ASE Diastolic Function Guidelines-Case Examples-Should LA Strain be Included?

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Doppler assessment of LV diastolic function and filling pressure has good accuracy in patients with cardiac disease but not in normal subjects in situations with acute changes in loading conditions.

I- ASE/EACVI 2016 guidelines explicitly state that recommendations are for estimation of early LV diastolic pressures, ie mean LA pressure, PCWP, and pre-A pressure

II-General guidelines should not be applied to specific patient populations

Diastolic Dysfunction in Special Diseases

- HCM
- Mitral stenosis, mitral regurgitation and severe MAC in patients with normal EF
- Severe AR with normal LV EF
- Sinus tachycardia with E and A merging
- Atrial flutter and atrial fibrillation
- LBBB, Ventricular pacing and AV block
- Group I pulmonary hypertension
- Constrictive Pericarditis
- Heart transplant recipients
- LVAD

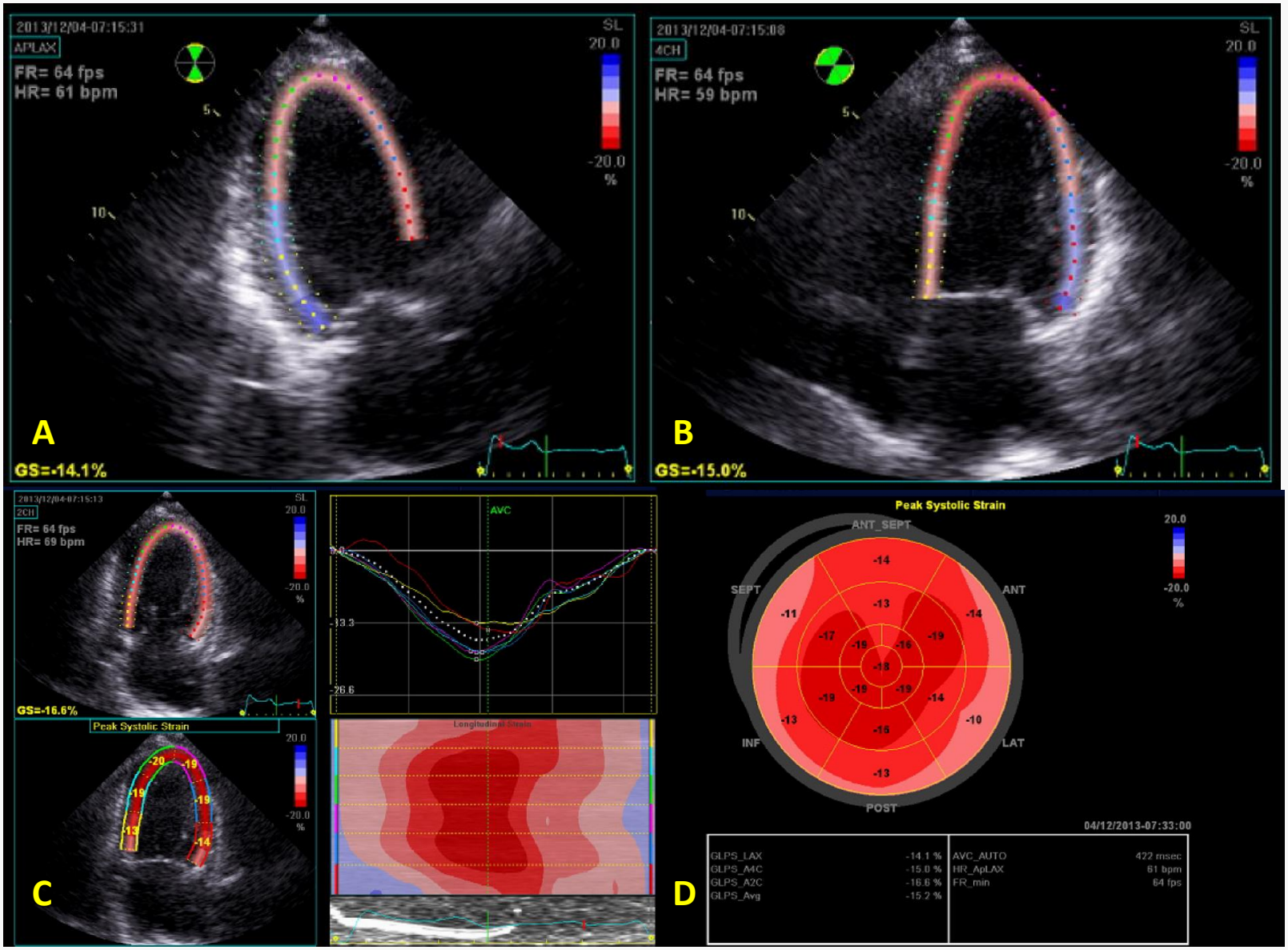
First Question: Is there diastolic dysfunction or a high likelihood of diastolic dysfunction?

To answer this question, need to look at evidence of cardiac disease (structural and/or functional abnormalities)

III-Clinical, 2D, LV Systolic Dysfunction Findings acknowledged as Indicators of Diastolic Dysfunction

- Known CV disease as CAD with segmental dysfunction
- Pathologic LVH (as in AS or hypertension)
- Hypertensive CV Disease (HTN+ LVH and/or HTN+LA enlargement)
- LV systolic Dysfunction as noted by depressed LV EF (<50%-need history, 2D, and Doppler findings to exclude athlete's heart)
- Abnormal LV GLS or MAPSE or mitral s' velocity

Abnormal LV Global Longitudinal Strain



IV-Detection of Diastolic Dysfunction can be challenging in normal EF and no apparent disease.

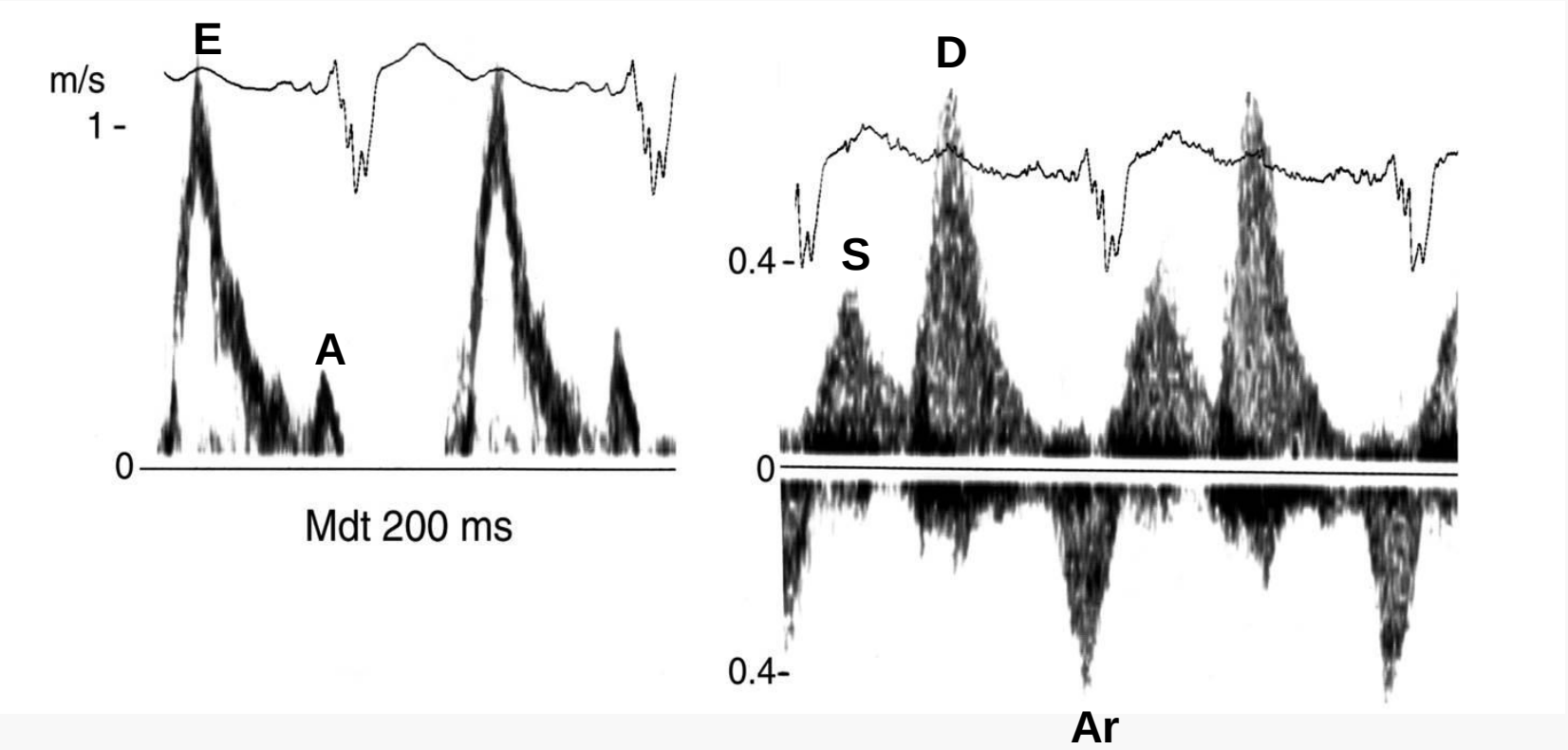
Few Doppler signals are not affected by age and by themselves can indicate abnormally elevated LV diastolic pressures

