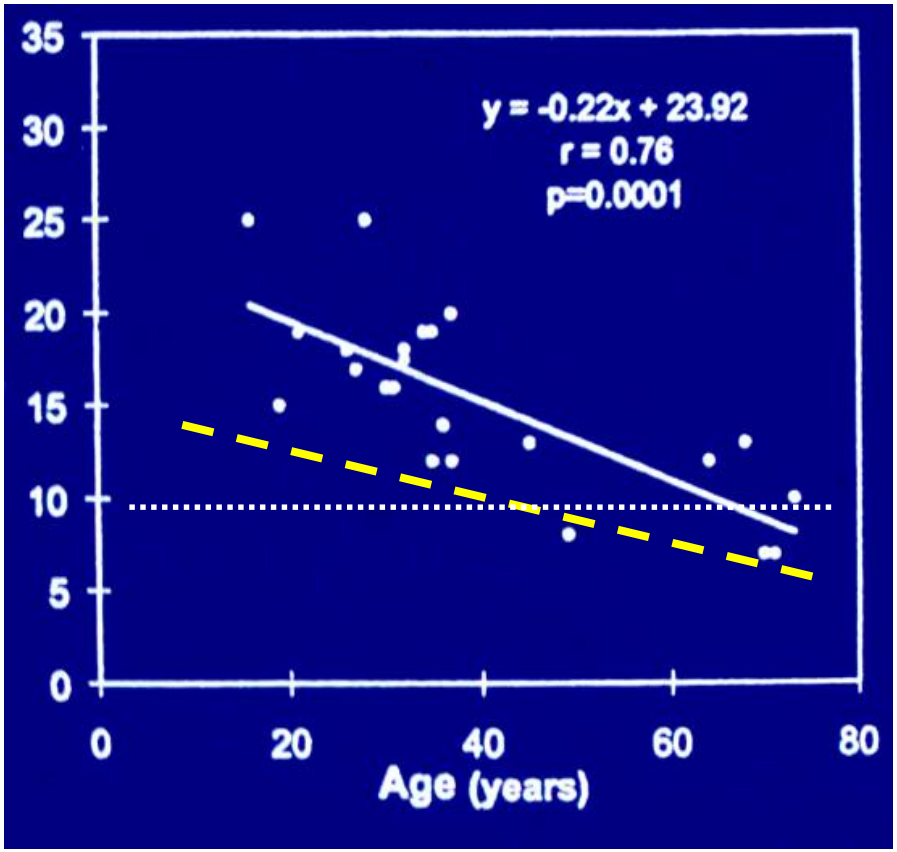
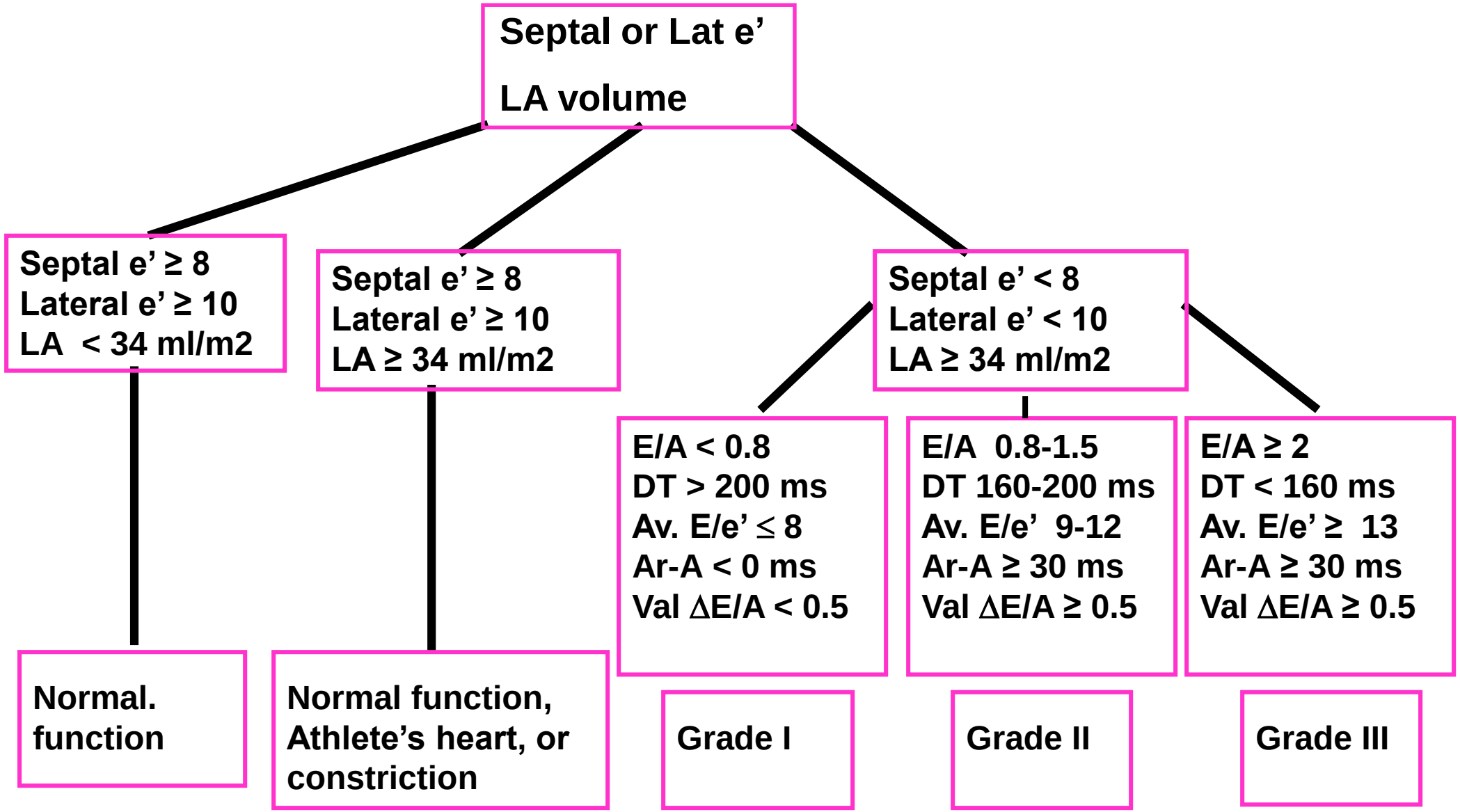


When is Type 1 abnormal versus due to old age?



What about age > 80?

Practical Approach to Grade Diastolic Dysfunction



Is LV relaxation normal or impaired?

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Findings universally associated with normal LV relaxation*

- Normal LV structure and EF
- Normal regional wall motion
- Transmitral E ≥ A
- Normal e' adjusted for age
- Normal LA volume

***All must be present to ensure normal LV relaxation**

-Exception: LA may be enlarged in:

Primary MV disease (MR or MS)

Athletes

High CO states

Atrial fibrillation

Normal Heart

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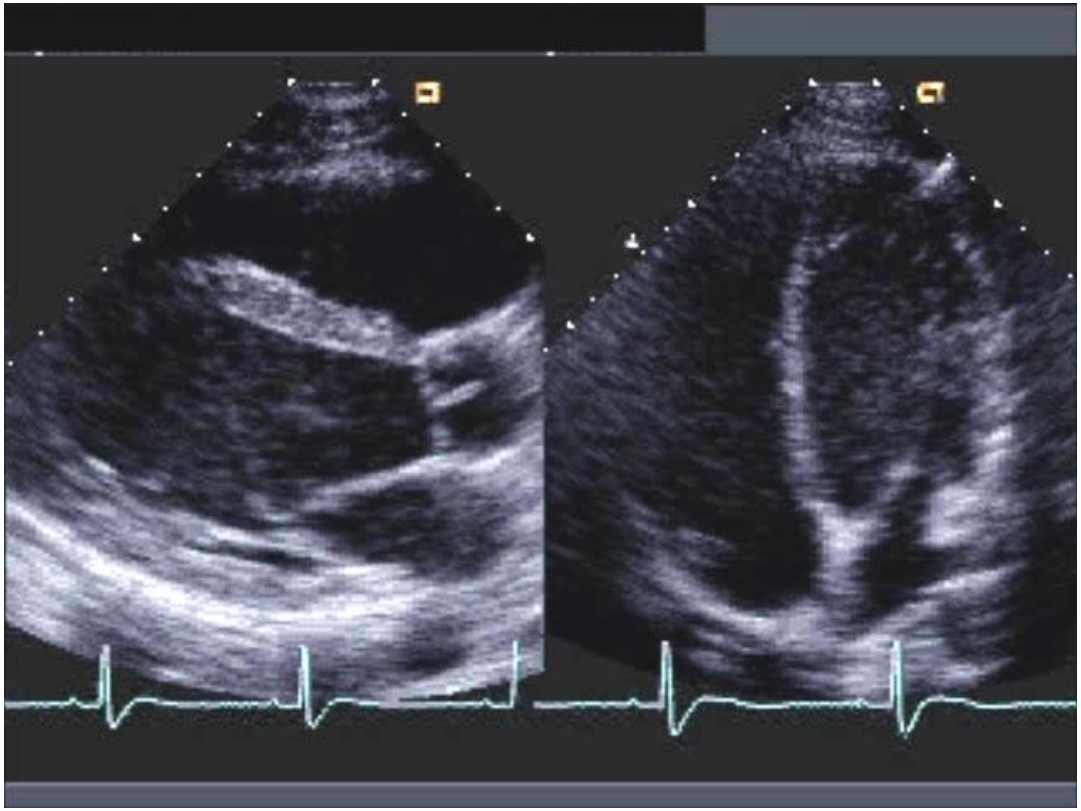

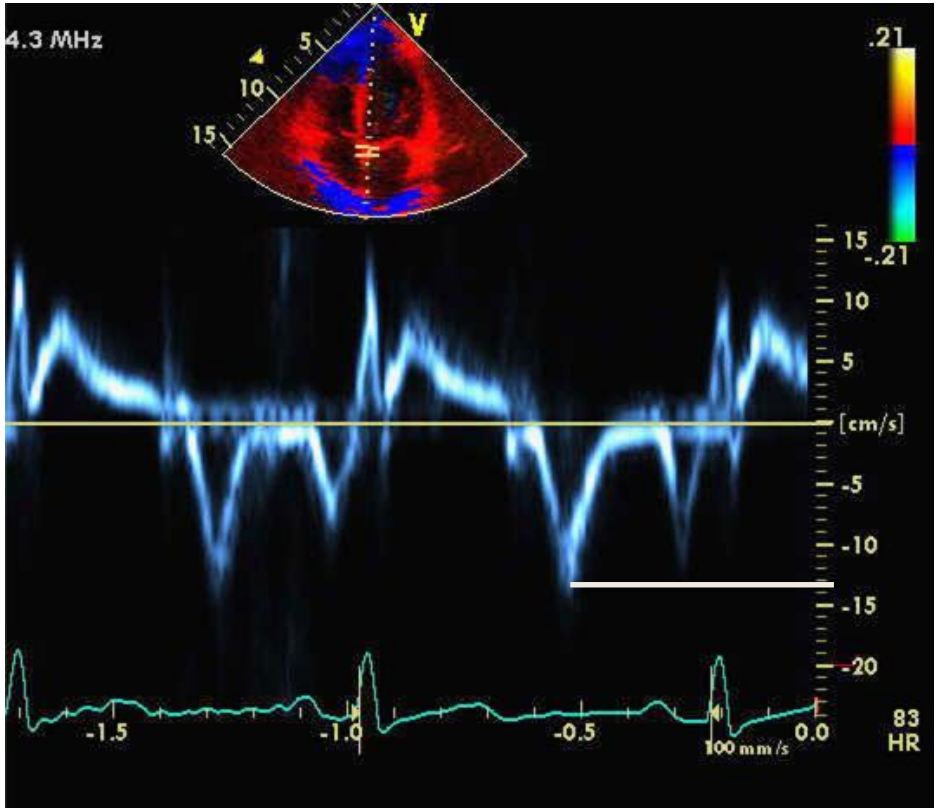

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- Low EF
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- Enlarged LA: found in >90% of patients with diastolic dysfunction
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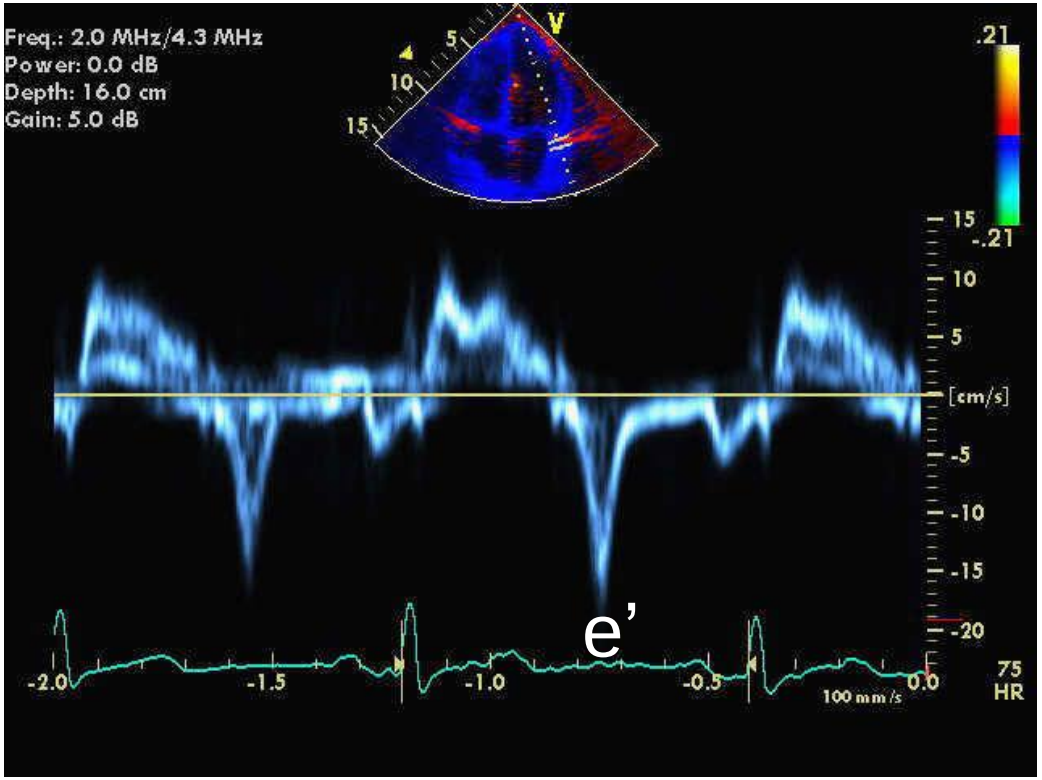
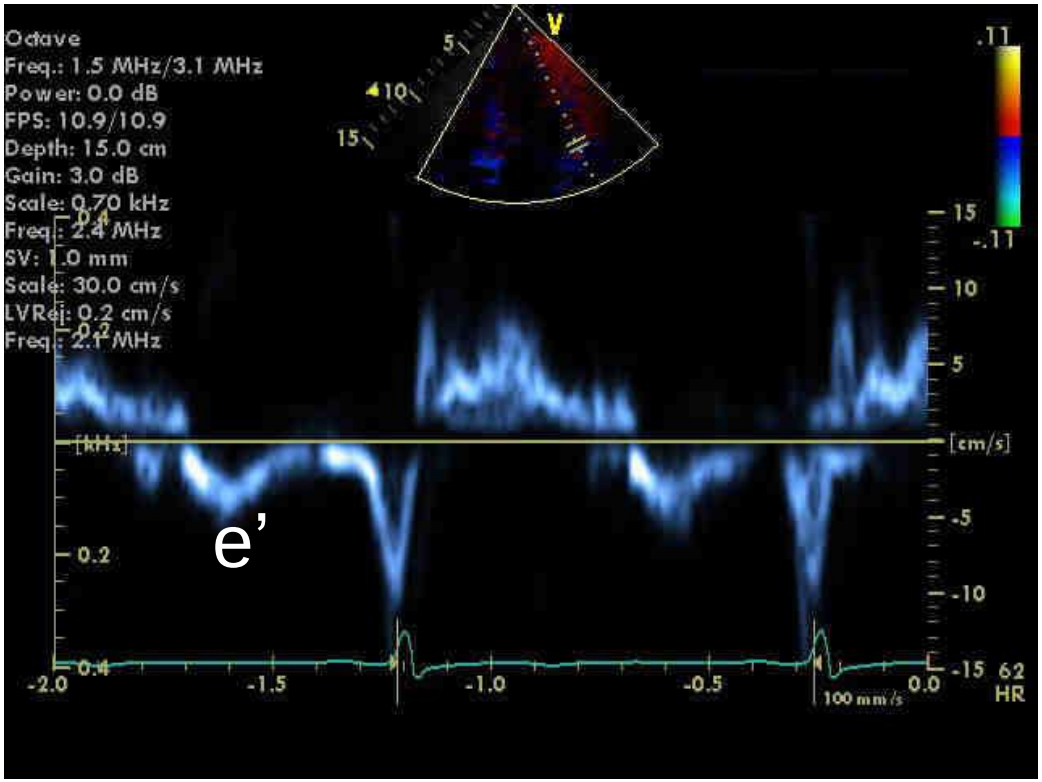
Myocardial (or annular) Velocity by Tissue Doppler