IV-Specific Echo Doppler Findings in Diastolic Dysfunction and Normal LV EF Should be Sought

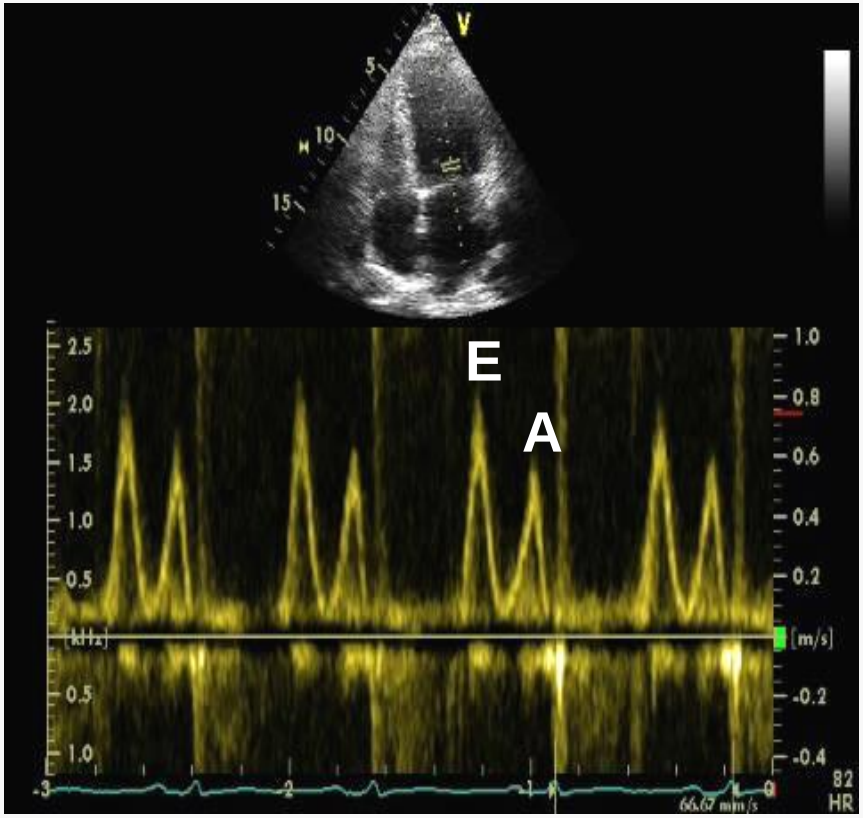
- Ar –A duration >30 ms
- Positive Valsalva maneuver
- Different inflow patterns for the LV and RV
- L wave in Mitral Inflow

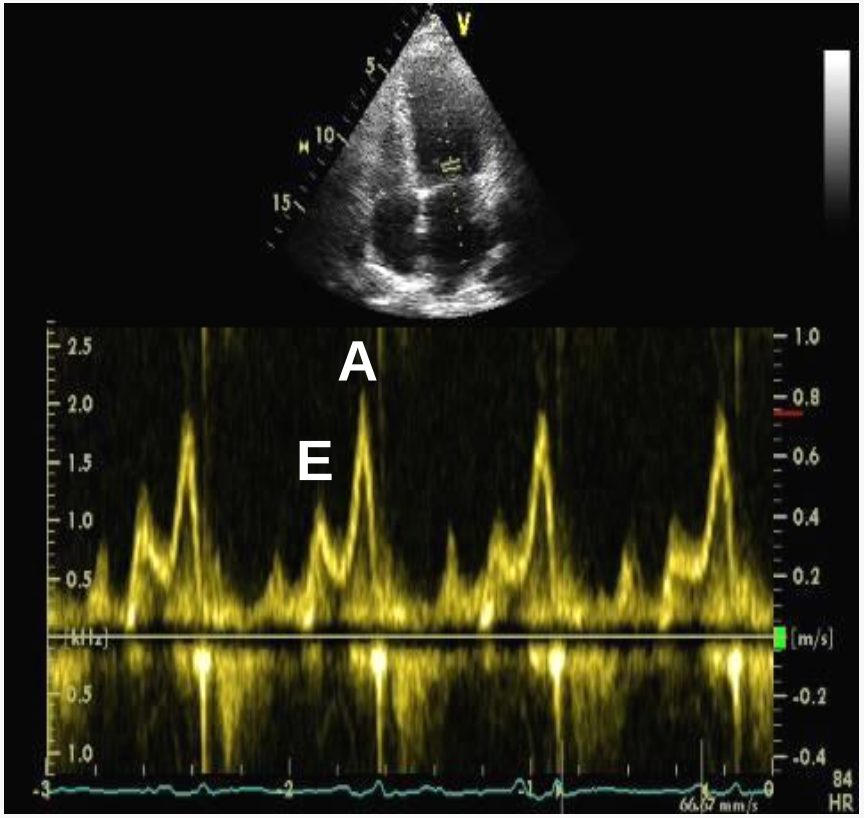
(incorrect application of the 2016 guidelines if they are ignored)

Pulmonary Vein Ar Velocity in a Patient with HFpEF

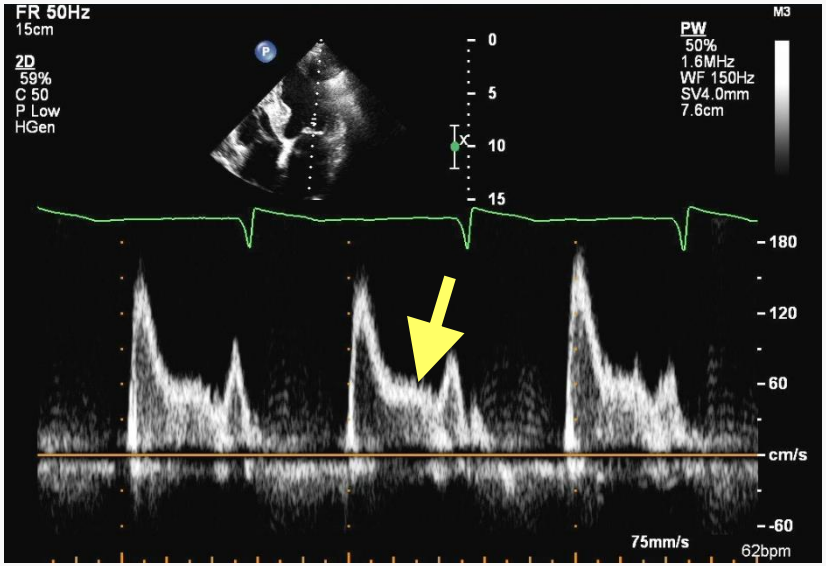


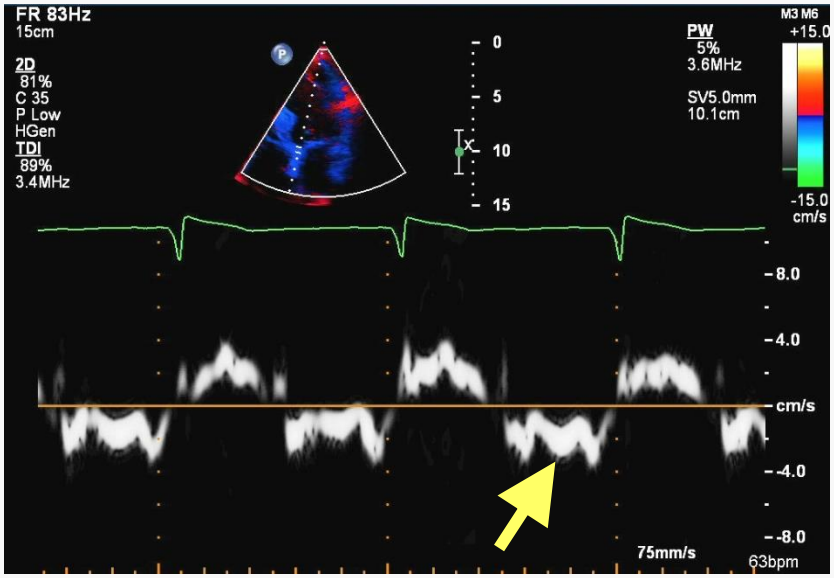
Changes in Mitral Inflow with Valsalva in a Patient with Pseudonormal LV Filling Pattern