Normal Relaxation



Impaired Relaxation

64F; HTN and dyspnea

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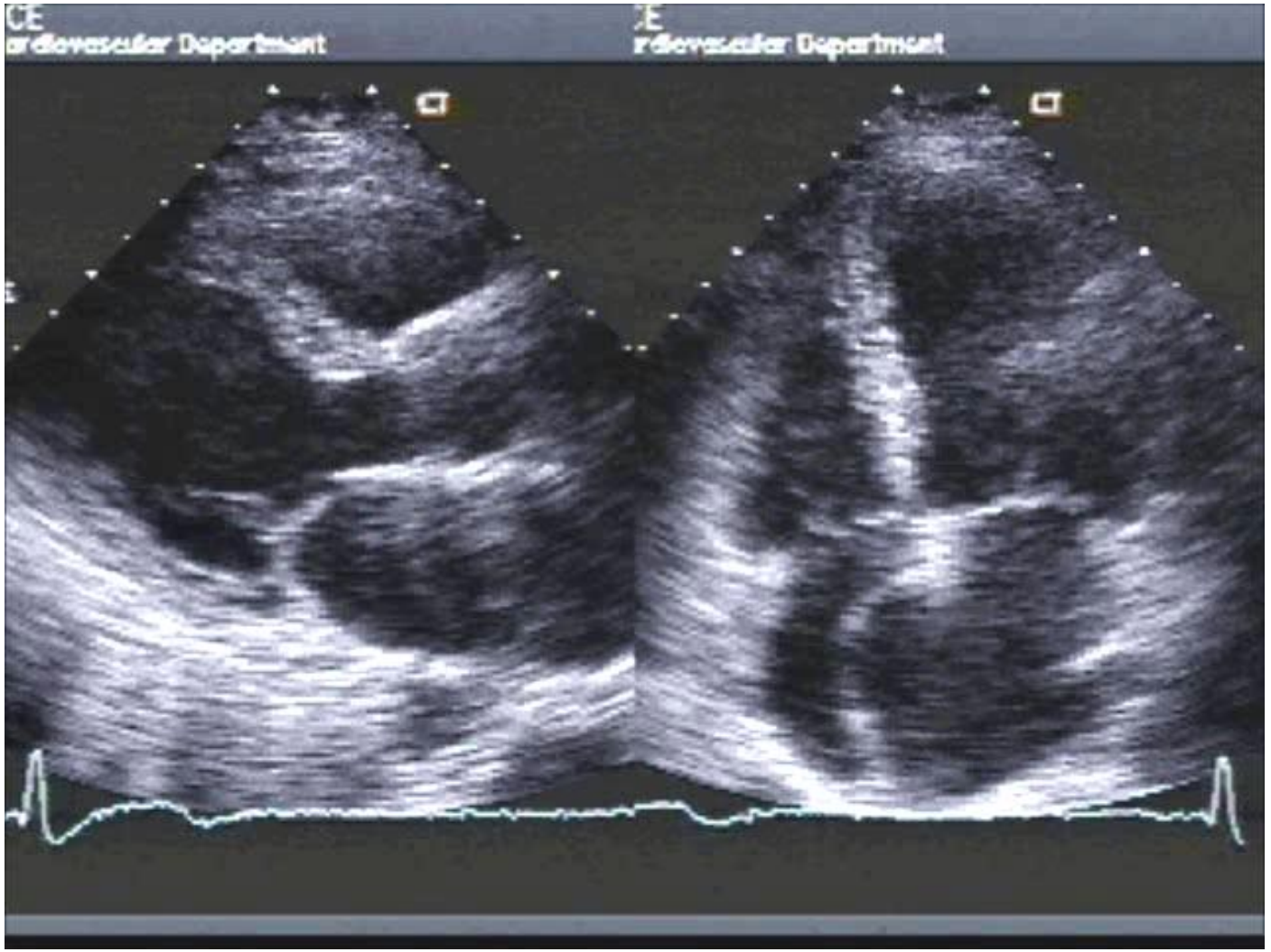
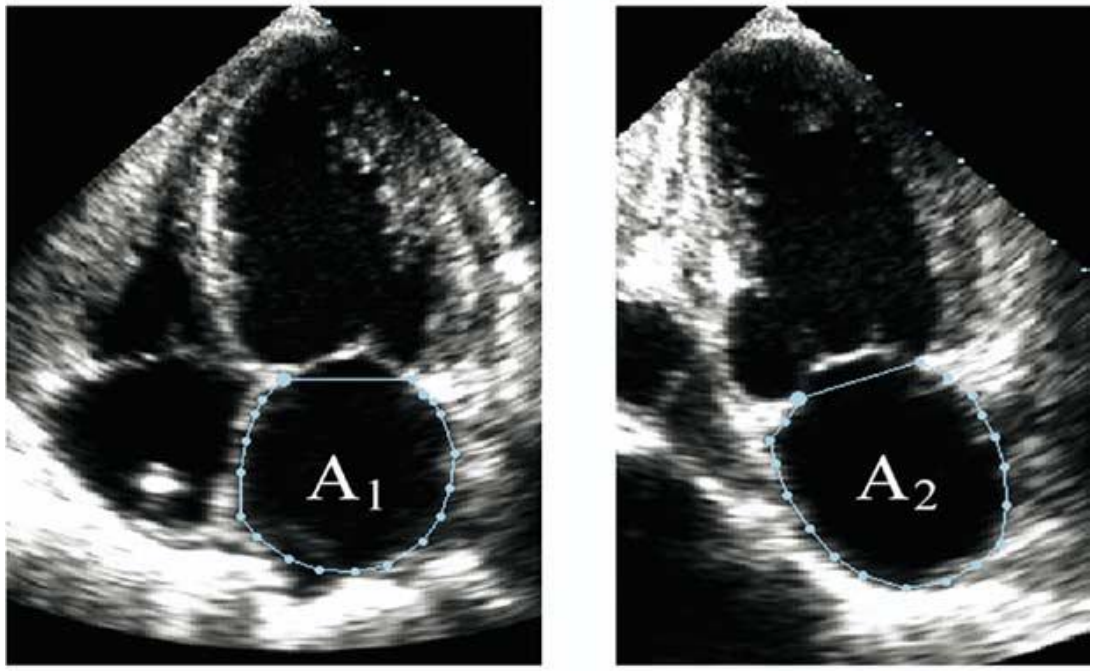


Assessment of Left Atrial Size

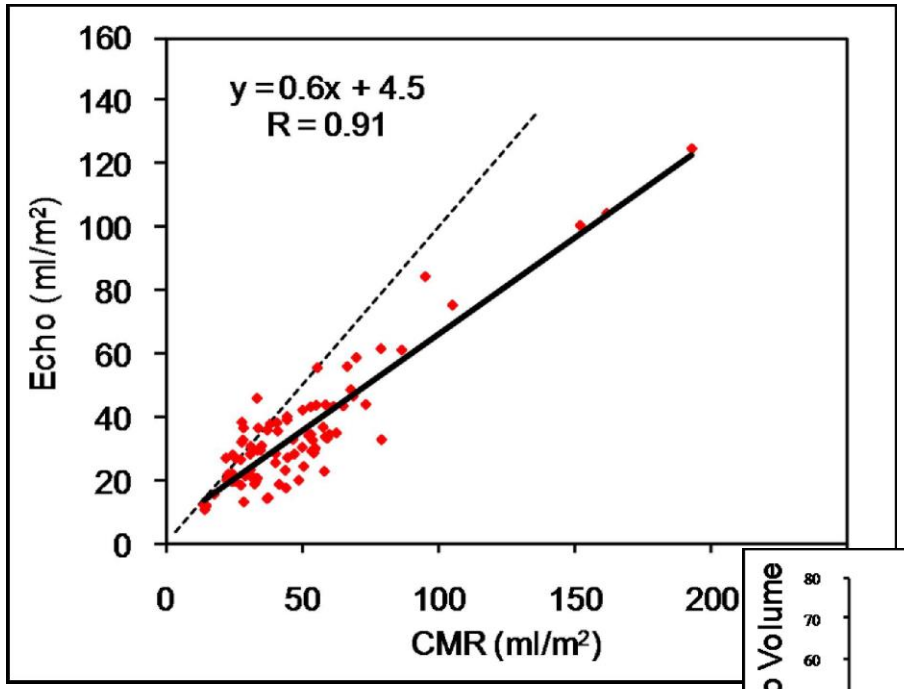


Left Atrial Volume =

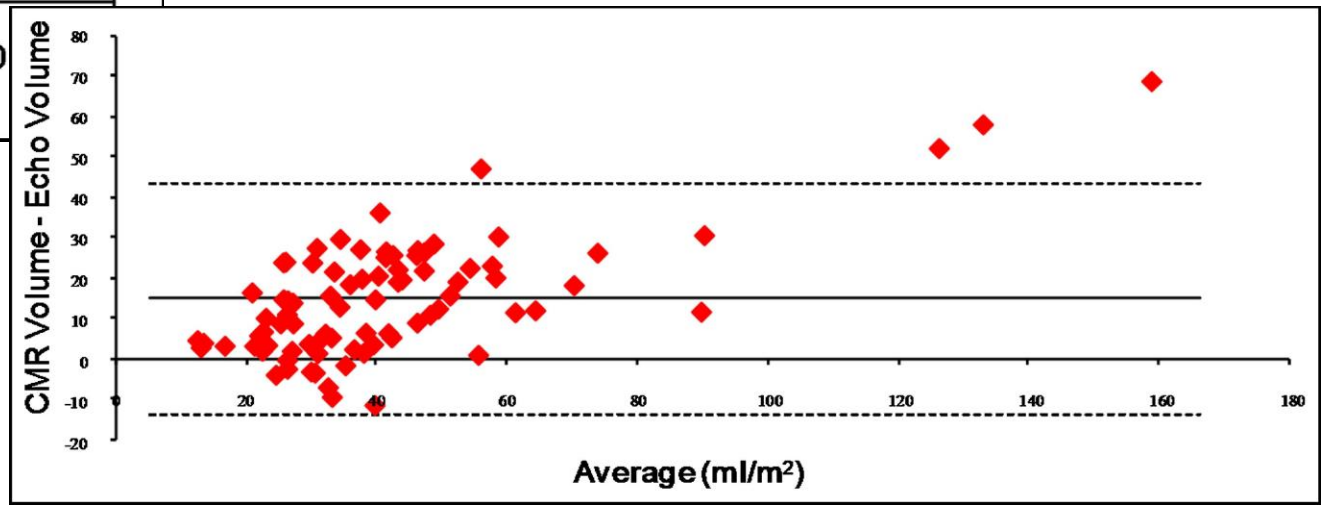
$$8/3\pi[(A_1)(A_2)/(L)]^*$$

Normal LA vol: ≥34ml/m^2

JASE 2005;18:1440



Comparison of left and right atrial volume by echocardiography versus cardiac magnetic resonance imaging using the area-length method



Whitlock M, et al. Am J Cardiol 2010;106:1345

55M with dyspnea: EF, 27%

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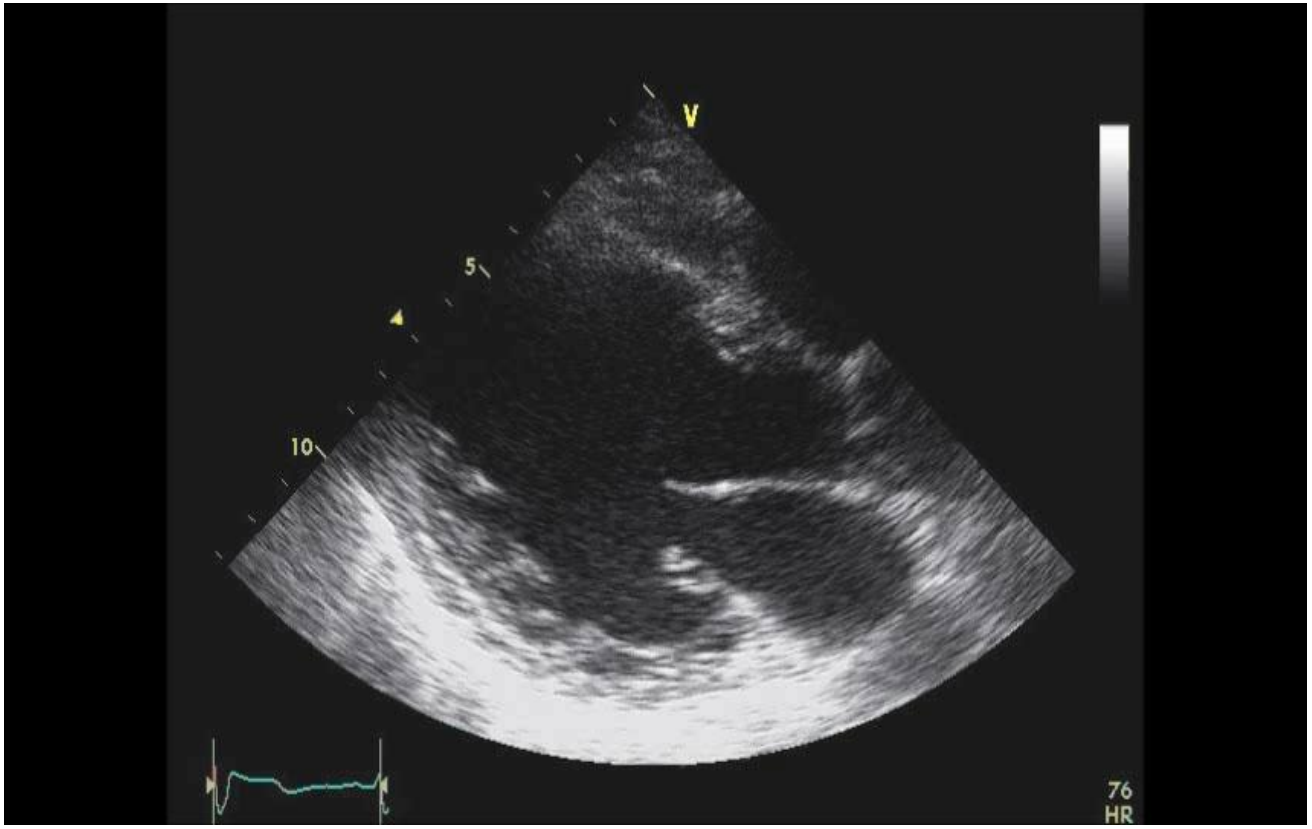

100% likelihood of impaired relaxation

Systolic Heart Failure

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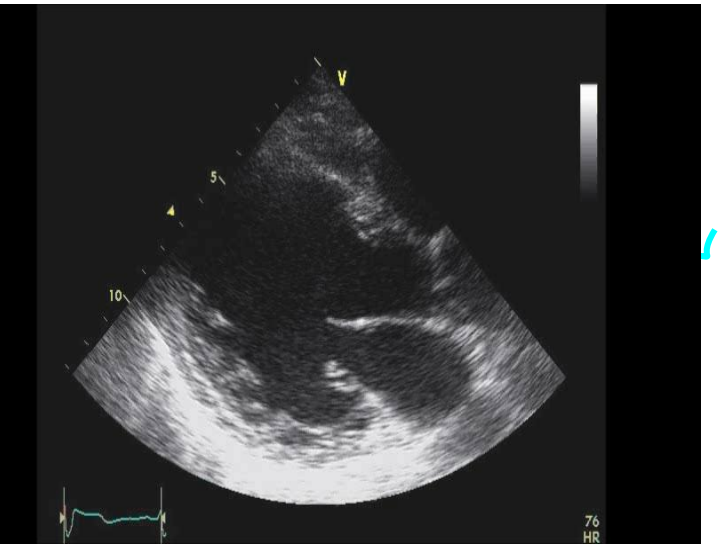
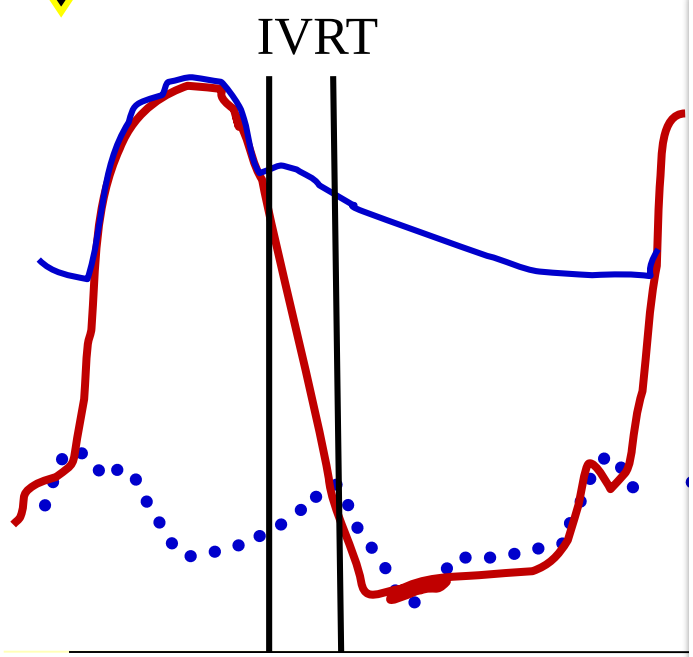
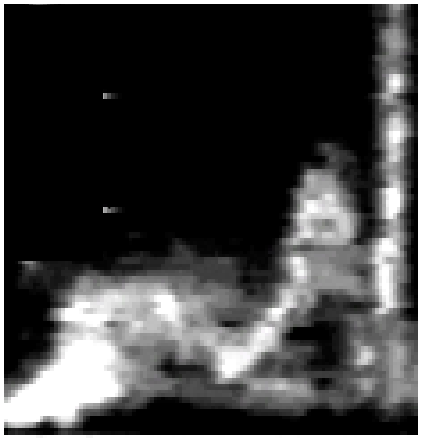
SYSTOLIC HF

RELAXATION







79M with HTN and dyspnea

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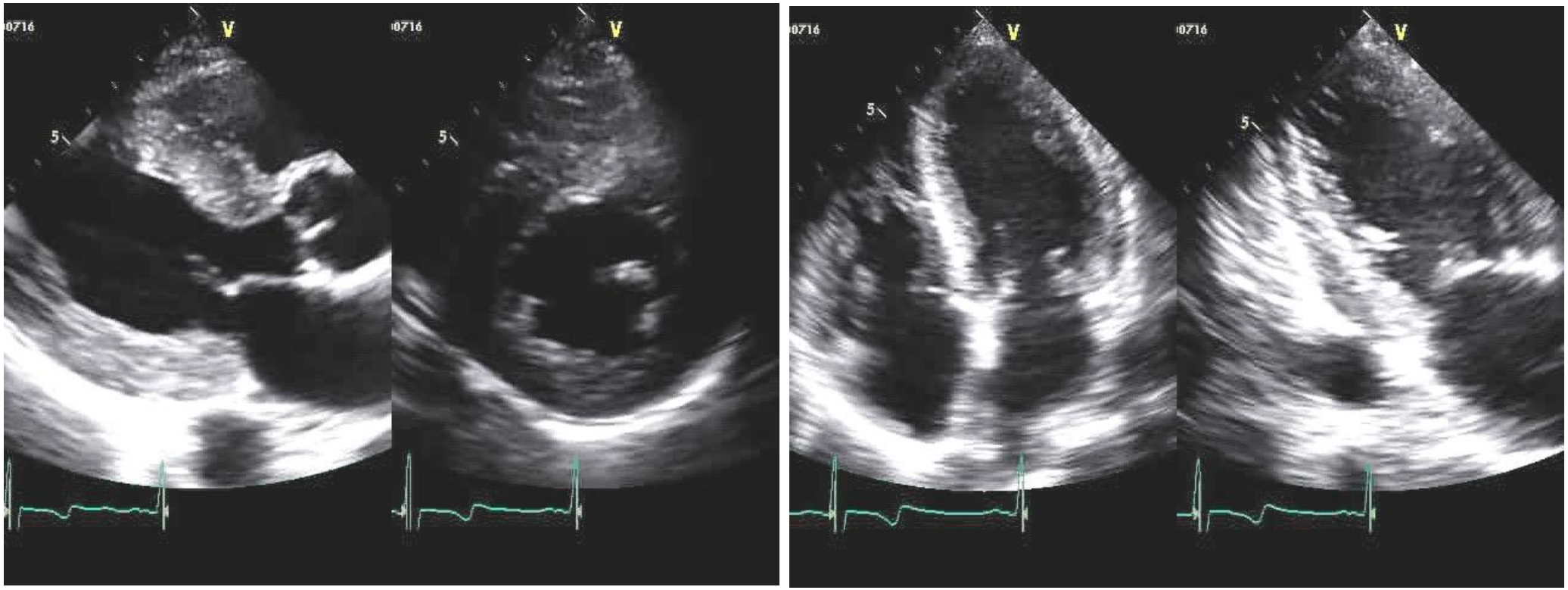

100% likelihood of abnormal relaxation

Diastolic Dysfunction

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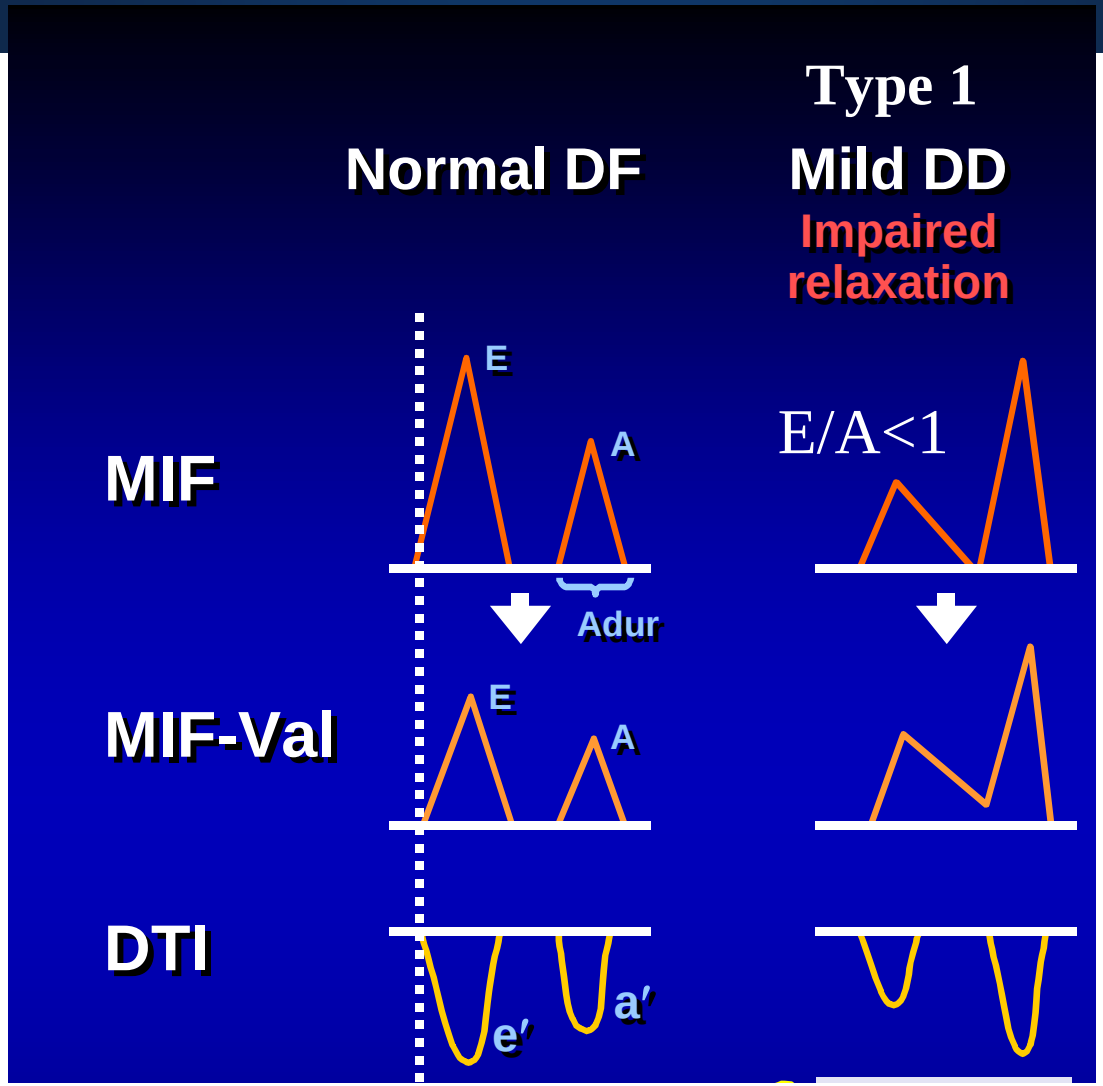

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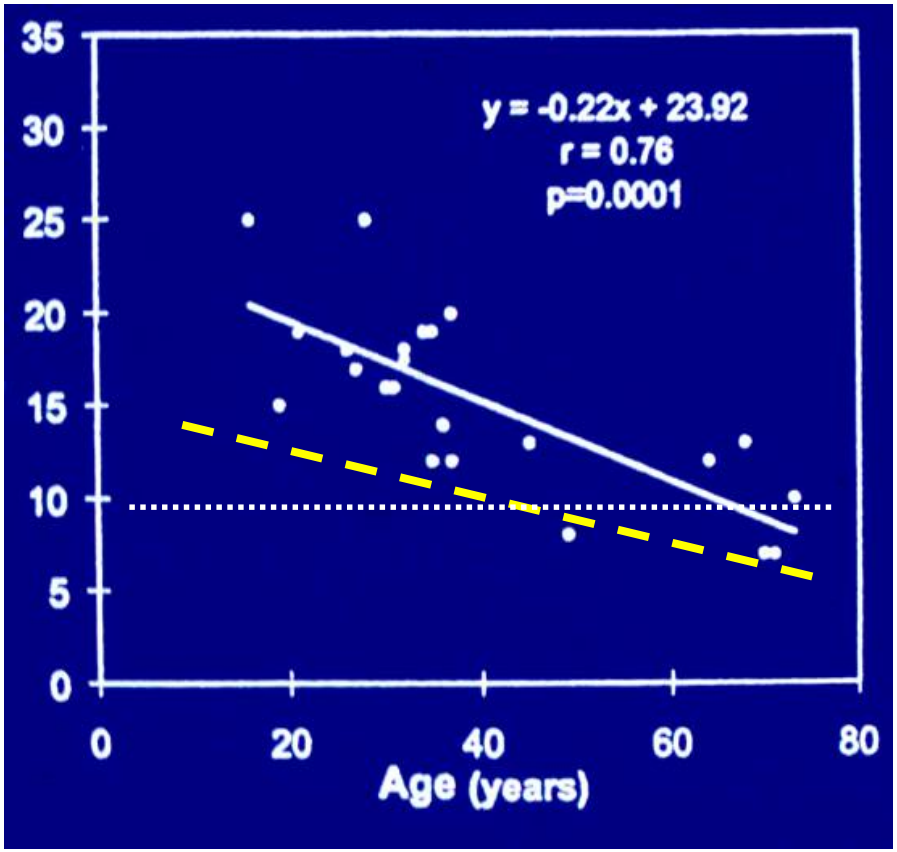

What about age > 80?

Cardiac Structure and Function in Persons >85 yrs

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Echocardiographic measurements in the cohort as a whole (n = 450)

Variable	All Participants	Women	Men
LA volume (ml)	64.6 ± 26	63 ± 23.7	66.2 ± 28.4
LV end-diastolic volume index (ml/m^2)	68.4 ± 18.7	64 ± 17.8	73.1 ± 18.5
LV end-systolic volume index (ml/m^2)	31.3 ± 14.2	28 ± 12.1	34.9 ± 15.4
LV mass index (g/m^2)	122 ± 35.9	122.7 ± 40.3	121.4 ± 30.6
E/A ratio	1 ± 1.1	0.99 ± 0.57	1.1 ± 1.4
Deceleration time	205.9 ± 68.1	210.3 ± 72.2	201.6 ± 63.6
Tissue Doppler lateral E wave (cm/s)	7.3 ± 2.2	7 ± 2.2	7.7 ± 2.2
Tissue Doppler lateral A wave (cm/s)	9.8 ± 3.4	9.4 ± 3.5	10.2 ± 3.4
Tissue Doppler septal E wave (cm/s)	6.2 ± 2	5.9 ± 1.9	6.5 ± 2
Tissue Doppler septal A wave (cm/s)	8.3 ± 2.8	7.9 ± 2.8	8.8 ± 2.7
E/E′ ratio	12.2 ± 4.9	13.1 ± 5	11.3 ± 4.6

Leibowitz D, et al. Am J Cardiol May 2011

Is LV relaxation normal or impaired?

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Findings universally associated with abnormal LV relaxation

- **Very advanced age**
- Low EF
- Abnormal Regional WM
- Concentric LVH
  - Exception: athletes
- Enlarged LA: found in >90% of patients with diastolic dysfunction
  - Sensitive but not specific
- Reduced e’

How To Assess Diastolic Function

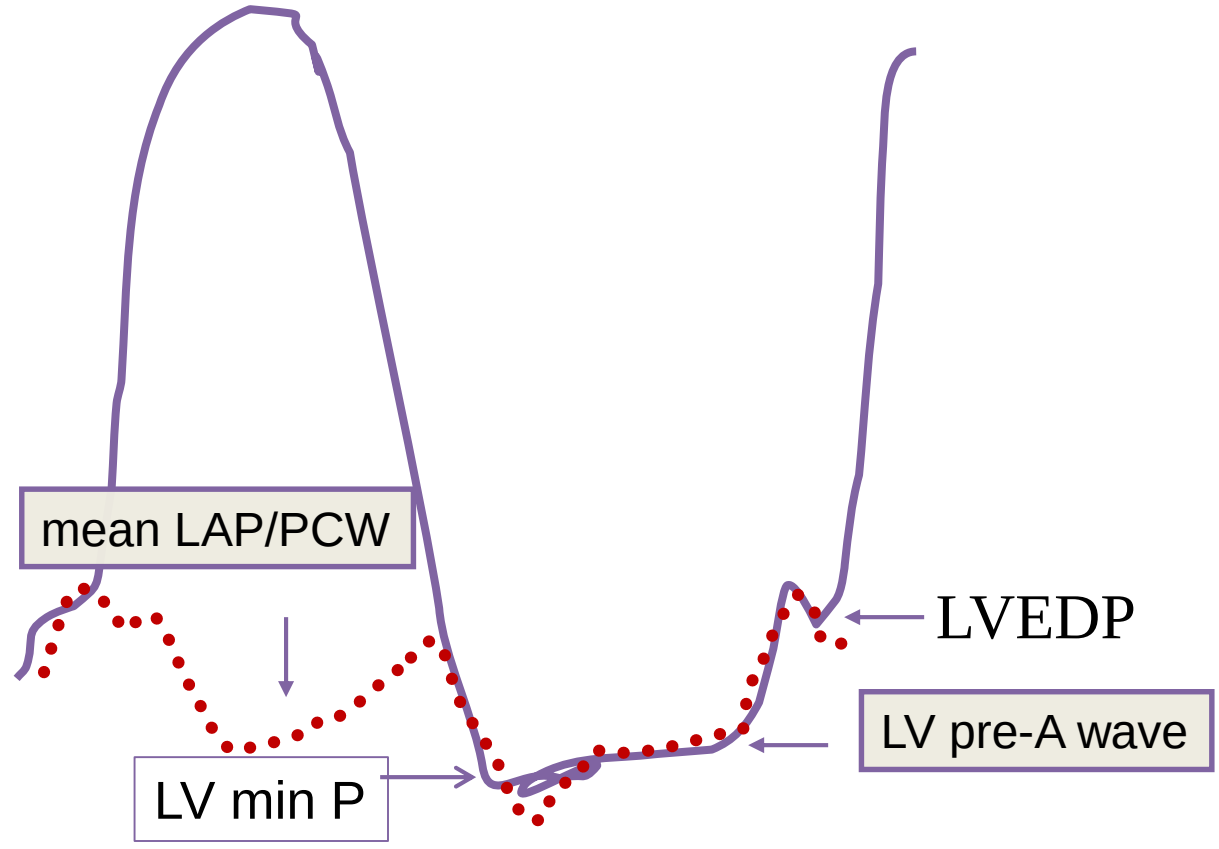
1st question:

Is LV relaxation normal, reduced by age or abnormal?

2nd question:

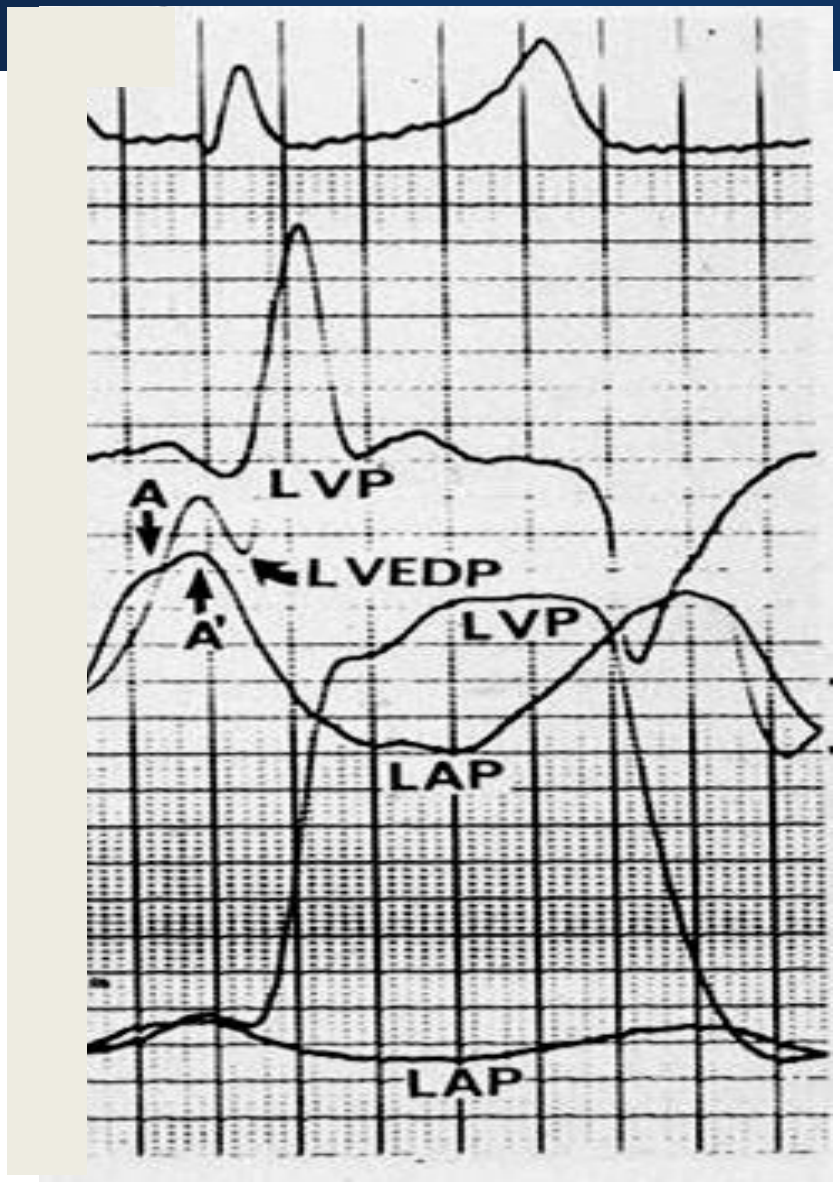
Are resting LVFP's normal or elevated?

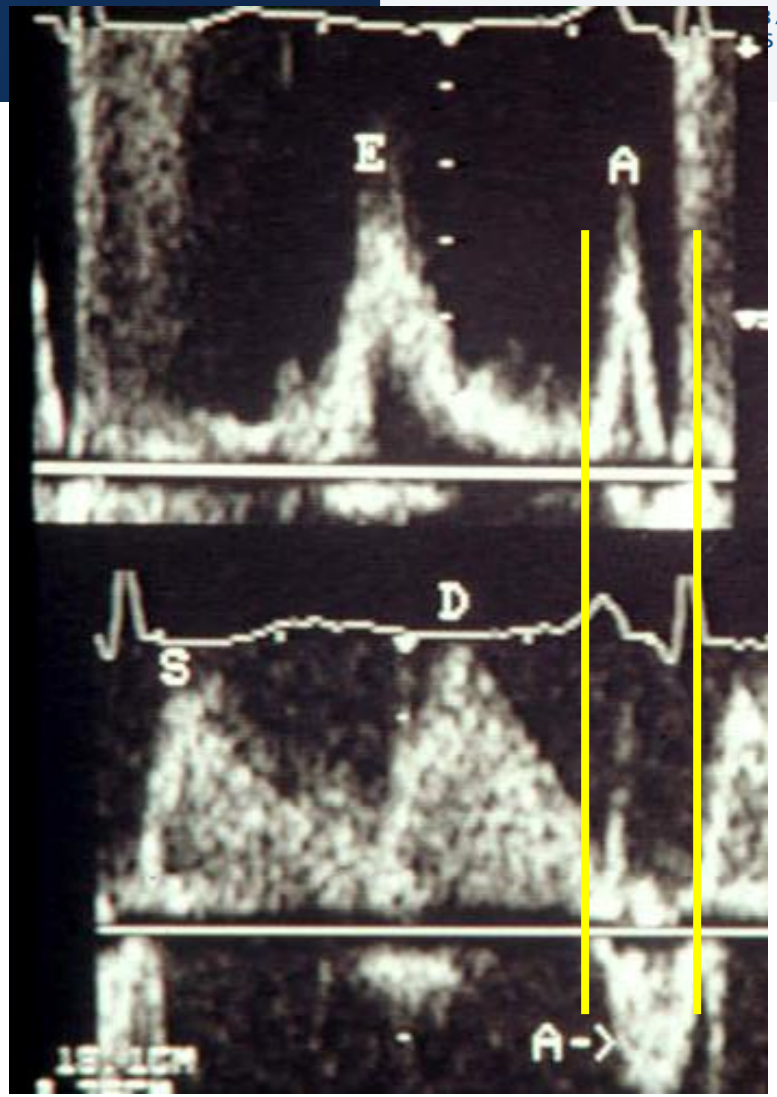
Filling Pressures: What should we measure?