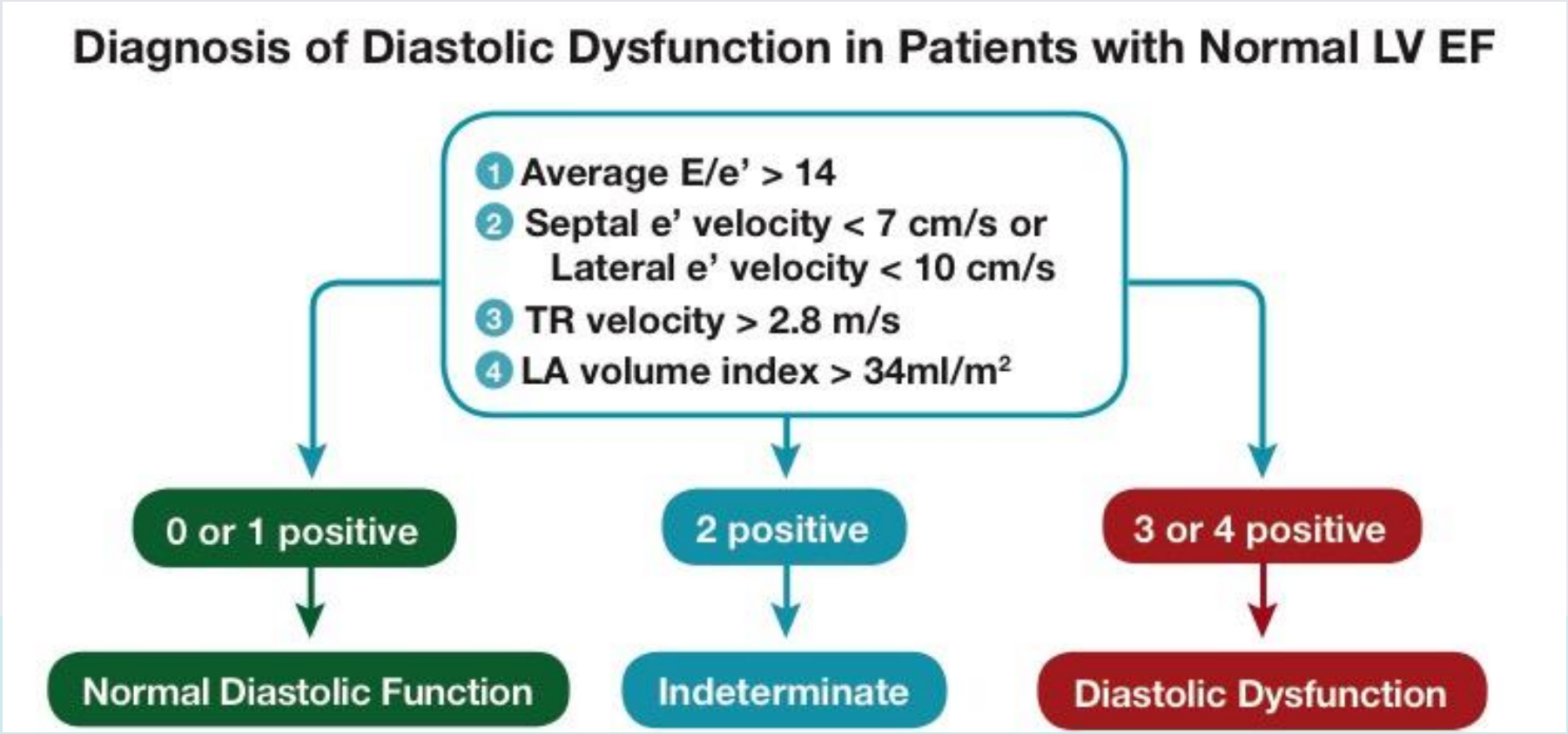
Mitral Inflow “L” Velocity





V-Algorithm in the absence of abnormal clinical, 2D, and Doppler findings

Criteria for Diagnosis of LV Diastolic Dysfunction

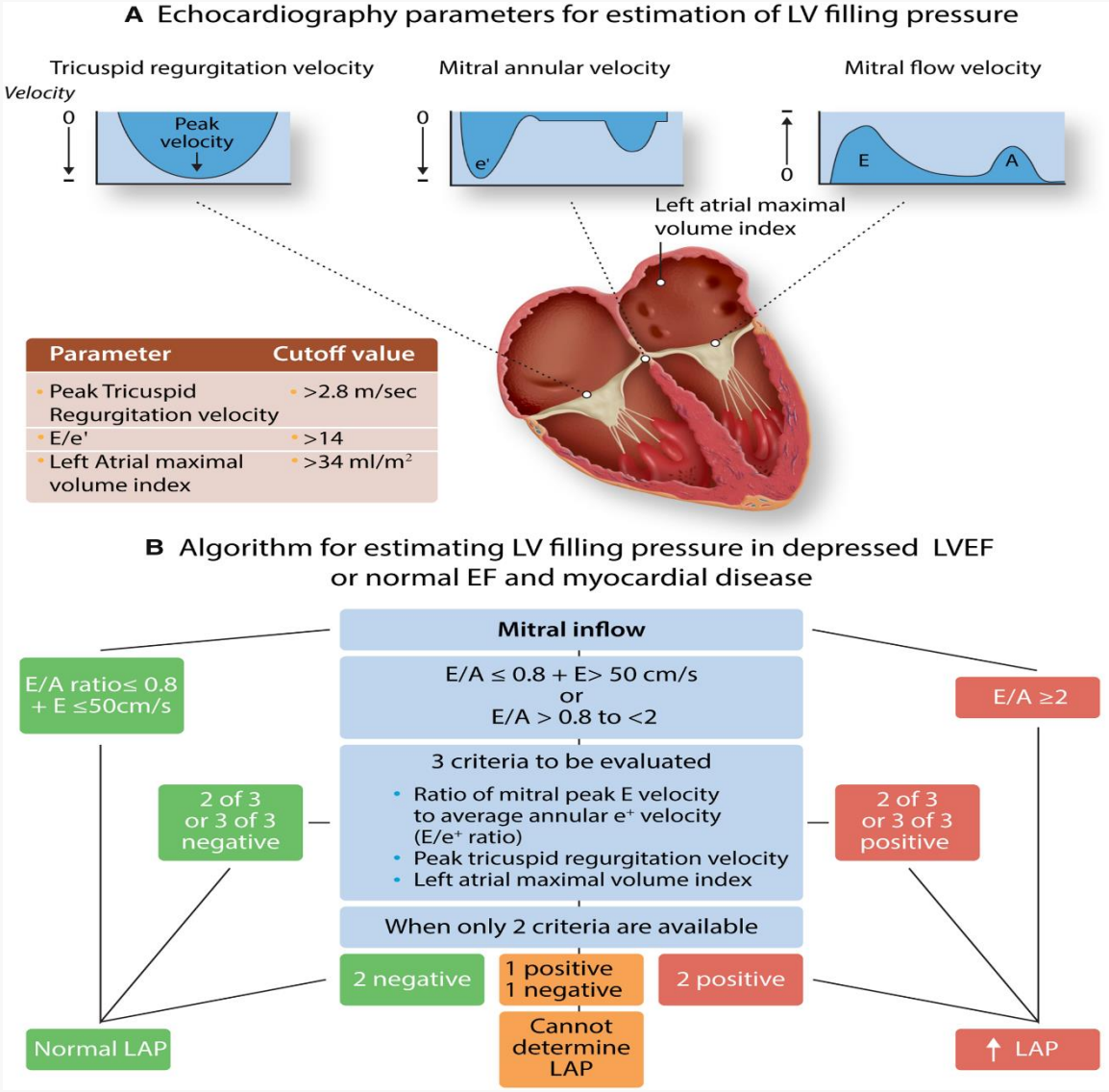


The algorithm is not needed in the presence of abnormal clinical, 2D, and/or Doppler findings

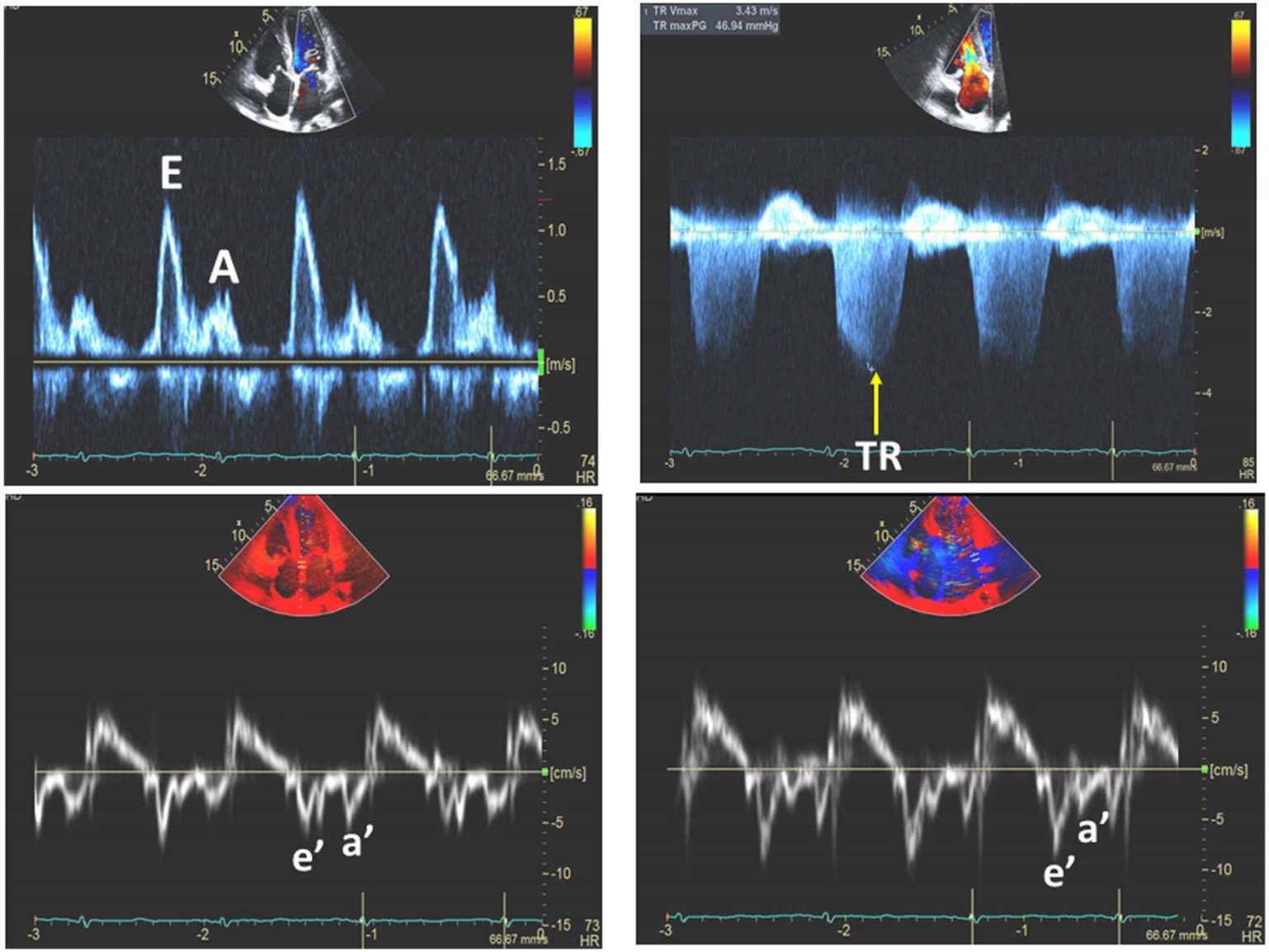
Apply algorithm if only 3 variables are available and DD is present if 3/3 or 2/3 are abnormal

VII-If the conclusion is reached that diastolic dysfunction is present with or without using the algorithm for diastolic dysfunction diagnosis, proceed to estimating LA pressure