Relate better with Sx's

Pulmonary Vein and Transmitral Velocity

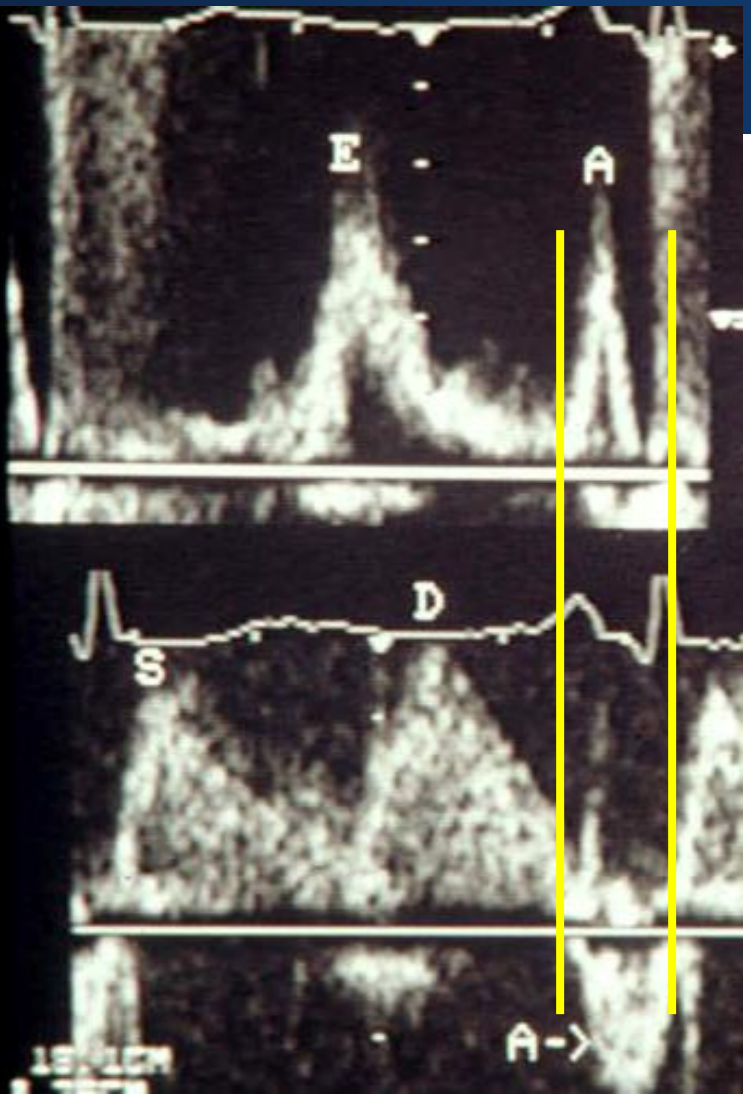




PV-Ad = 170ms

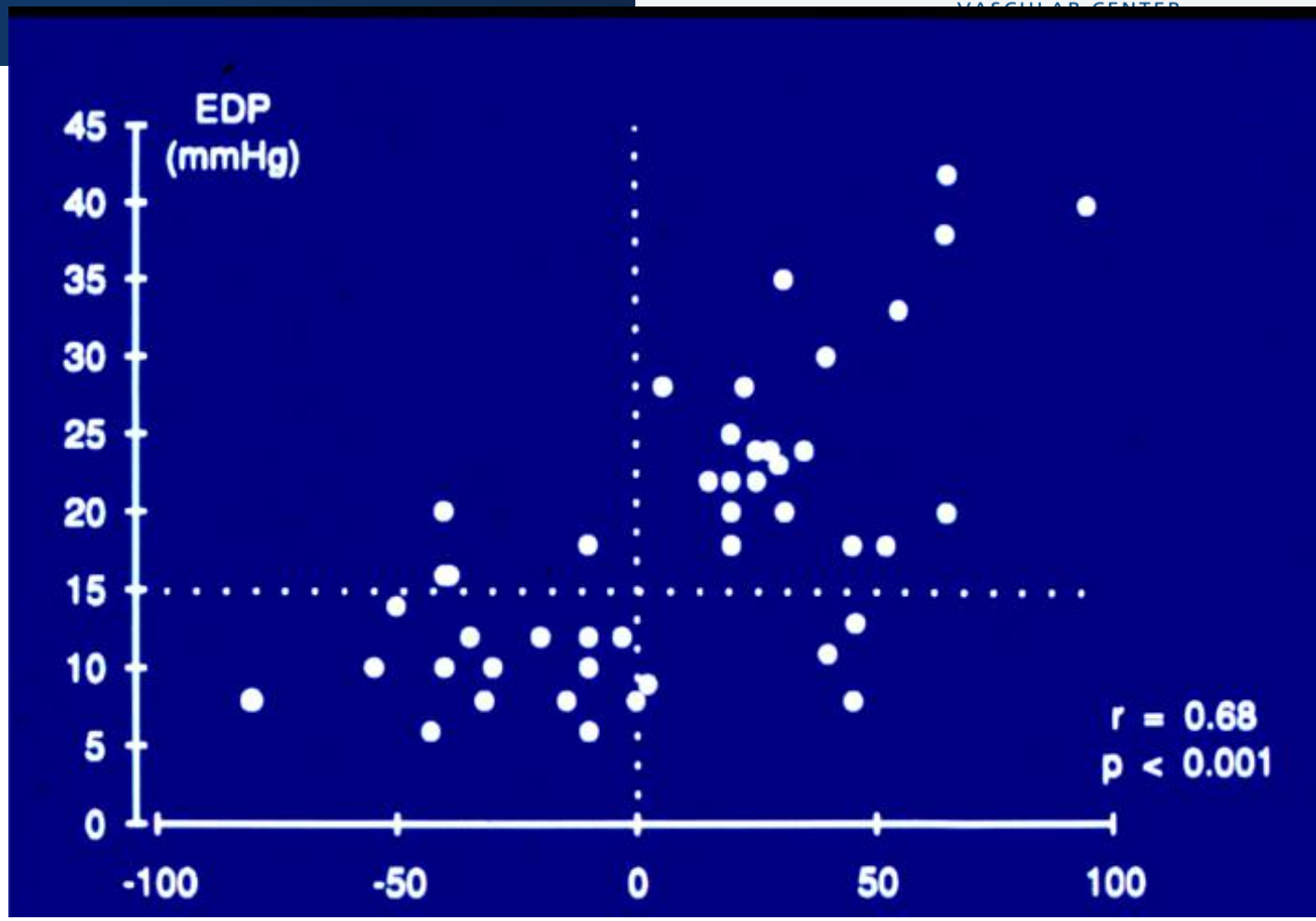
MV-Ad = 120ms

Estimation of LVEDP



PV-Ad = 170ms

MV-Ad = 120ms



PVAd - MVAd

Rossvoll O, Hatle LK JACC 1993;21:1687

Systolic Heart Failure

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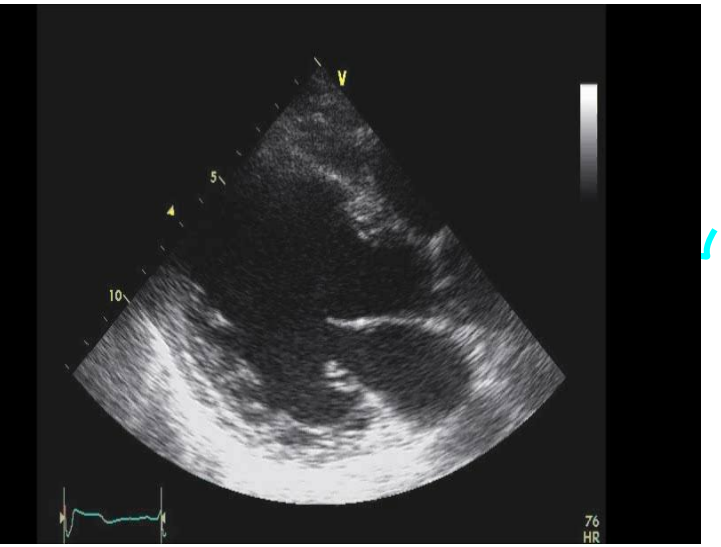
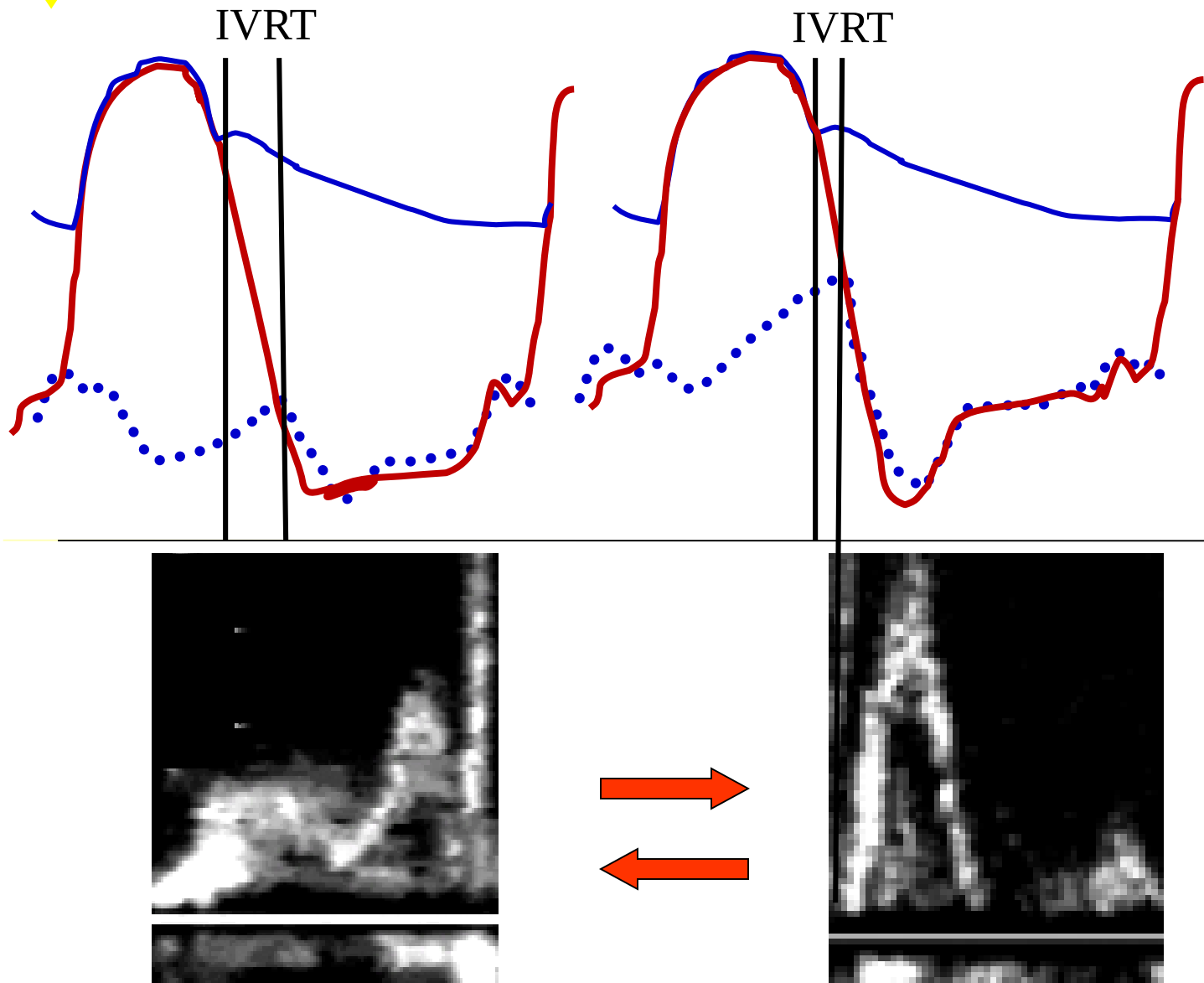
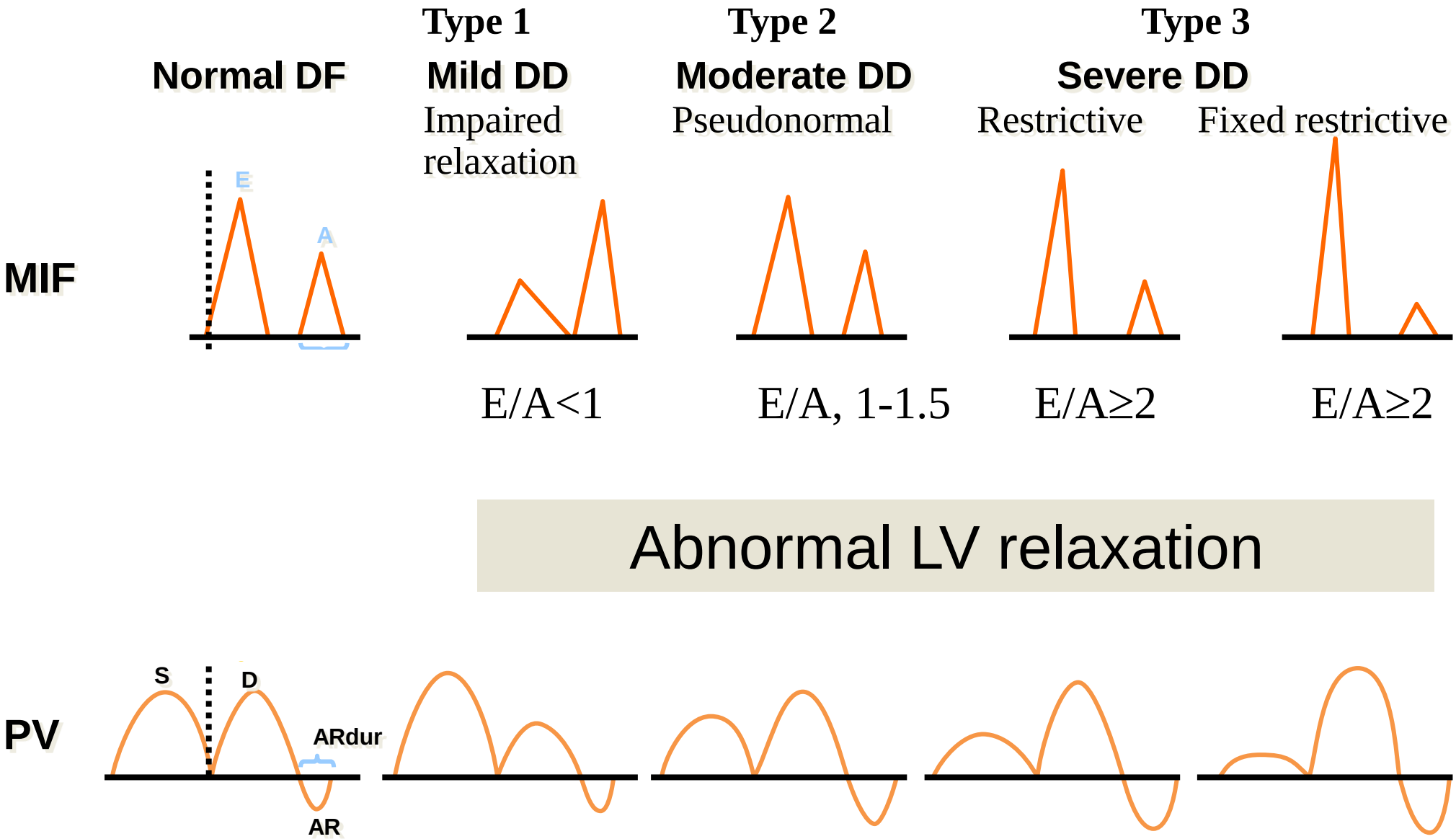
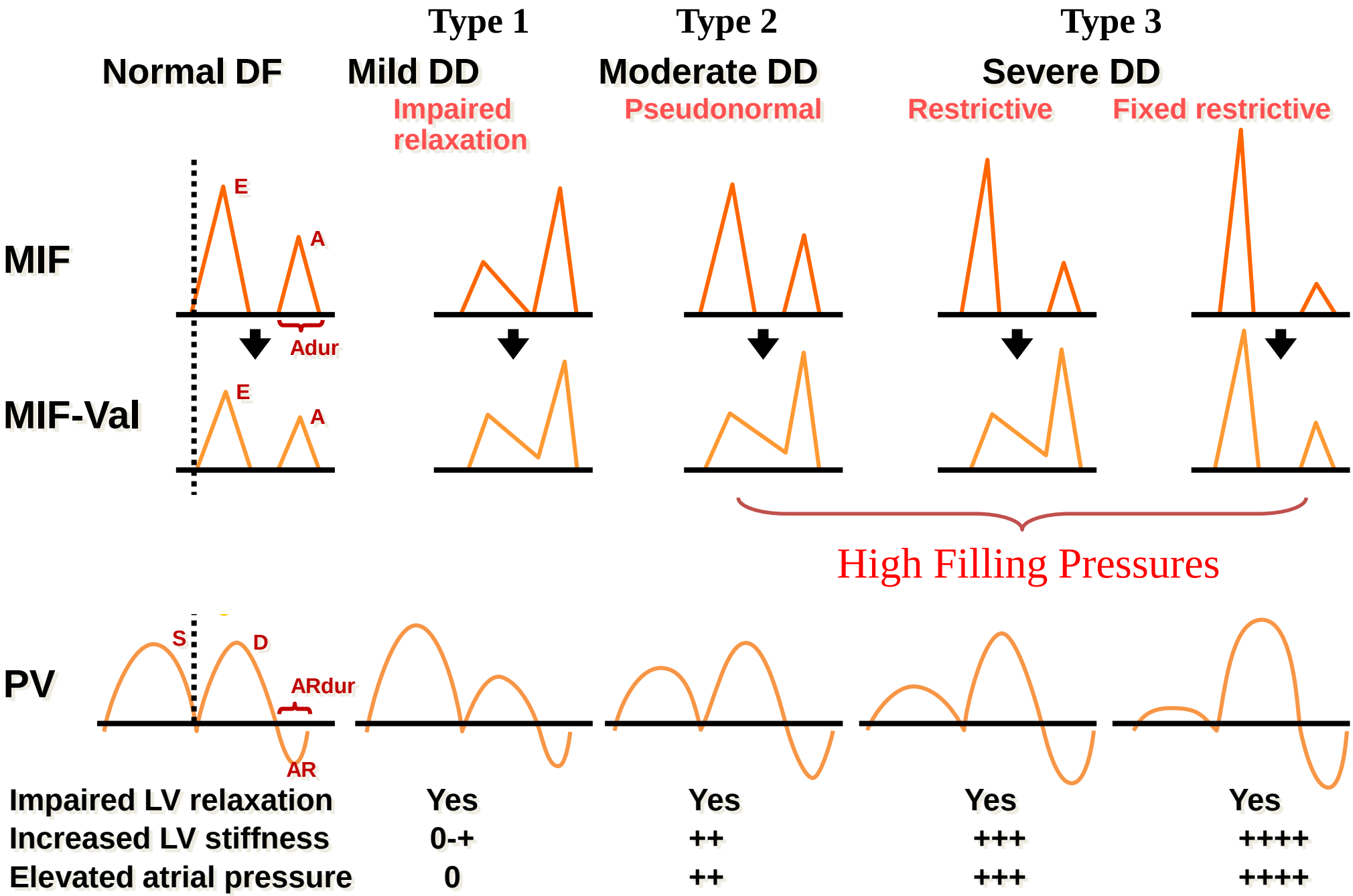
RELAXATION

SYSTOLIC HF






Type 1
Type 2
Type 3
Normal DF
Mild DD
Moderate DD
Severe DD
Impaired relaxation
Pseudonormal
Restrictive
Fixed restrictive
MIF
E
A
E/A<1
E/A, 1-1.5
E/A≥2
E/A≥2
Abnormal LV relaxation
PV
S
D
ARdur
AR
Impaired LV relaxation
Yes
Yes
Yes
Yes
Increased LV stiffness
0-+
++
+++
++++
Elevated atrial pressure
0
++
+++
++++


Type 1
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Normal DF
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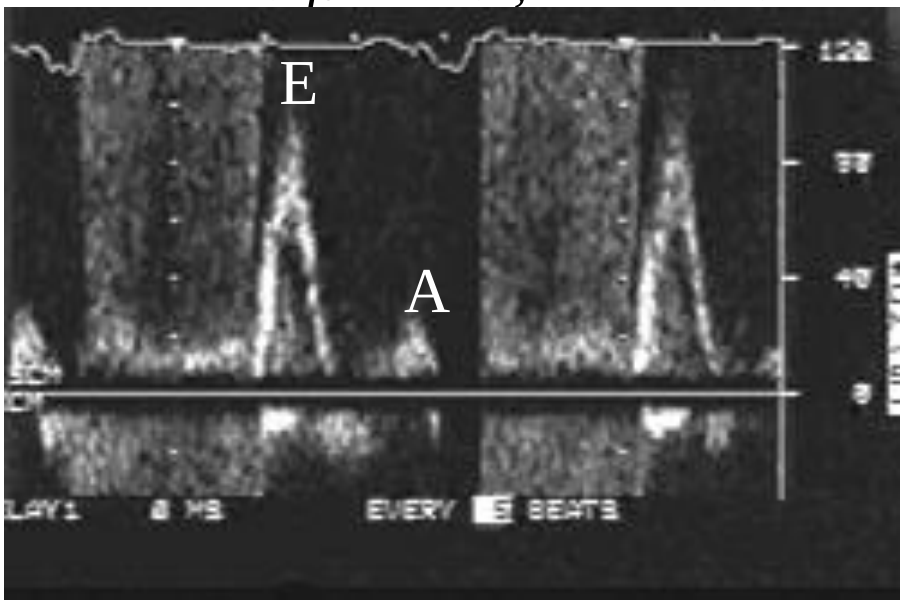
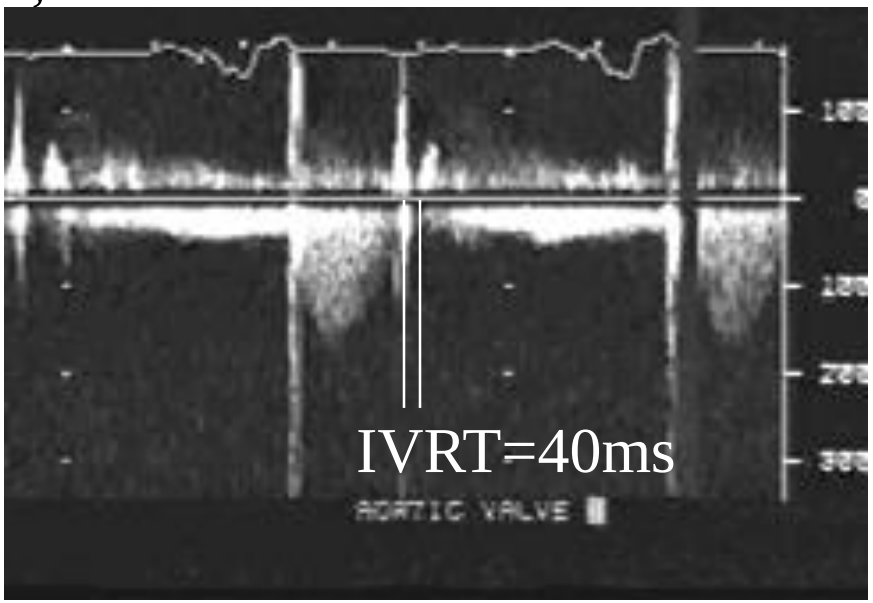
MIF
MIF-Val
E
A
Adur
High Filling Pressures
PV
S
D
ARdur
AR
Impaired LV relaxation Yes Yes Yes Yes
Increased LV stiffness 0-+ ++ +++ ++++
Elevated atrial pressure 0 ++ +++ ++++