Echocardiographic LAP Estimation

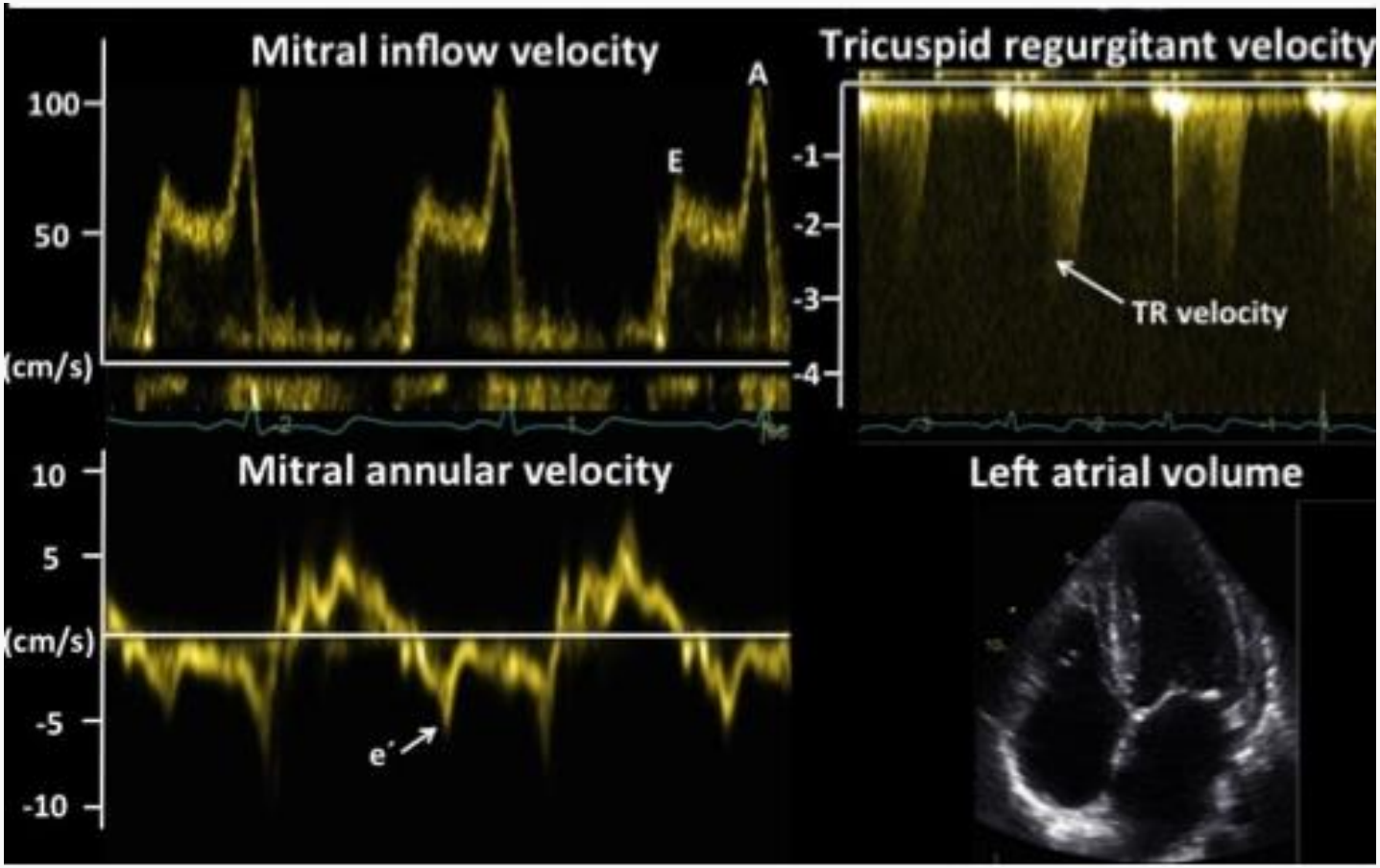


Doppler Findings in HFpEF-Case I



Case II

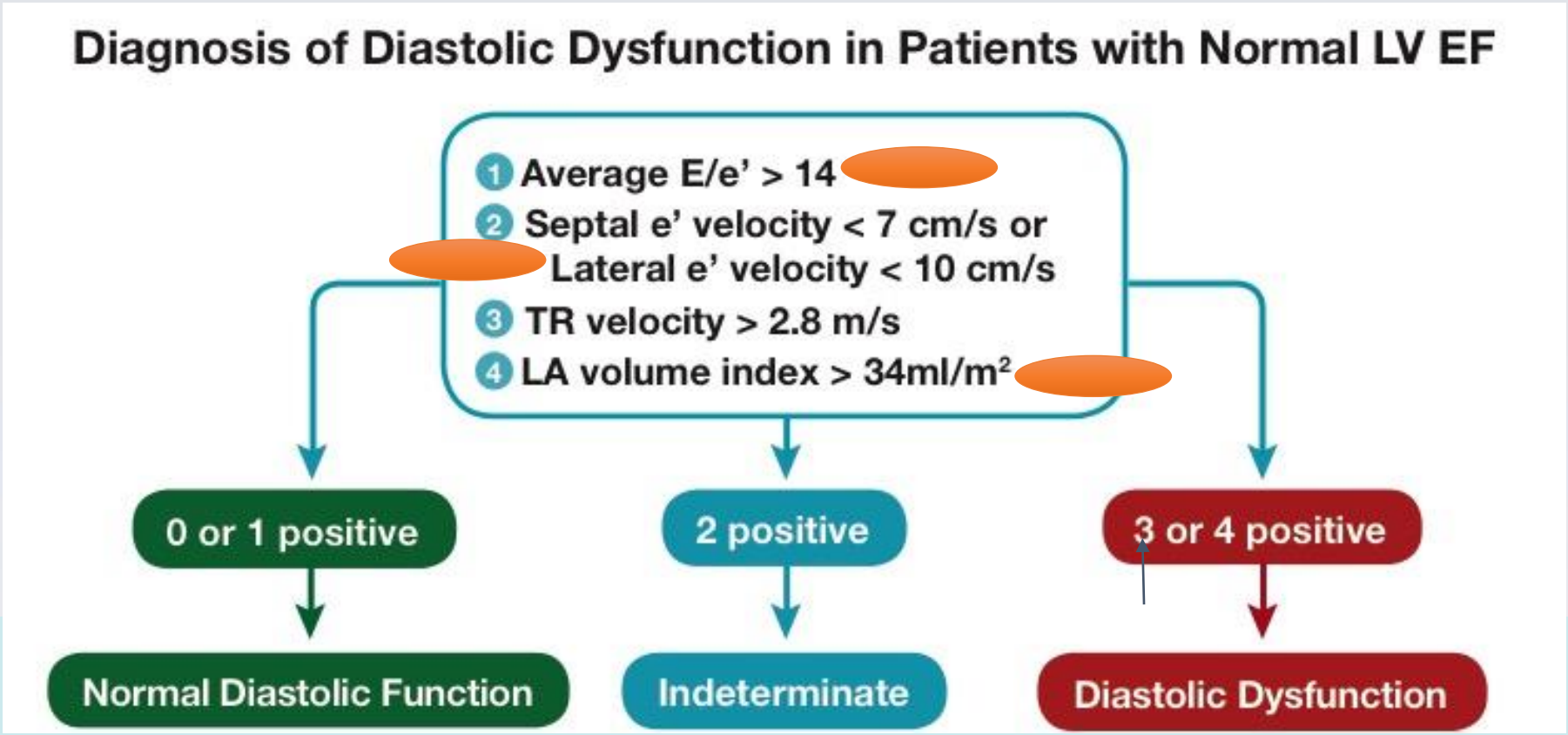
Case II: Echocardiographic Findings



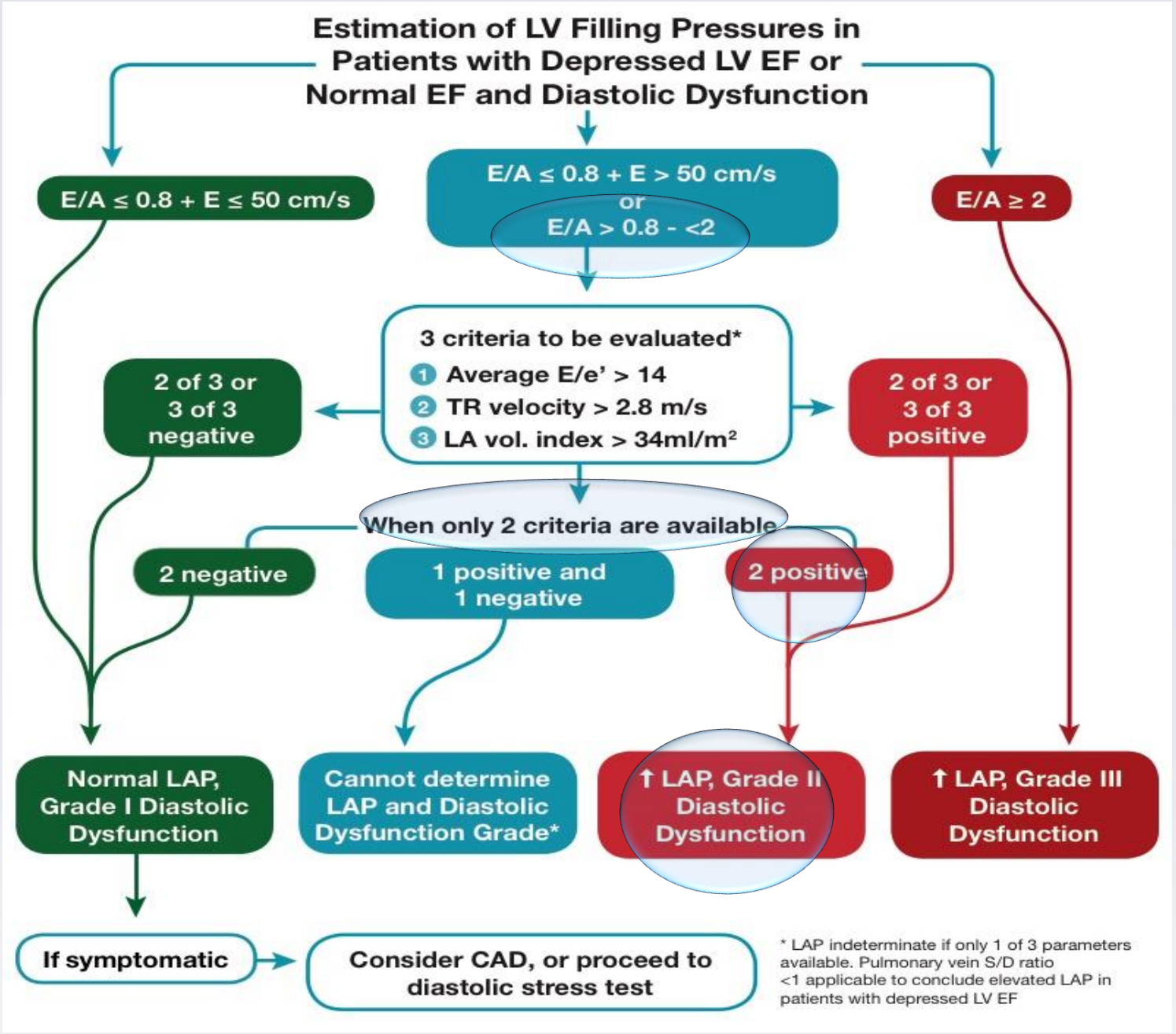
Summary

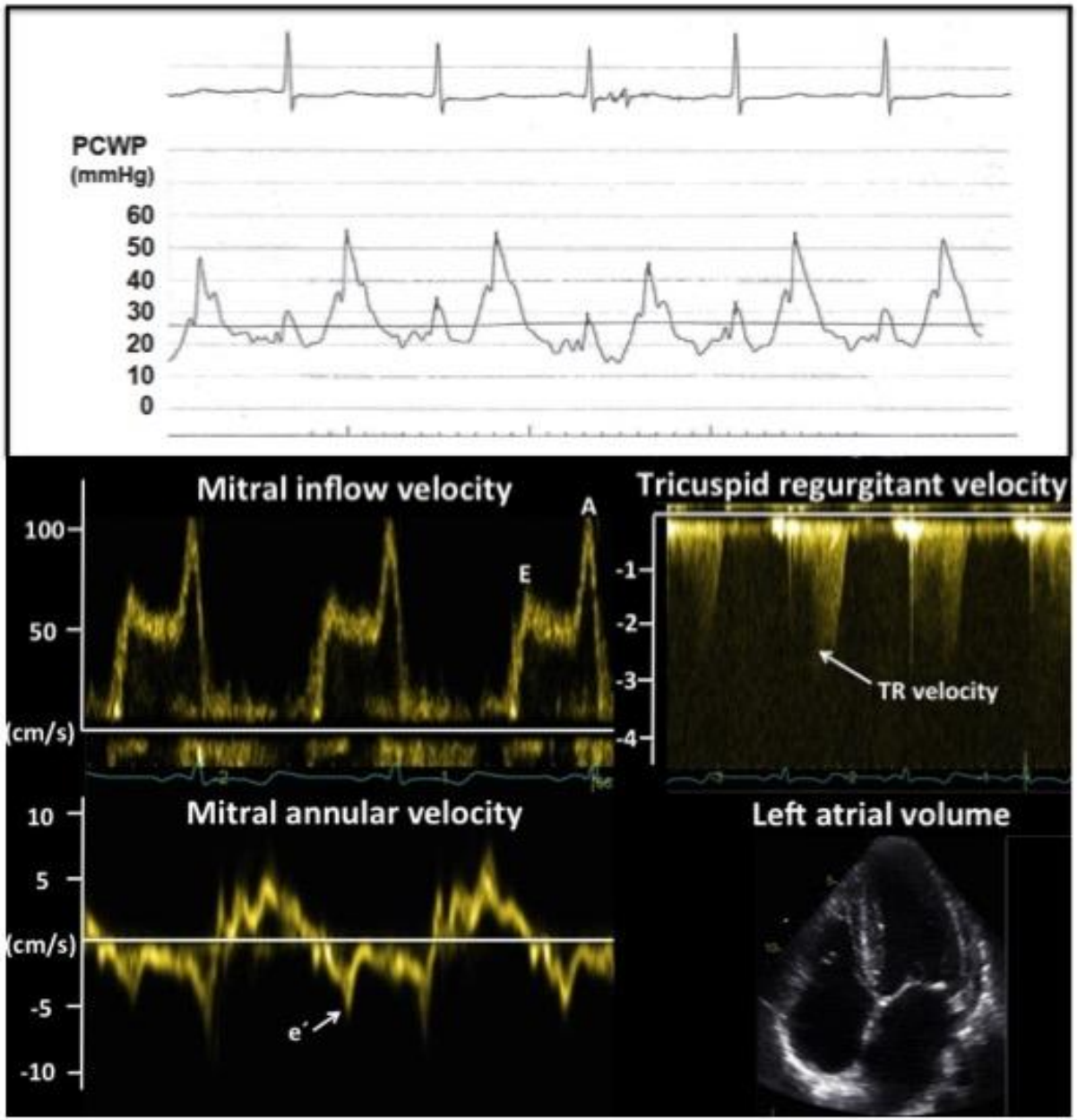
- E/A ratio at 0.8-0.9, peak E >50 cm/s
- Average E/e’ = 15
- LA maximum volume index = 51 mL/m^2
- TR incomplete

Criteria for Diagnosis of LV Diastolic Dysfunction



Diastolic Dysfunction is present
Proceed to Estimation of PCWP


Estimation of LV Filling Pressures in Patients with Depressed LV EF or Normal EF and Diastolic Dysfunction
E/A ≤ 0.8 + E ≤ 50 cm/s
E/A ≤ 0.8 + E > 50 cm/s or E/A > 0.8 - <2
E/A ≥ 2
3 criteria to be evaluated*
1 Average E/e' > 14
2 TR velocity > 2.8 m/s
3 LA vol. index > 34ml/m²
2 of 3 or 3 of 3 negative
2 of 3 or 3 of 3 positive
When only 2 criteria are available
2 negative
1 positive and 1 negative
2 positive
Normal LAP, Grade I Diastolic Dysfunction
Cannot determine LAP and Diastolic Dysfunction Grade*
↑ LAP, Grade II Diastolic Dysfunction
↑ LAP, Grade III Diastolic Dysfunction
If symptomatic
Consider CAD, or proceed to diastolic stress test
* LAP indeterminate if only 1 of 3 parameters available. Pulmonary vein S/D ratio <1 applicable to conclude elevated LAP in patients with depressed LV EF



Andersen et al J Am Coll Cardiol 2017;69:1937-48

Case III
Patient with depressed LV EF

Case III

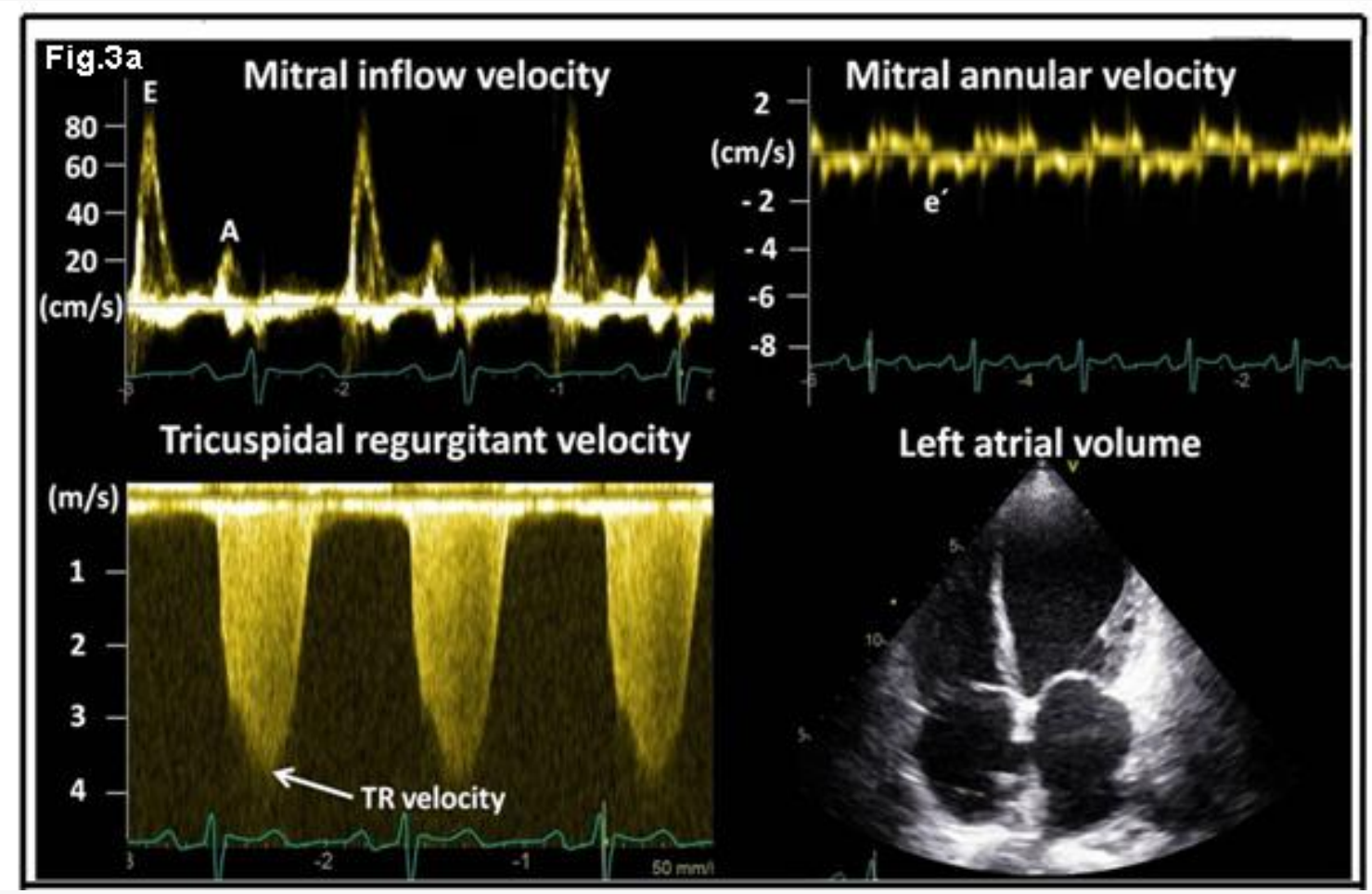
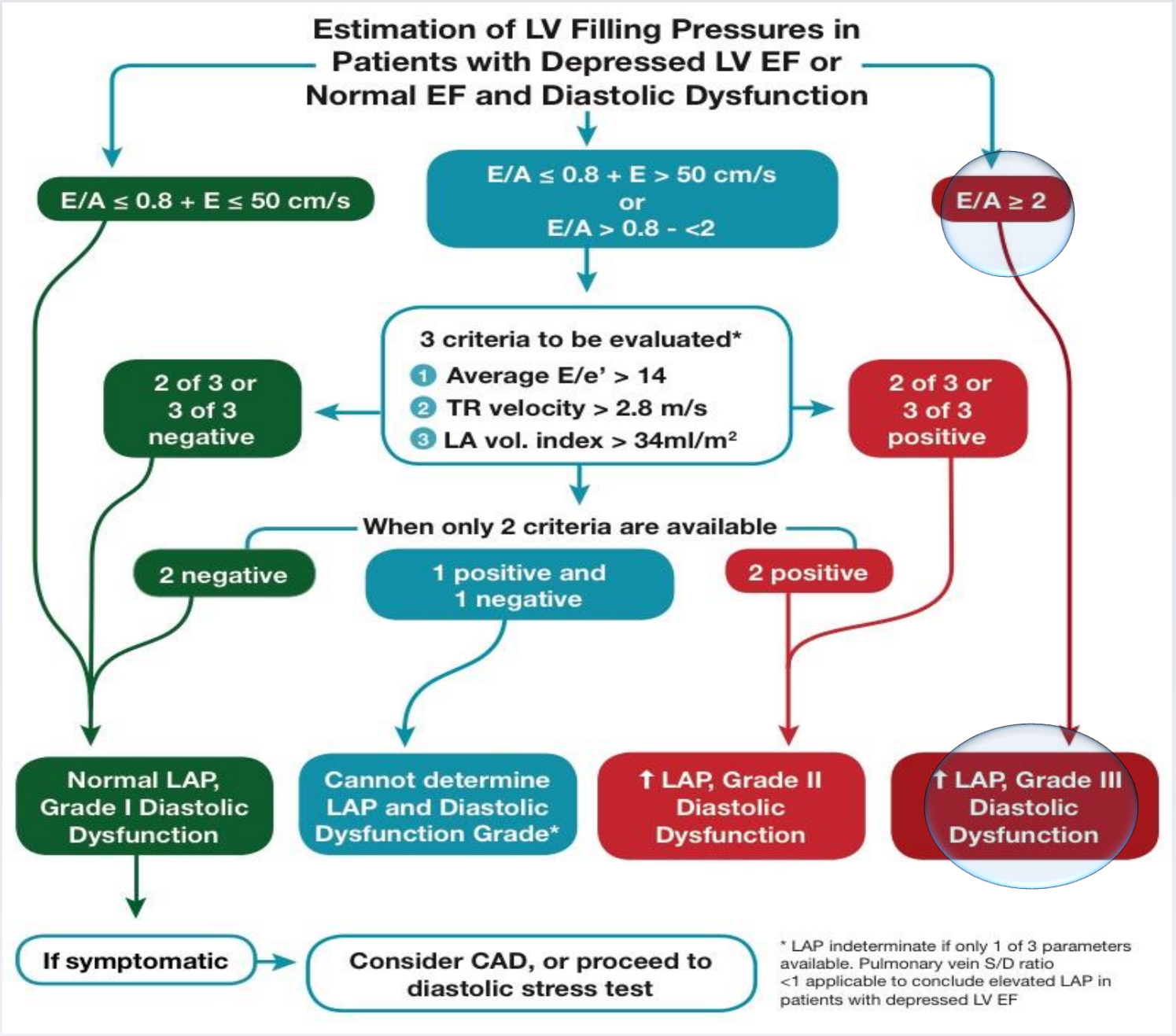