Doppler estimation of LV filling pressures in Patients With Depressed LVEF

mean PCWP = 17 + 5.3EA - 0.11IVRT

Naqueh et al, Am J Cardiol 75: 1256, 1995



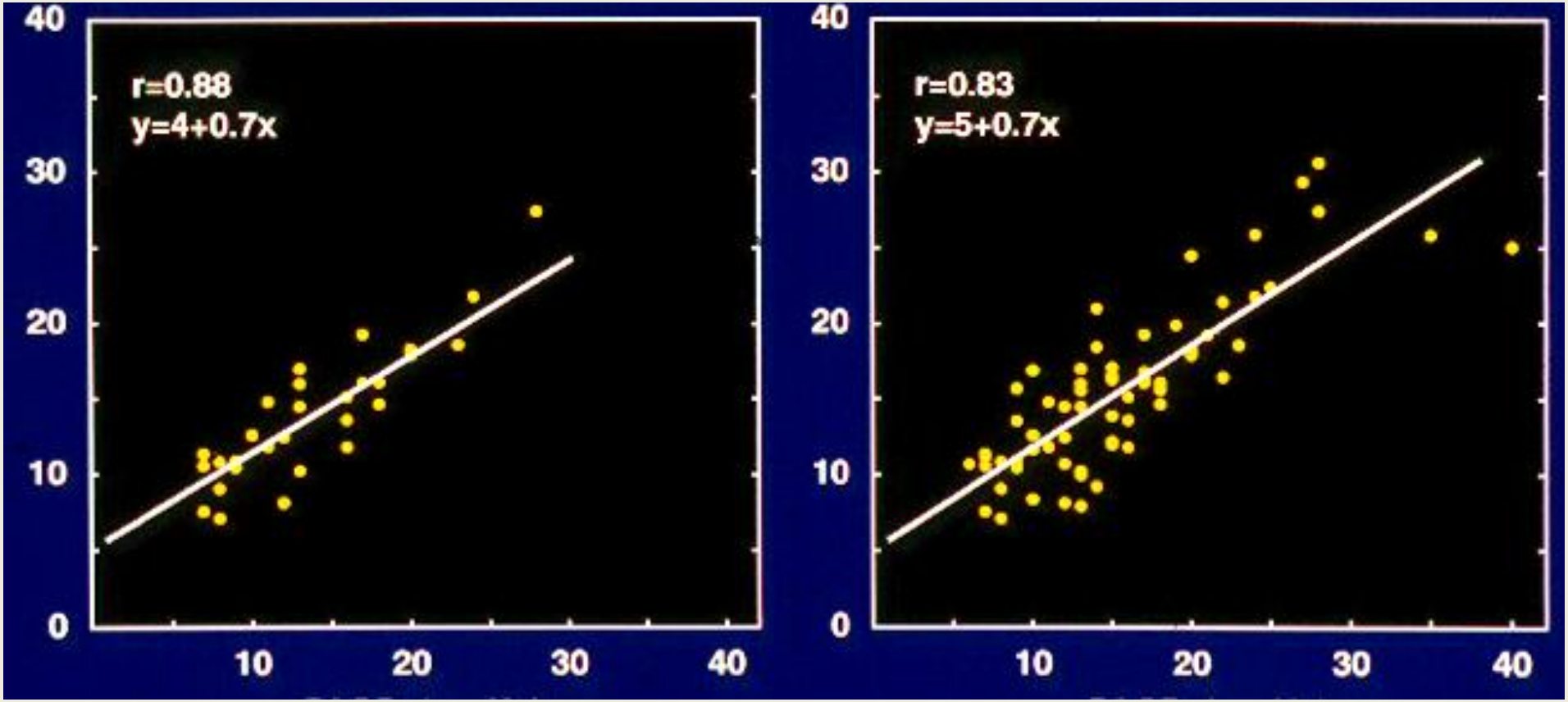


Mean PCWP= [17 + (5 x E/A)] -(0.1 x IVRT)
= [17 + 17.5] - 4 = 31mmHg

mean PCWP = 17 + 5.3EA - 0.11IVRT

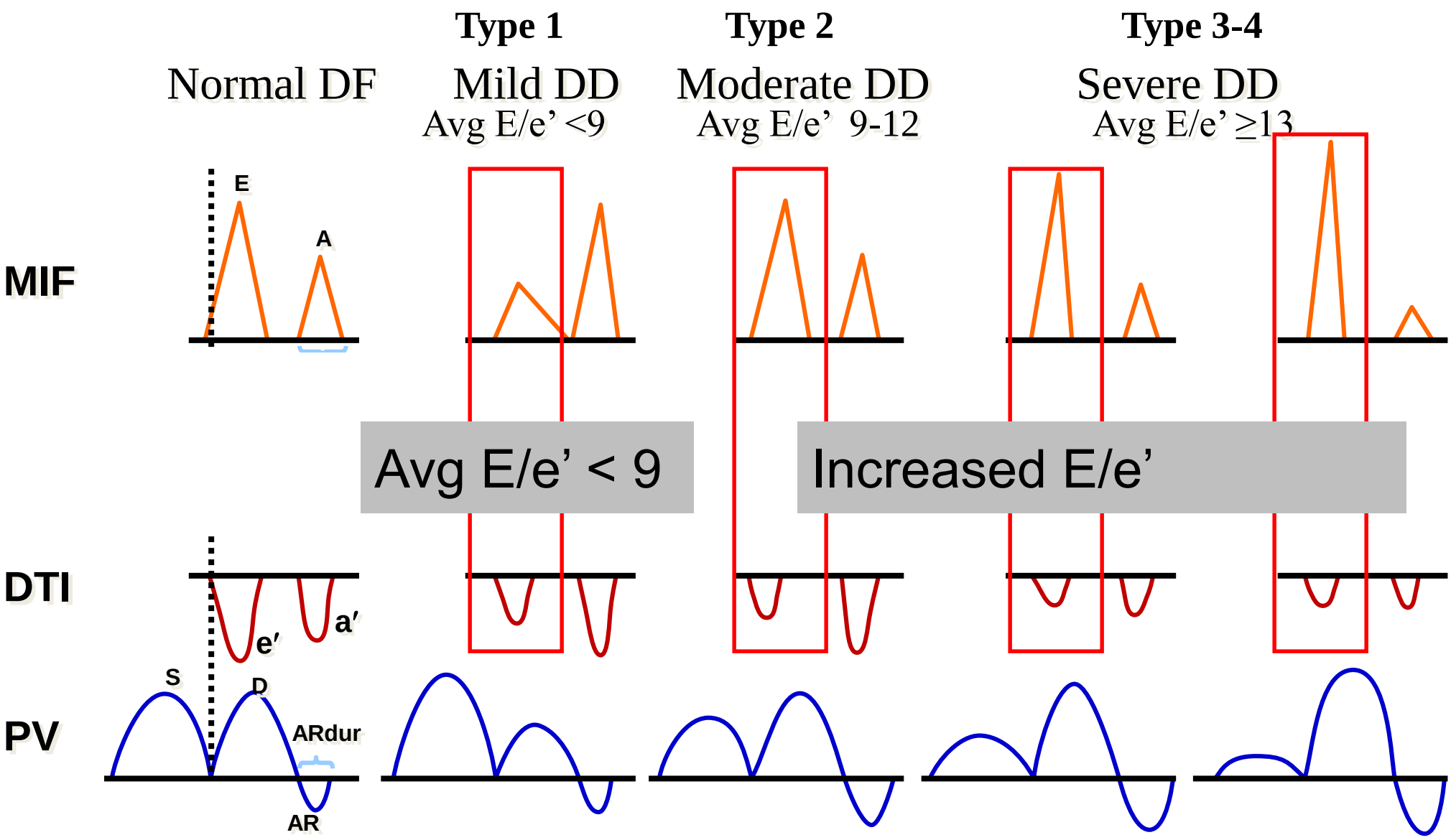
Prospective Group

All Patients



Methodist DeBakey Heart & Vascular Center

Naqueh et al, Am J Cardiol 75: 1256, 1995


Type 1
Type 2
Type 3-4
Normal DF
Mild DD
Avg E/e' <9
Moderate DD
Avg E/e' 9-12
Severe DD
Avg E/e' ≥13
MIF
E
A
Avg E/e' < 9
Increased E/e'
DTI
e'
a'
PV
S
D
ARdur
AR
Impaired LV relaxation Yes Yes Yes Yes
Increased LV stiffness 0-+ ++ +++ ++++
Elevated atrial pressure 0 ++ +++ ++++

56M with HTN and dyspnea

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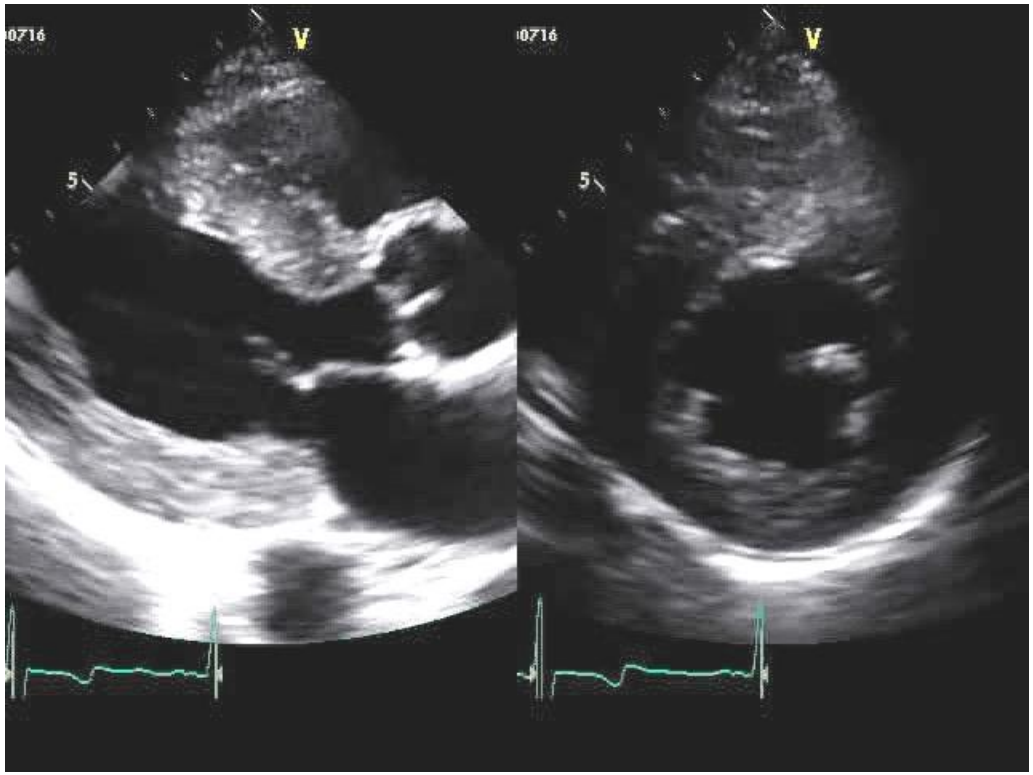
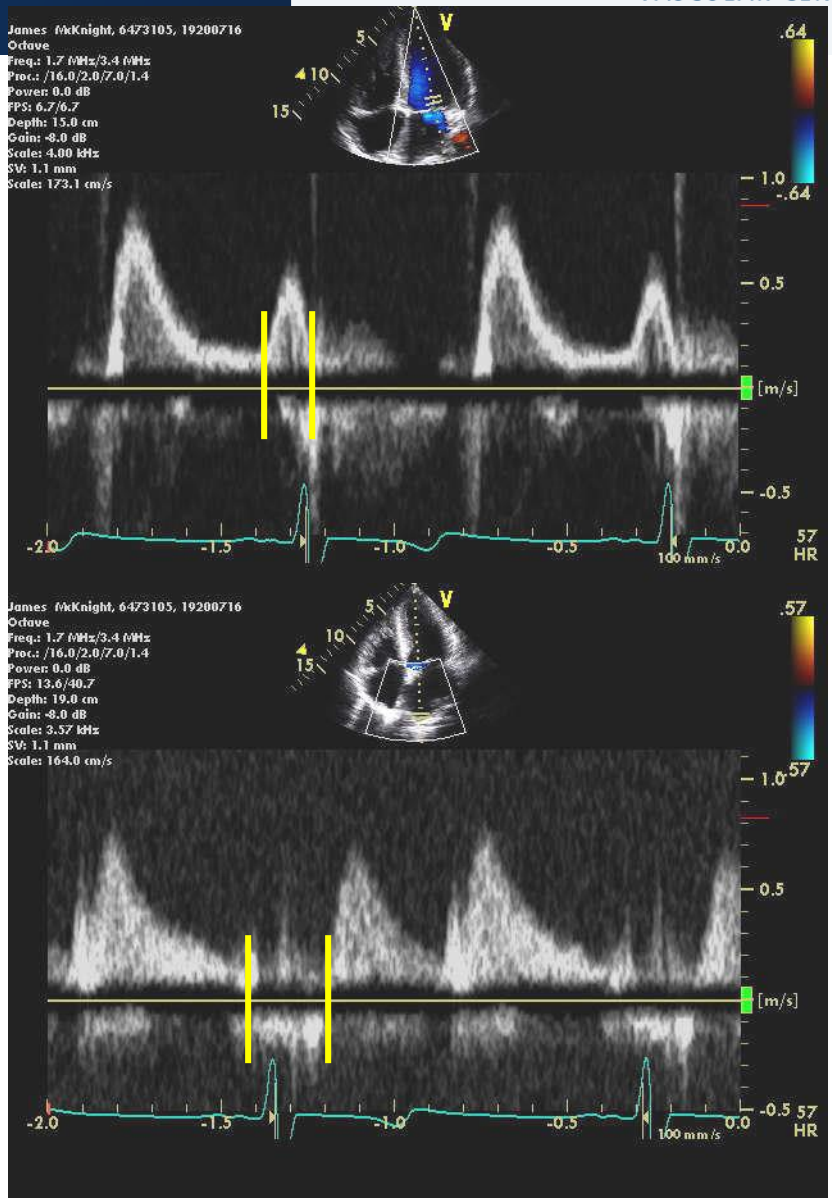
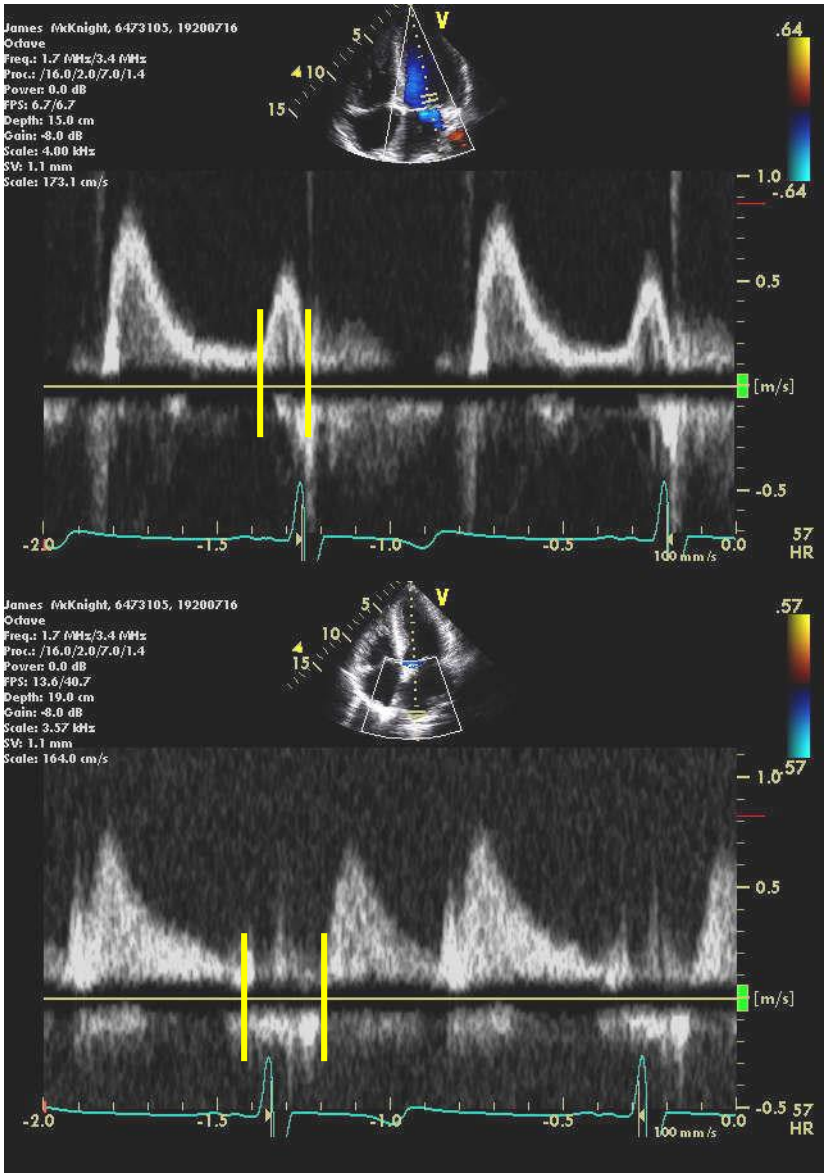




56M with HTN and dyspnea

HOUSTON Methodist DEBAKEY HEART & VASCULAR CENTER

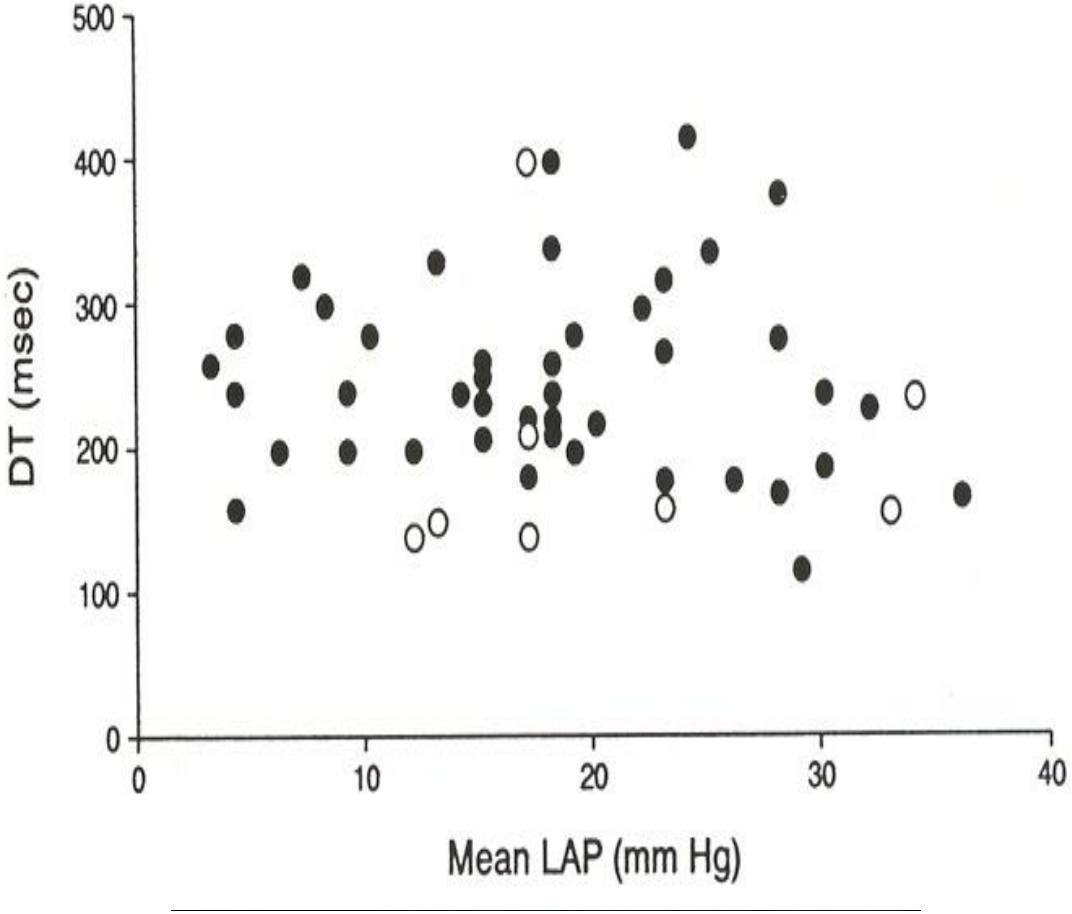


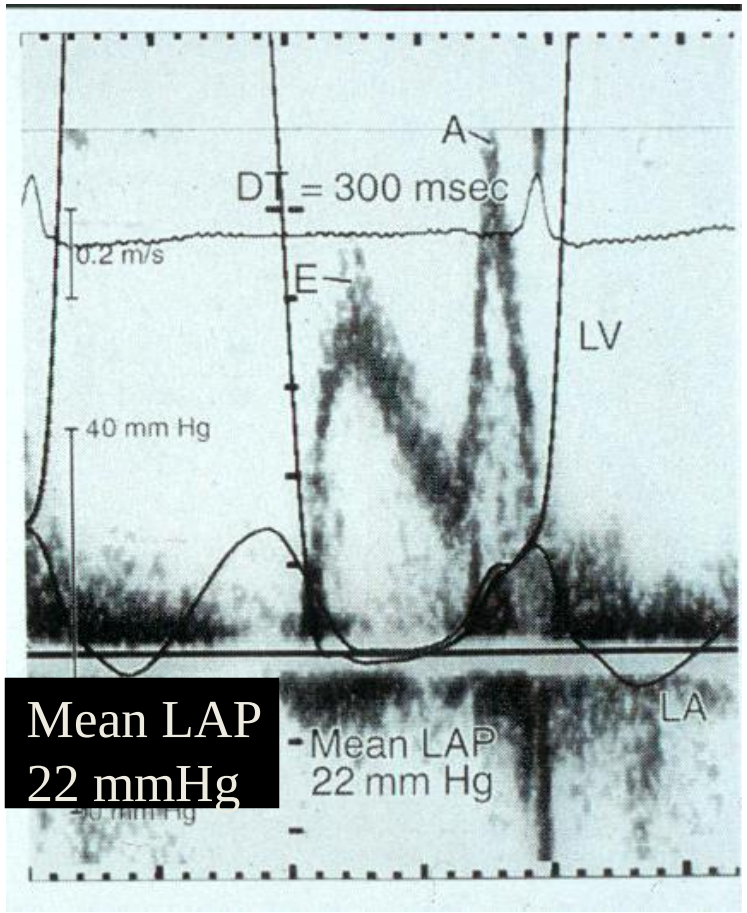
Normal filling vs Pseudonormal?