Fig.3a
Mitral inflow velocity
E
A
80
60
40
20
(cm/s)
Mitral annular velocity
2
(cm/s)
- 2
- 4
-6
-8
e´
Tricuspidal regurgitant velocity
(m/s)
1
2
3
4
TR velocity
Left atrial volume

Summary

- E/A ratio > 2
- E/e’ ratio > 14
- Peak TR velocity >3.5 m/s
- LA enlarged > 34 mL/m^2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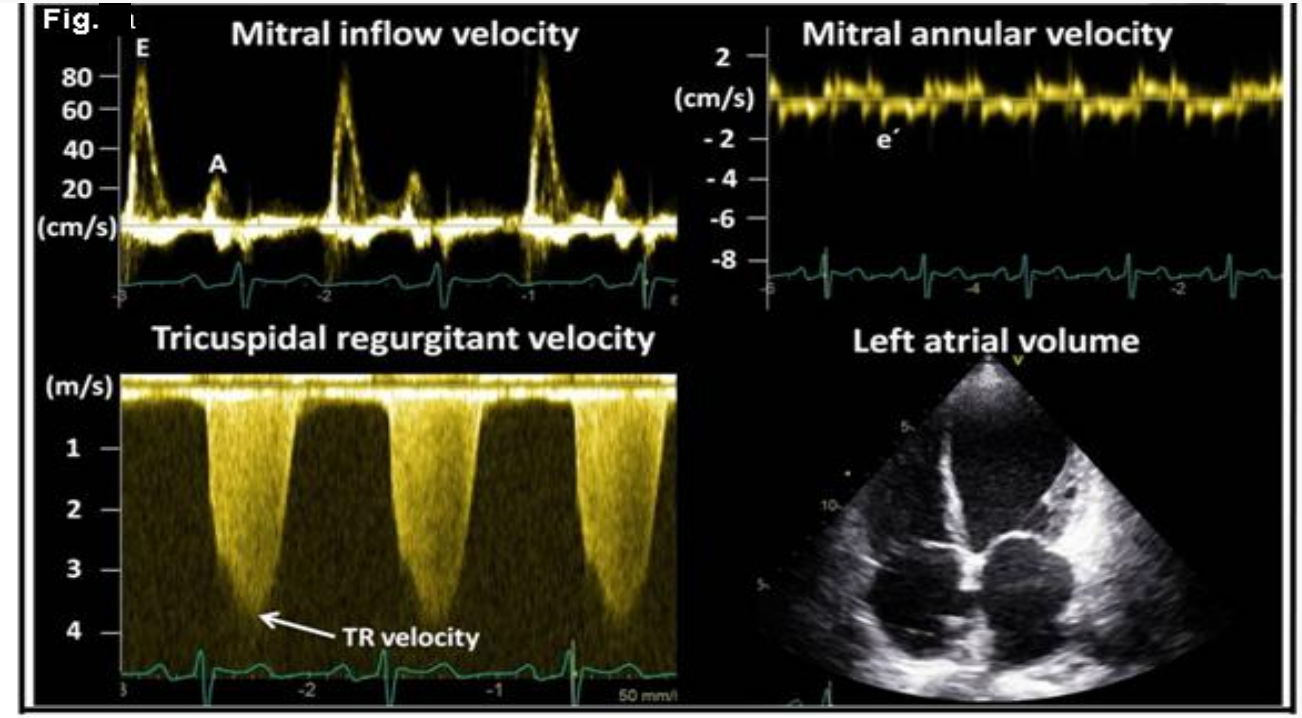


Andersen et al J Am Coll Cardiol 2017;69:1937-48

Accuracy of Guidelines

Accuracy of 2016 Guidelines (N= 450)

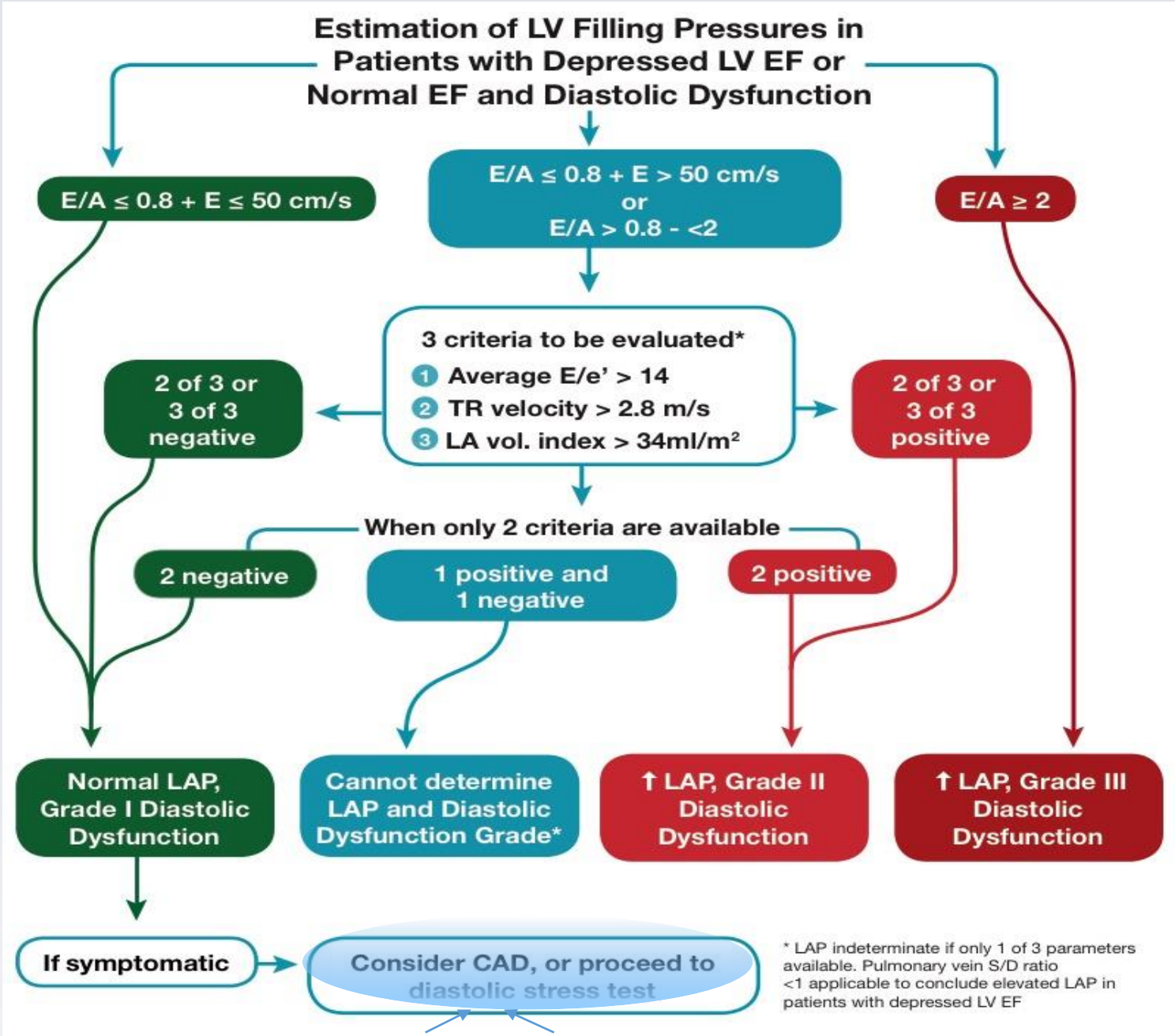
	Clinical (95% CI)	Echocardiographic (95% CI)	p Value* Clinical vs. Echo
Sensitivity	74 (68-79)	87 (81-91)	0.001
Specificity	69 (62-75)	88 (82-93)	<0.001
PPV	77 (71-82)	91 (86-94)	<0.001
NPV	65 (58-72)	83 (76-88)	<0.001
Overall accuracy	72 (67-76)	87 (84-91)	<0.001

Andersen et al J Am Coll Cardiol 2017;69:1937-48

Accuracy of 2016 Guidelines: Subgroup Analysis

	Clinical Accuracy	Echo Accuracy	p Value Clinical vs. Echo
LVEF <50% (n = 209)	81	91	0.01
LVEF ≥50% (n = 241)	64	84	<0.001
Obesity (n = 193)	76	87	0.015
Diabetes mellitus (n = 48)	70.8	88	0.08
Chronic kidney disease (n = 47)	61.7	79	0.12
Hypertension (n = 167)	68	86.7	<0.001
CAD (n = 155)	73.5	92.7	<0.001
Pulmonary parenchymal or vascular disease (n = 71)	53.5	81	0.001