Findings that favor pseudonormal

- HTN with LVH
- Large LA
- Apv duration > Amv duration

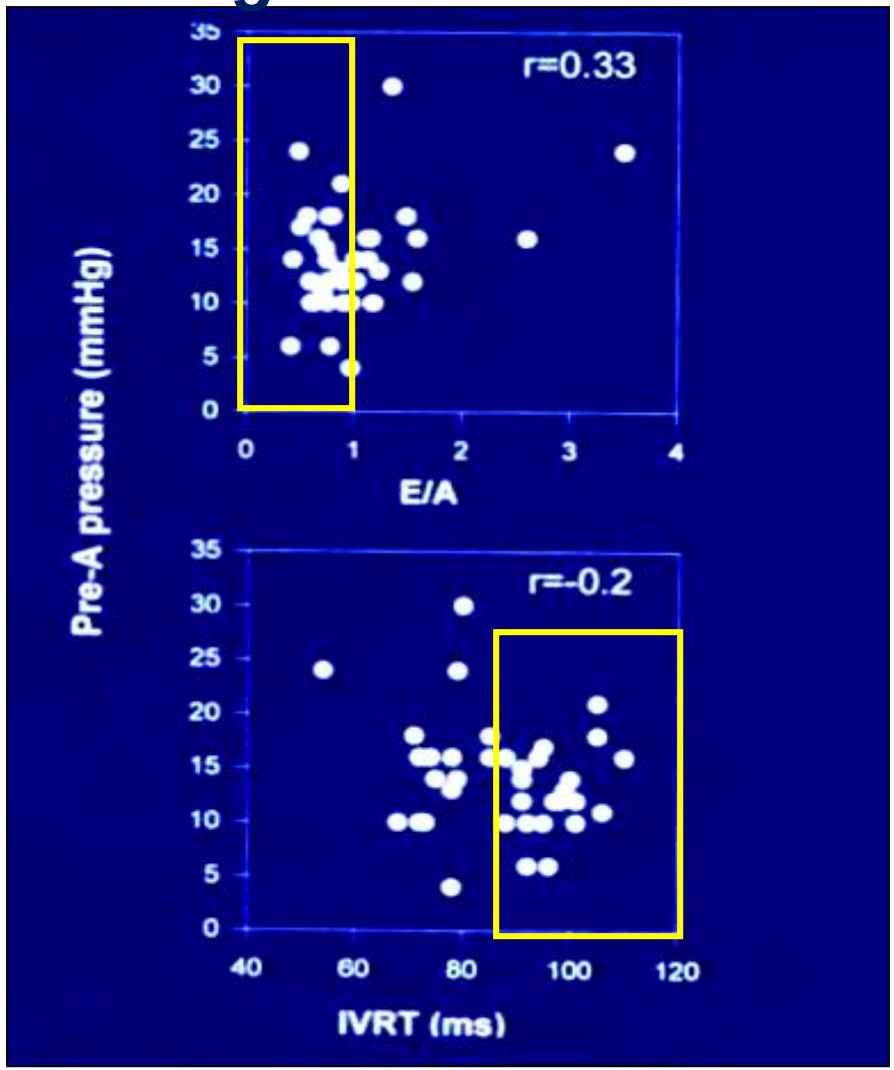
Severe LVH With E/A <1 and Elevated LAP





Nishimura et al, JACC 1996;28:1226

Conventional Doppler Estimation of LV Filling Pressures In HCM



Nagueh et al Circulation 1999;99:254-261

NORMAL

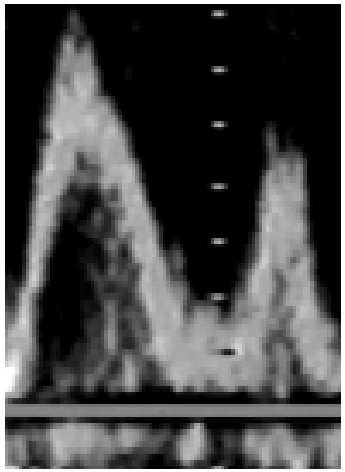
RELAXATION

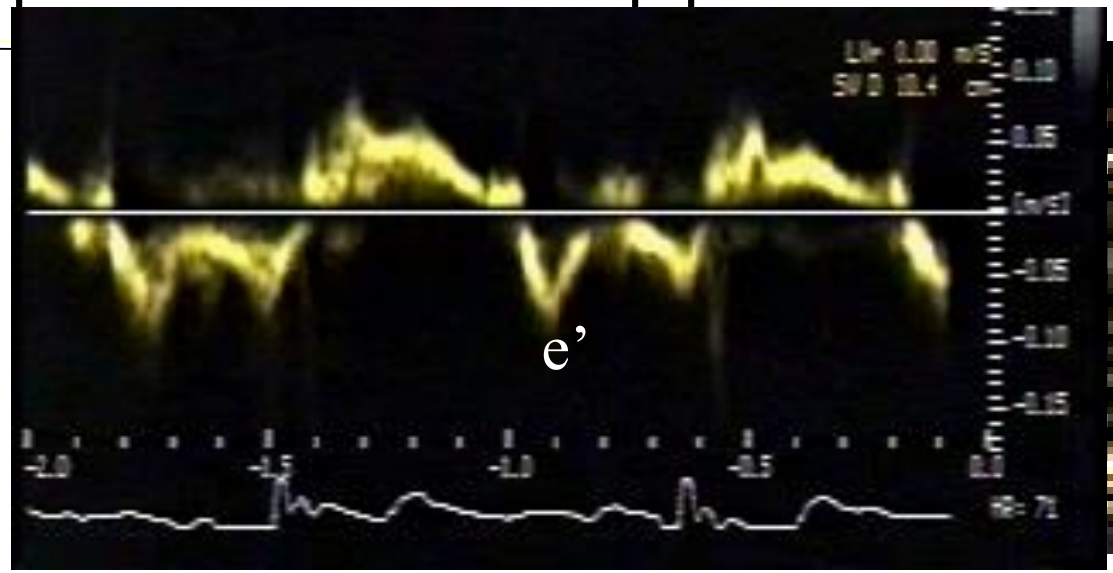
DIASTOLIC HF

IVRT

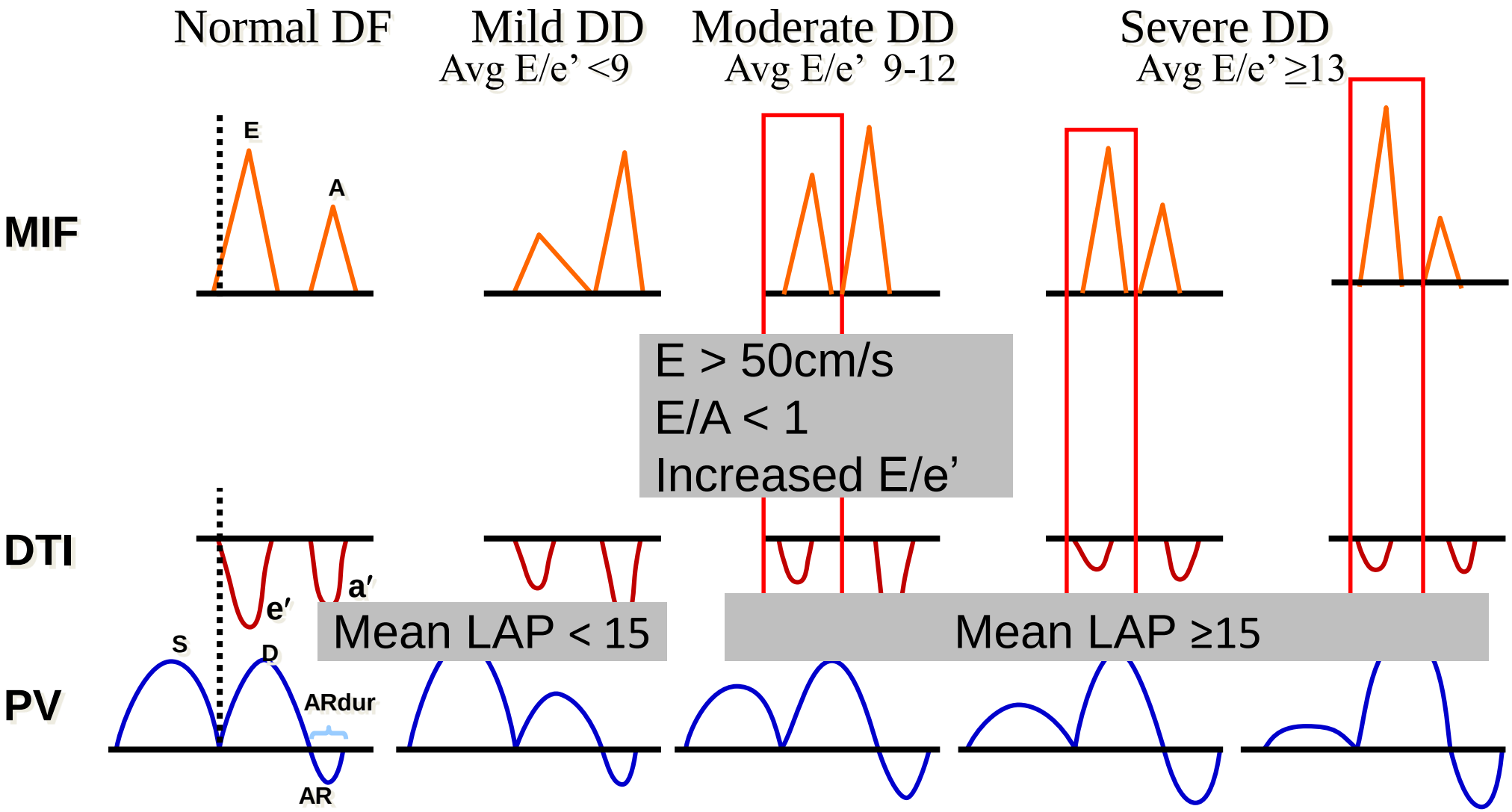
IVRT

IVRT

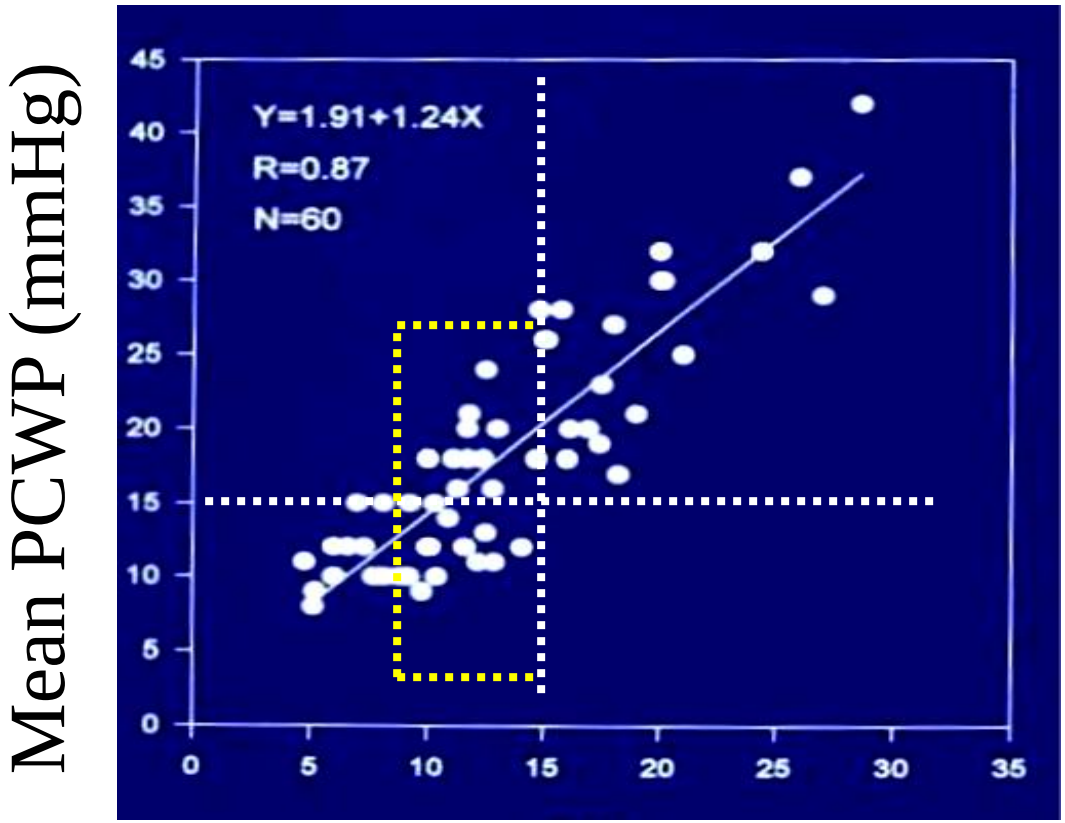


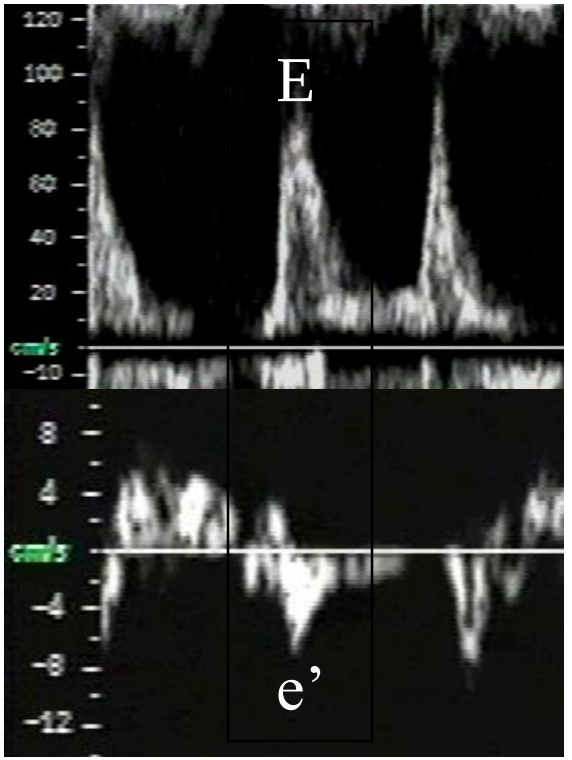


Estimation of mean LAP: Normal LVEF



The ratio of transmitral E-vel to e' relates well with mean PCWP

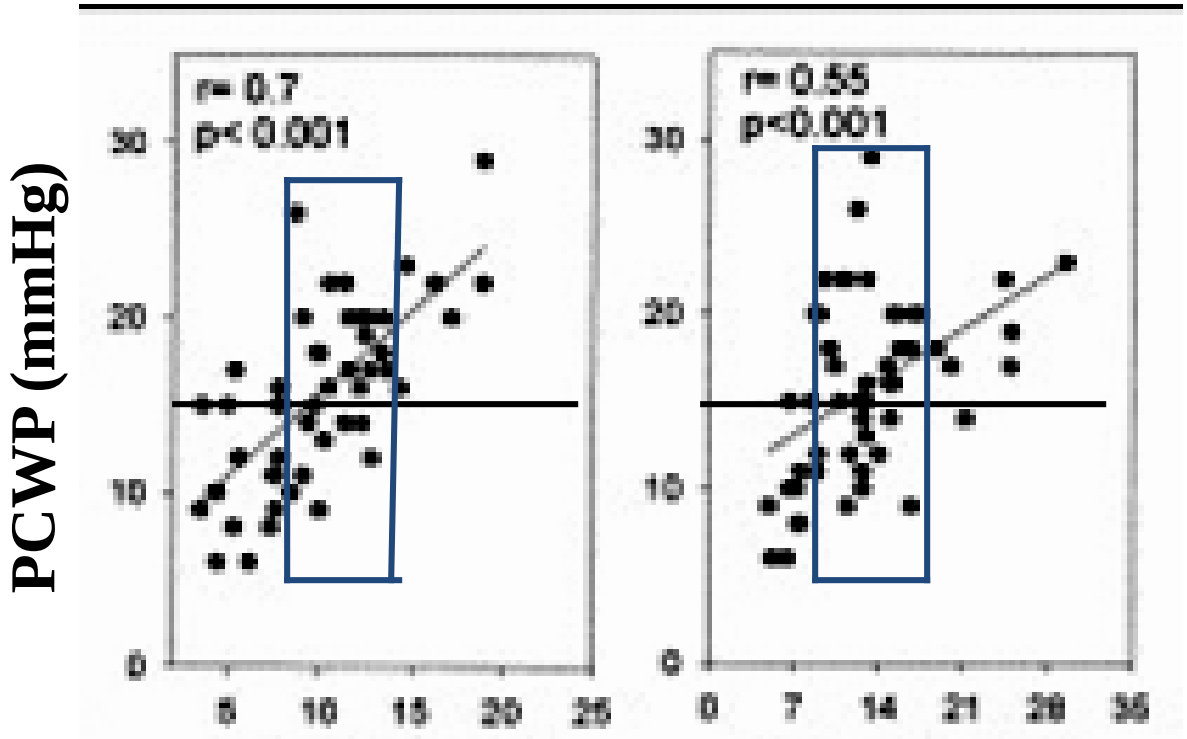




Nagueh et al, JACC 1997;30:1527-1533

Impact of LVEF on Estimation of Filling Pressures

LVEF > 50%



Rivas-Gotz et al Am J Cardiol 2003;91:780

65F diabetic; HTN with dyspnea

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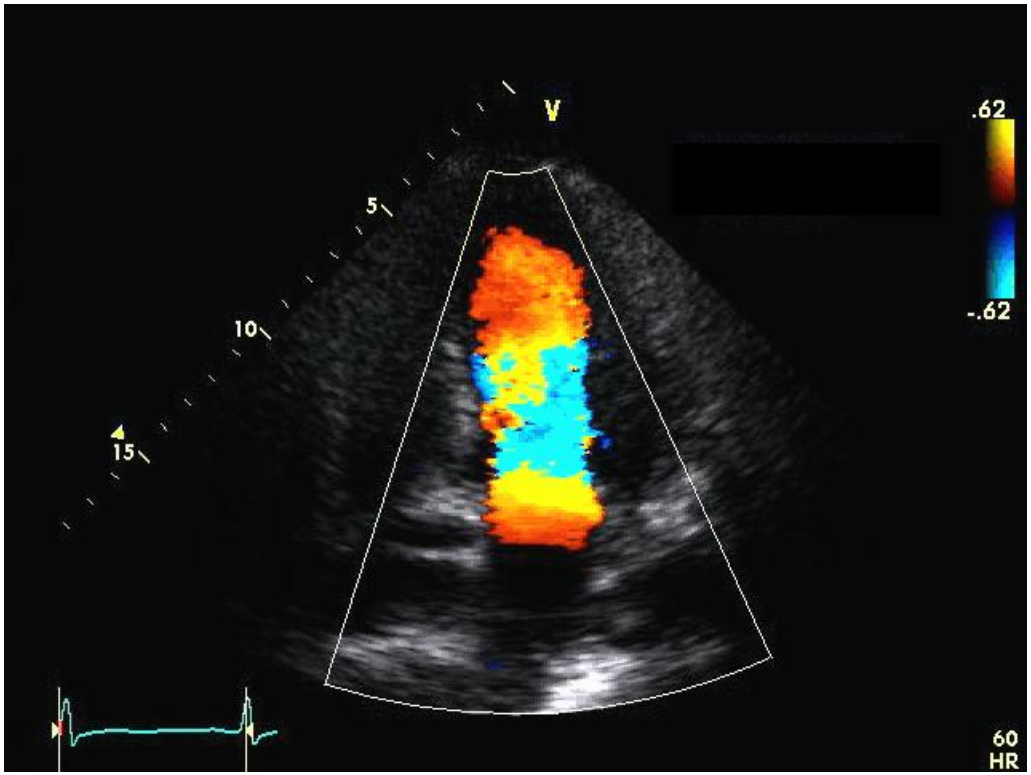
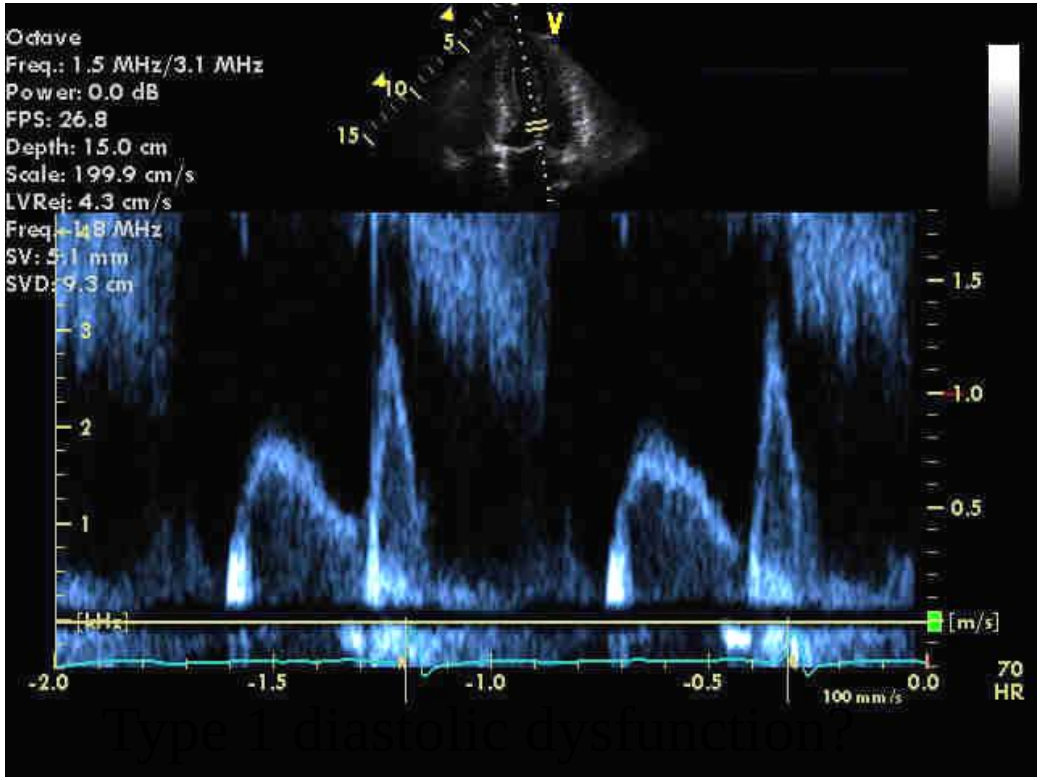




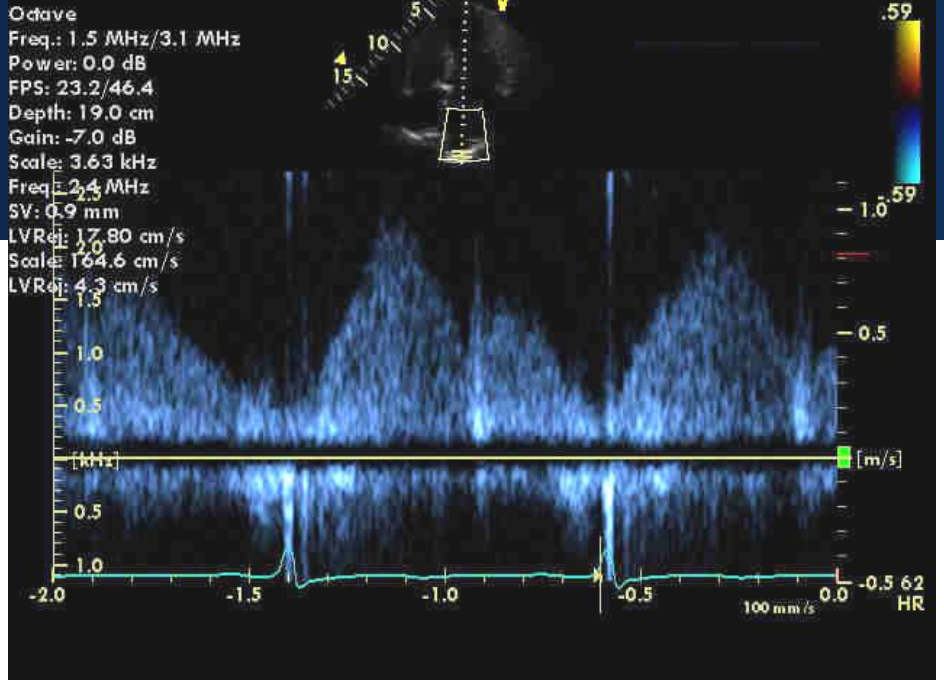
Type 1 diastolic dysfunction?

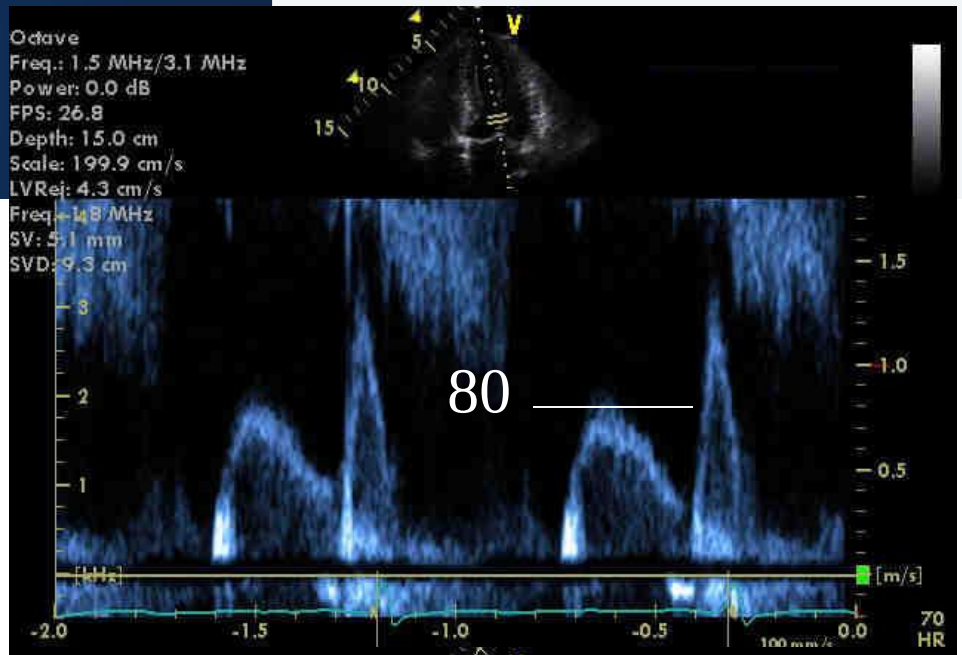
Filling pressures are:

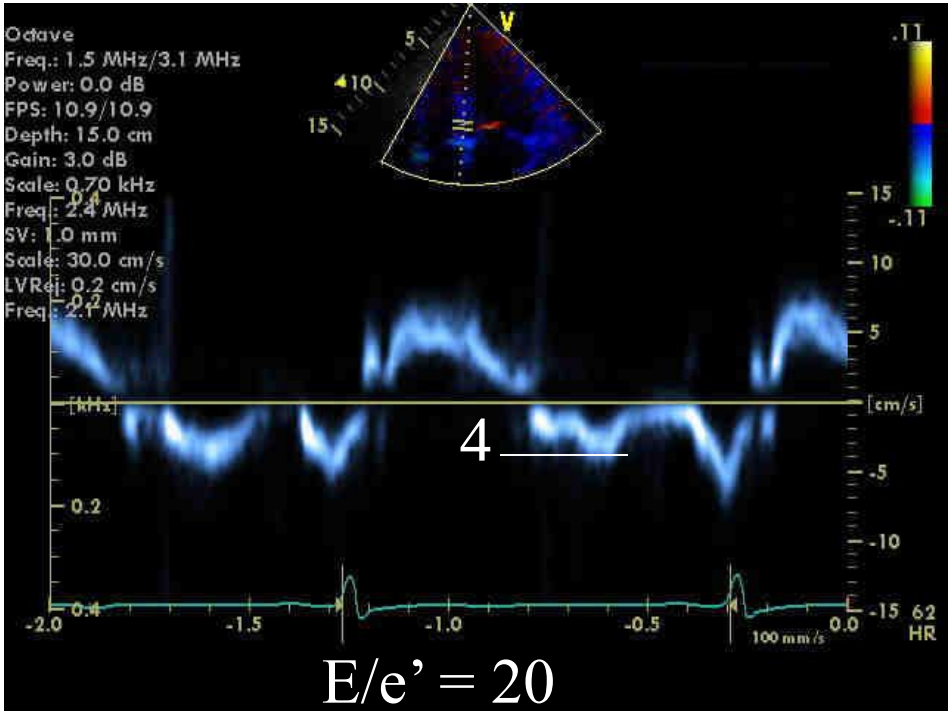
A. normal

B. elevated

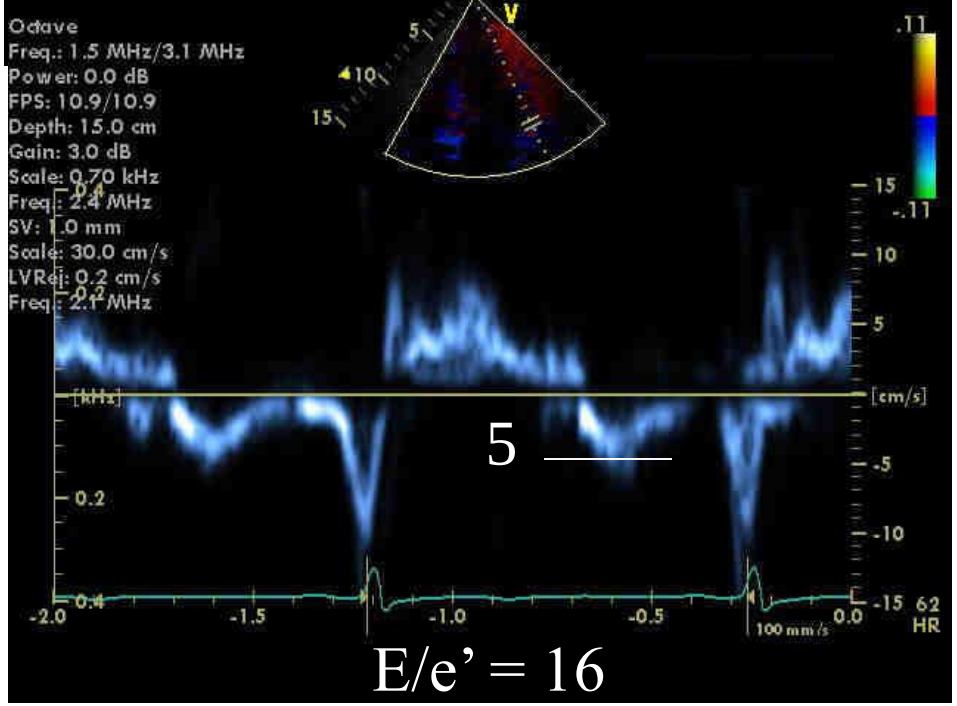
C. ???


Octave
Freq.: 1.5 MHz/3.1 MHz
Power: 0.0 dB
FPS: 23.2/46.4
Depth: 19.0 cm
Gain: -7.0 dB
Scale: 3.63 kHz
Freq: 2.4 MHz
SV: 0.9 mm
LVRej: 17.80 cm/s
Scale: 164.6 cm/s
LVRej: 4.3 cm/s
[kHz]
[m/s]
100 mm/s
HR


Octave
Freq.: 1.5 MHz/3.1 MHz
Power: 0.0 dB
FPS: 26.8
Depth: 15.0 cm
Scale: 199.9 cm/s
LVRej: 4.3 cm/s
SV: 5.1 mm
SVD: 9.3 cm
80
[kHz]
[m/s]
100 mm/s
70
HR

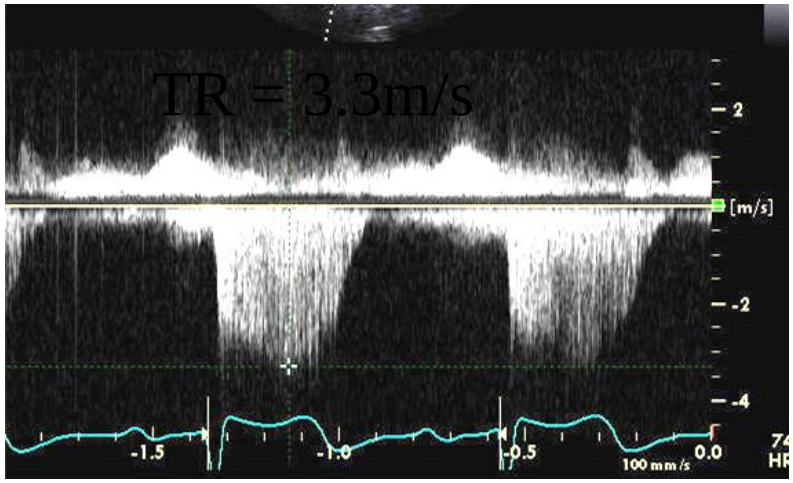

Octave
Freq.: 1.5 MHz/3.1 MHz
Power: 0.0 dB
FPS: 10.9/10.9
Depth: 15.0 cm
Gain: 3.0 dB
Scale: 0.70 kHz
Freq: 2.4 MHz
SV: 1.0 mm
Scale: 30.0 cm/s
LVRej: 0.2 cm/s
Freq: 2.1 MHz
4
[kHz]
[cm/s]
100 mm/s
62
HR

E/e’ = 20


Octave
Freq.: 1.5 MHz/3.1 MHz
Power: 0.0 dB
FPS: 10.9/10.9
Depth: 15.0 cm
Gain: 3.0 dB
Scale: 0.70 kHz
Freq: 2.4 MHz
SV: 1.0 mm
Scale: 30.0 cm/s
LVRej: 0.2 cm/s
Freq: 2.1 MHz
5
[kHz]
[cm/s]
100 mm/s
62
HR

E/e’ = 16

65F diabetic; HTN with dyspnea

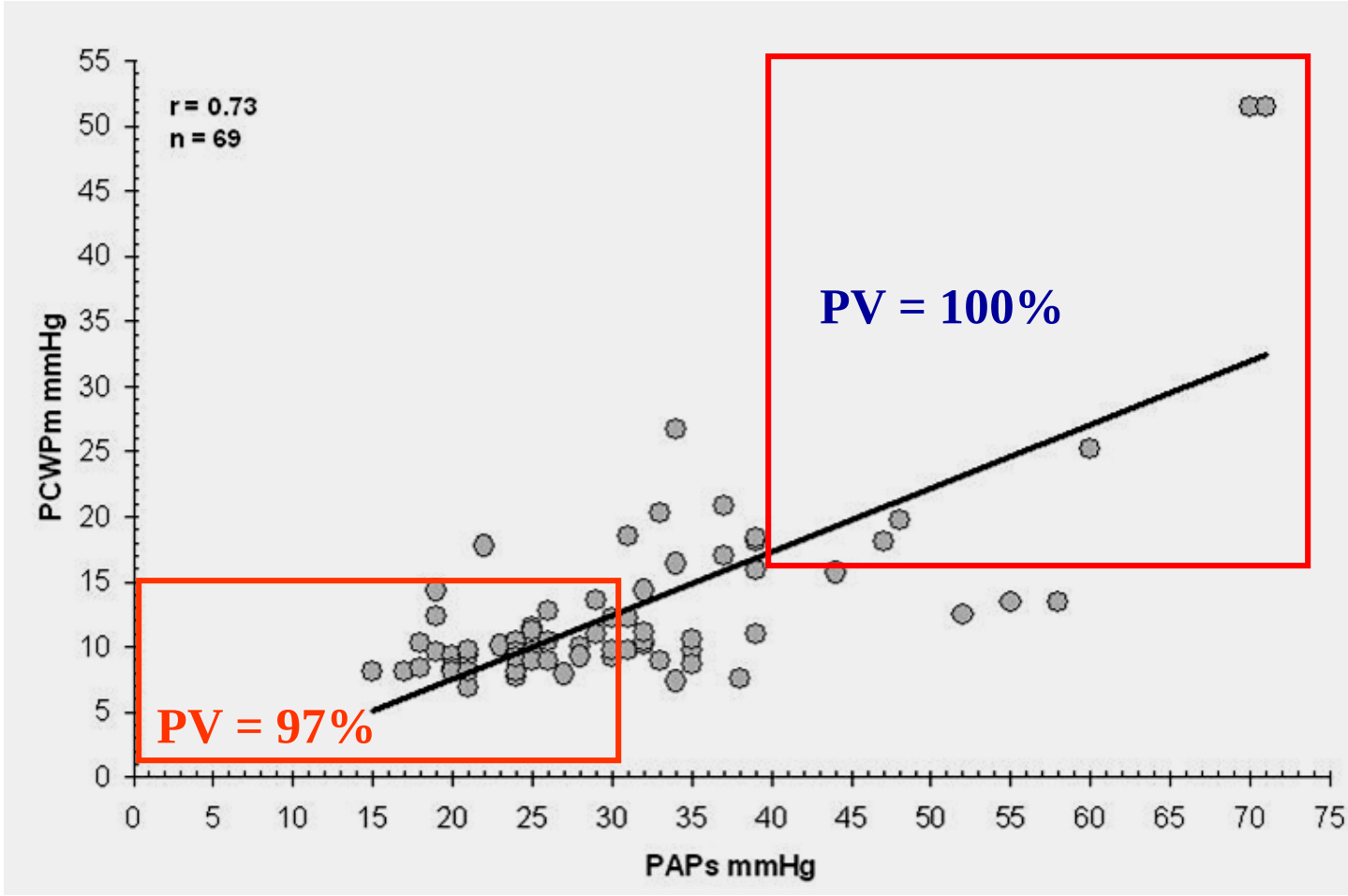


PASP = 44mmHg +RAP

Patient responded to therapy with diuretics and blood pressure reduction

Usefulness of PA systolic pressure to predict pulmonary arterial wedge pressure in patients with normal LV systolic function

Bouchard JL, Aurigemma GP, et al. Am J Cardiol 2008;101:1673



Estimation of LV Filling Pressures

A practical approach

Dyspnea, enlarged LA, and high PASP = diastolic HF

E/e' and TR vel are very helpful in validating Dx

Combining 2D LV and LA evaluation with Doppler was 85% sensitive and 95% specific for detecting heart failure and superior to BNP > 150pg/ml
(Dokainish Am J Cardiol 2004; 93:1130)

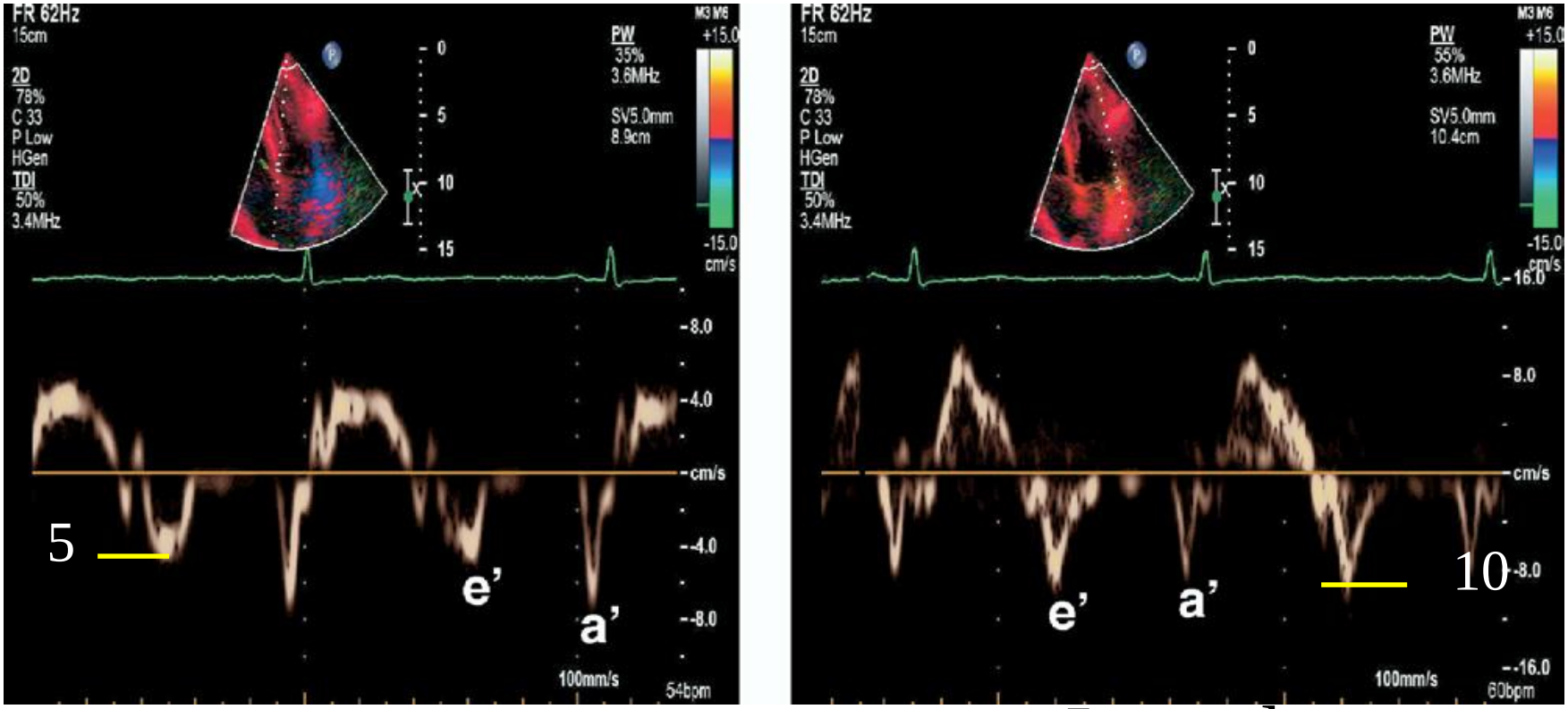
Limitations of Annular Velocity (e')

- E/e' cannot be used as an index of LV filling pressures in patients with mitral stenosis, prosthetic valve or even severe annular calcification
  - Short IVRT in the presence of reduced e' is a marker of elevated LVFP
    - Particularly is LA is enlarged and PASP is elevated

Limitations of Annular Velocity (e')

- E/e' is unreliable in normal-healthy hearts
  - Ex: normal heart with severe MR
- E/e' is unreliable in constrictive pericarditis.
  - Ea remains preserved despite increased LV diastolic pressure
- e' is a regional index; thus, it can vary between sampling sites and in patients with abnormal regional wall motion

Patient with an anterior MI



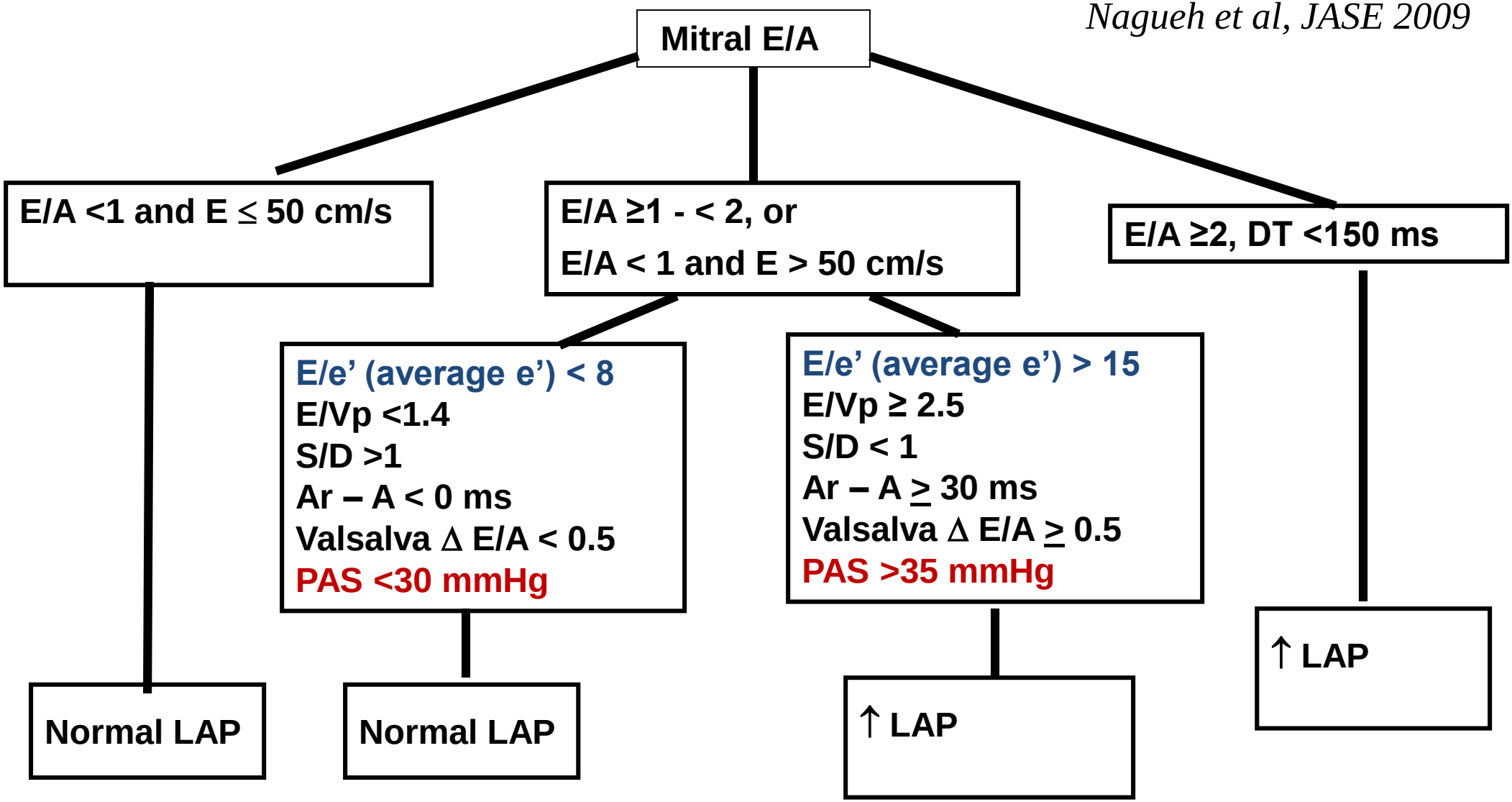
Septal Lateral

Avg e' = 7.5cm/s

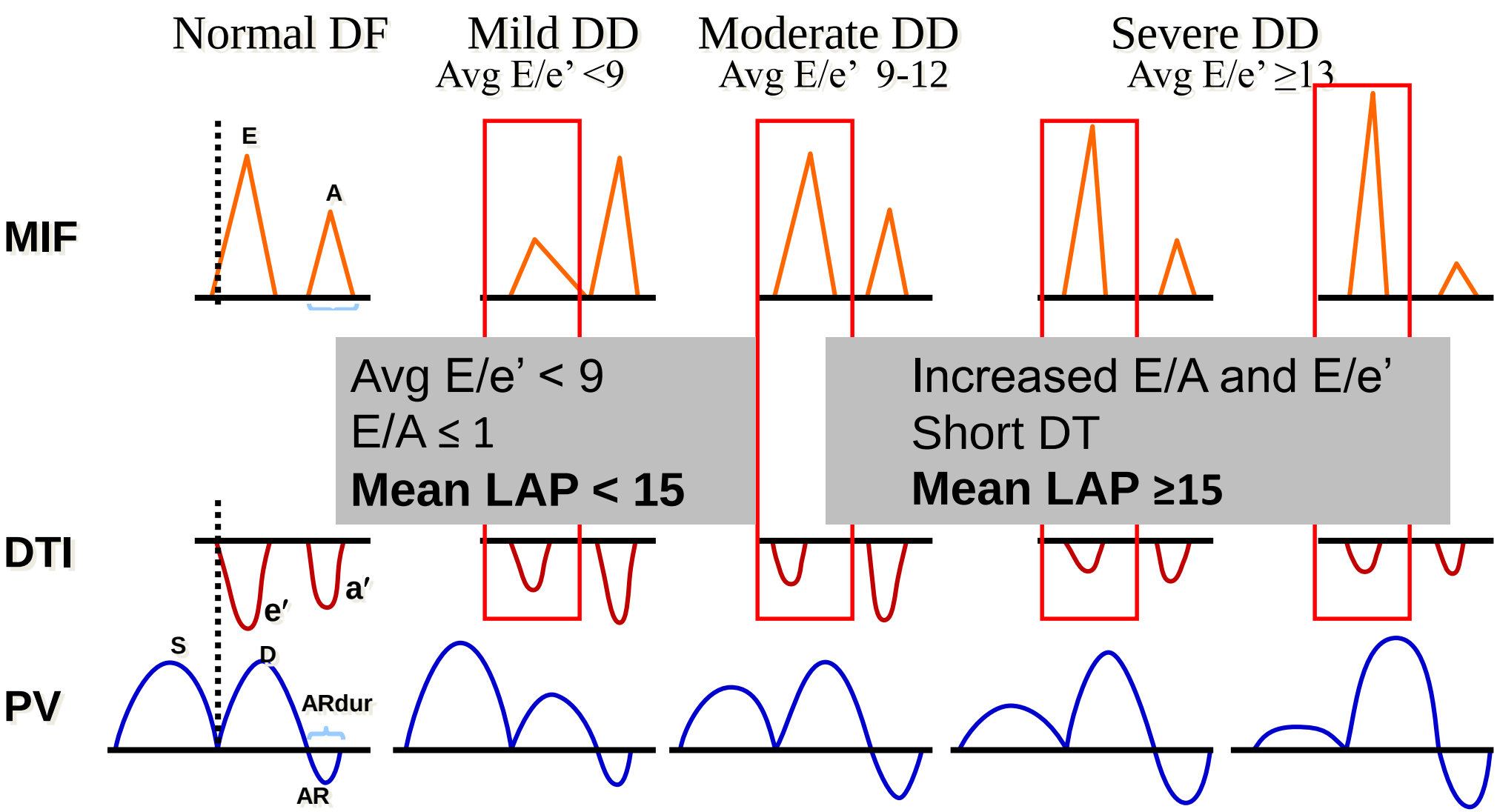
Nagueh et al. JASE 2009

Estimation of Filling Pressures in Patients with Depressed EF

Nagueh et al, JASE 2009



Estimation of mean LAP: Depressed LVEF

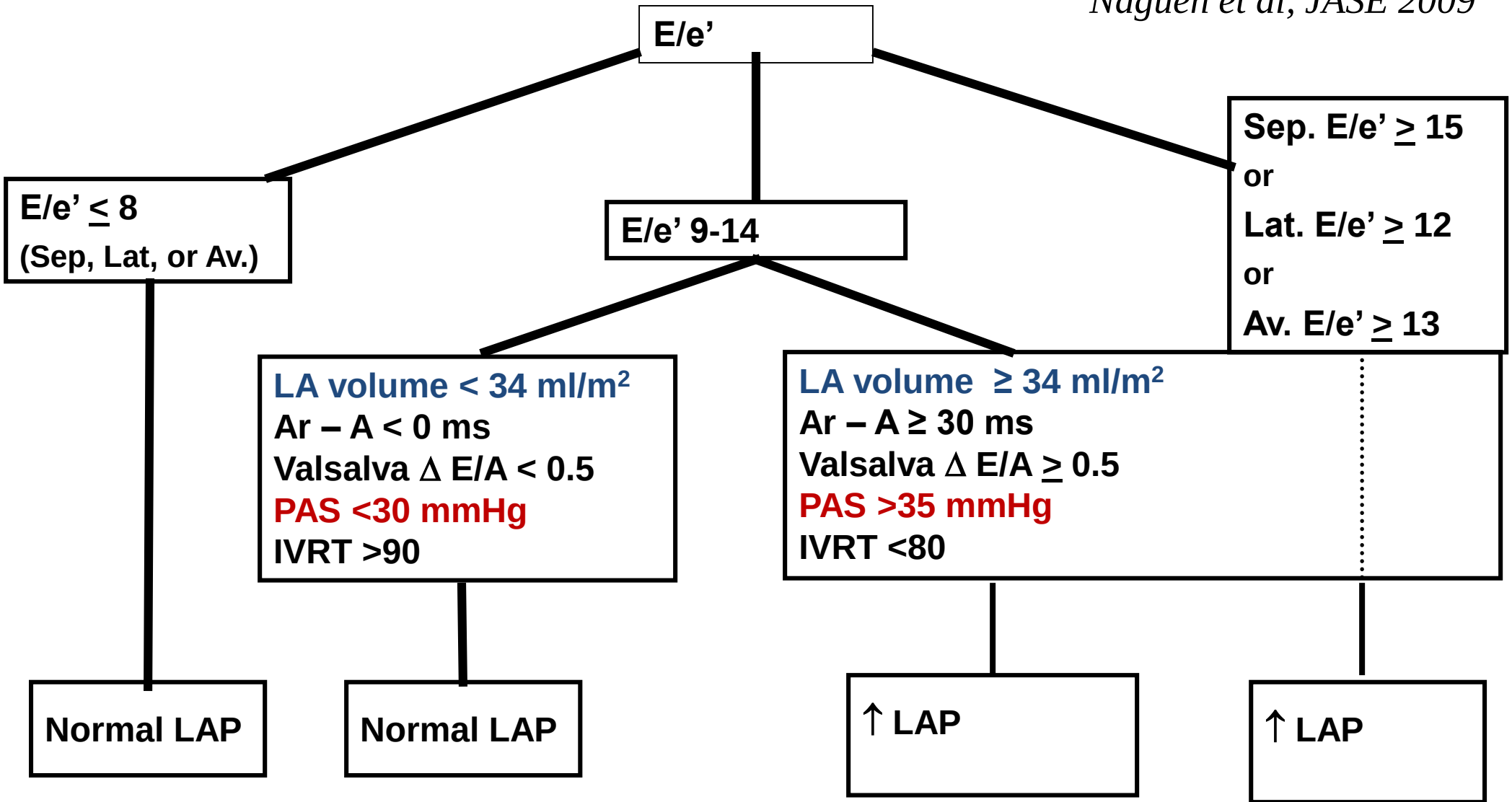


~ 85 % accurate in patients with depressed LVEF

LA enlargement in > 95%

Estimation of Filling Pressures in Patients with Normal EF

Nagueh et al, JASE 2009



Estimation of LV Filling Pressures

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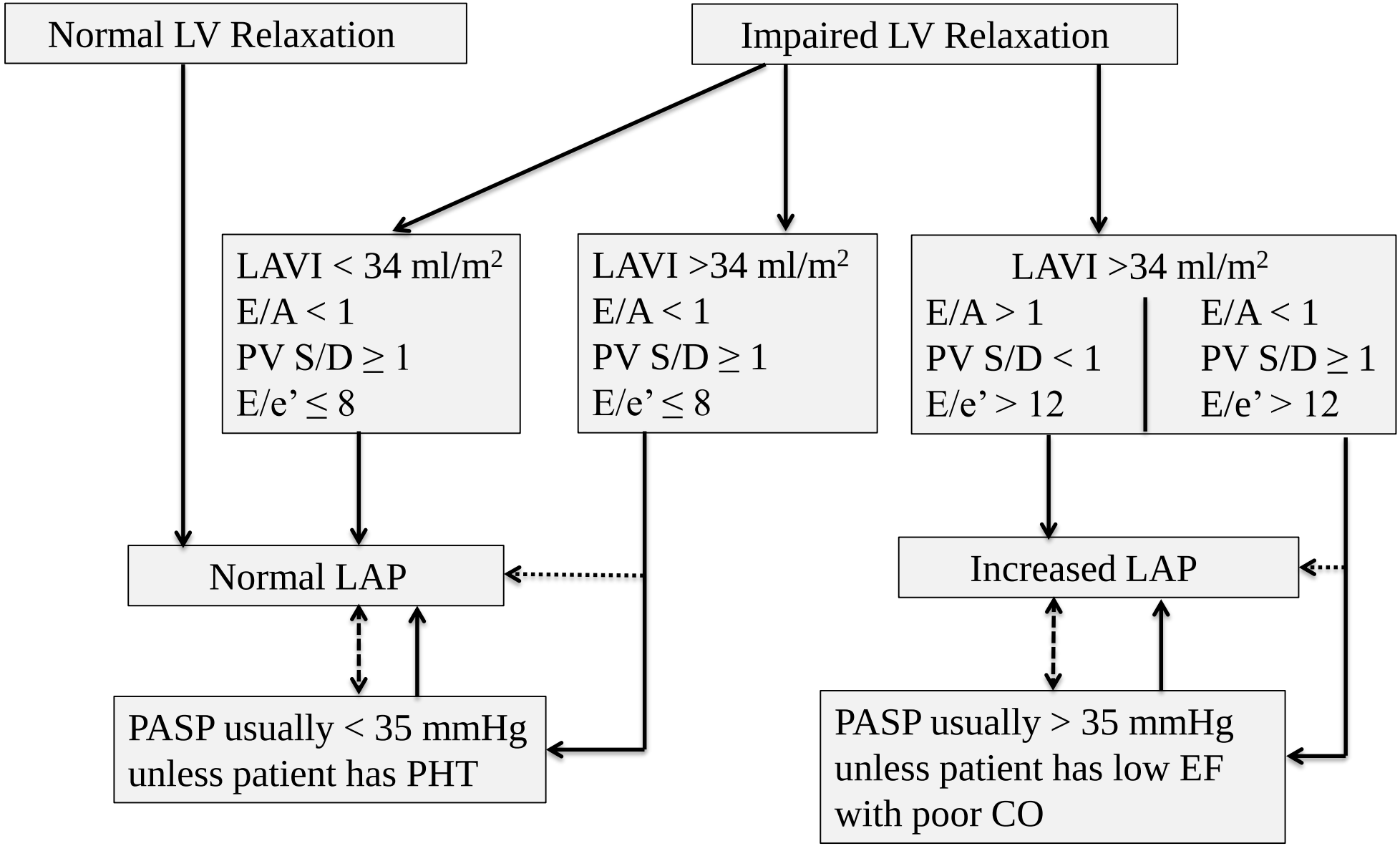
- In pts with normal EF: look for LA enlargement
  - -With type I pattern (E/A<1):
    - -E ≤50cm/s: high PCWP is highly unlikely
    - -E>50cm/s: use E/e' or short IVRT

  - -With type II or III/IV pattern:
    - -LVFP's are most likely elevated (particularly if other 2D findings support it)
    - -low e' usually present

Confirm with PASP by TR velocity

Estimation of mean LA Pressure



Estimation of LV Filling Pressures

Atrial Fibrillation

- Elderly pt with dyspnea and PASP ≥40mmHg has high LVFP until proven otherwise
- Exception
  - RV > LV with septal flattening
- DT <150ms predicts high LVFP in EF<40%
- E/e' is problematic

Thanks