Andersen et al J Am Coll Cardiol 2017;69:1937-48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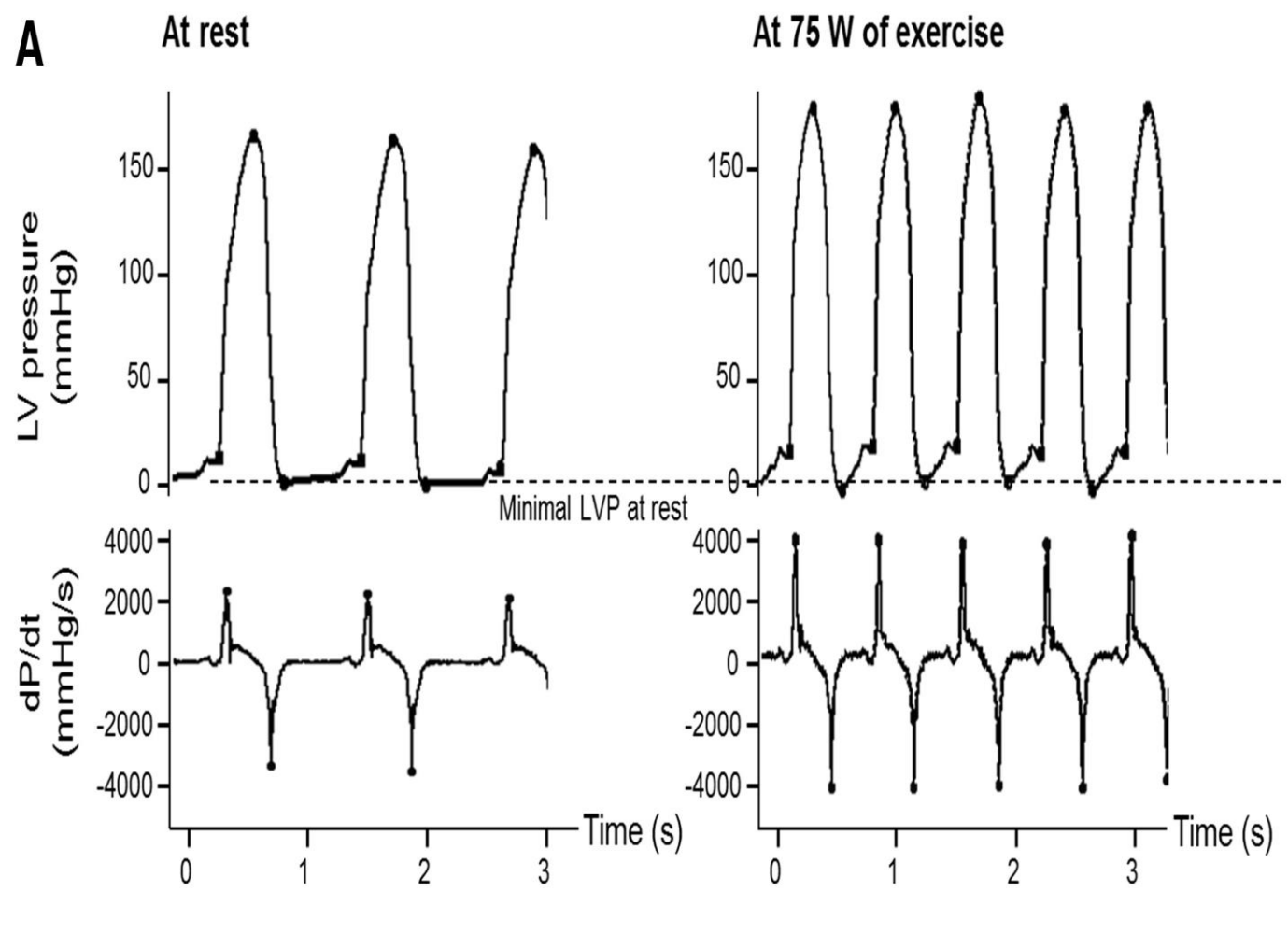
Hemodynamic Changes with Exercise

- Increased heart rate, stroke volume, and cardiac output
- Stroke volume increases due to increased contractility but LV filling has to be maintained for LV stroke volume to increase
- LV filling increases with exercise because of lower LV minimal pressure with exercise, leading to increased transmitral pressure gradient
- In normal subjects this occurs without an increase in LA pressure

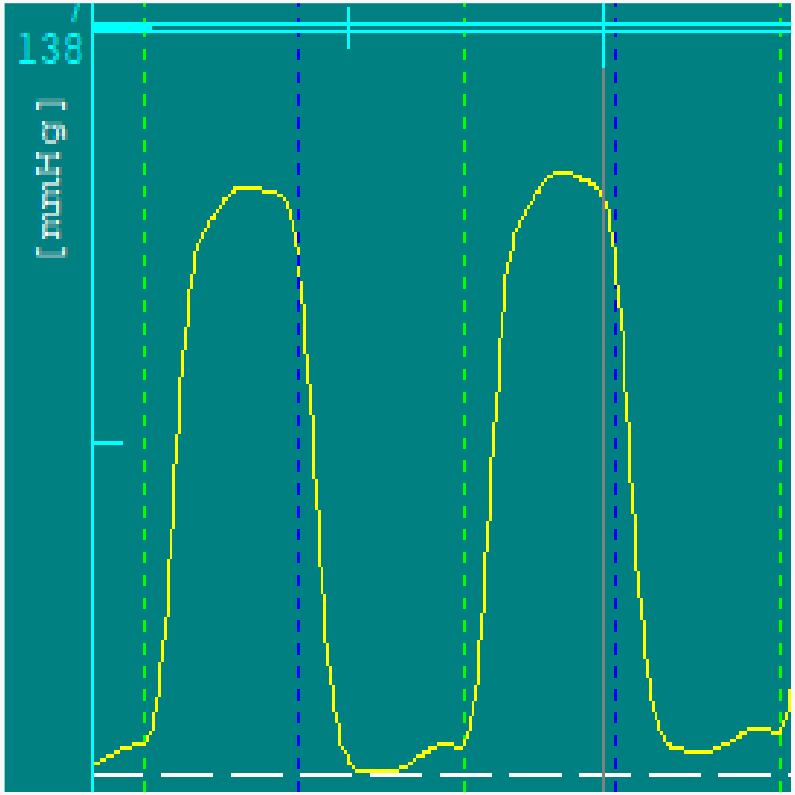
LV Minimal Pressure at Rest and Exercise



Hong et al. Eur Heart J Cardiovasc Imaging 2018;19:12-19

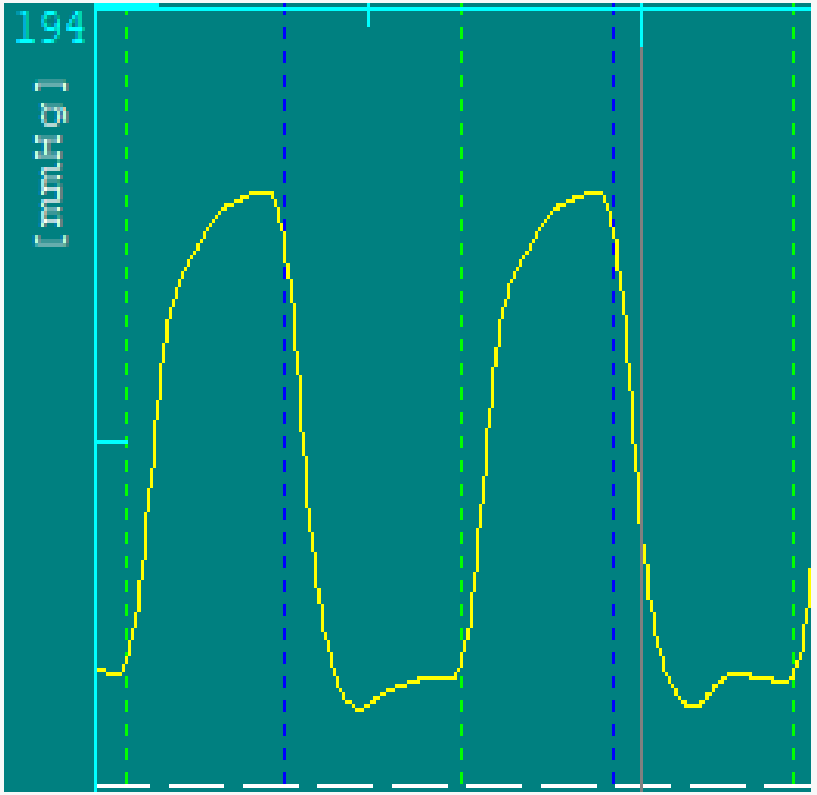
LV Diastolic Pressures: Rest and Exercise

Baseline



LV Minimum pressure = 1 mmHg
LV EDP = 11 mmHg

Exercise



LV Minimum pressure = 16 mmHg
LV EDP = 30 mmHg

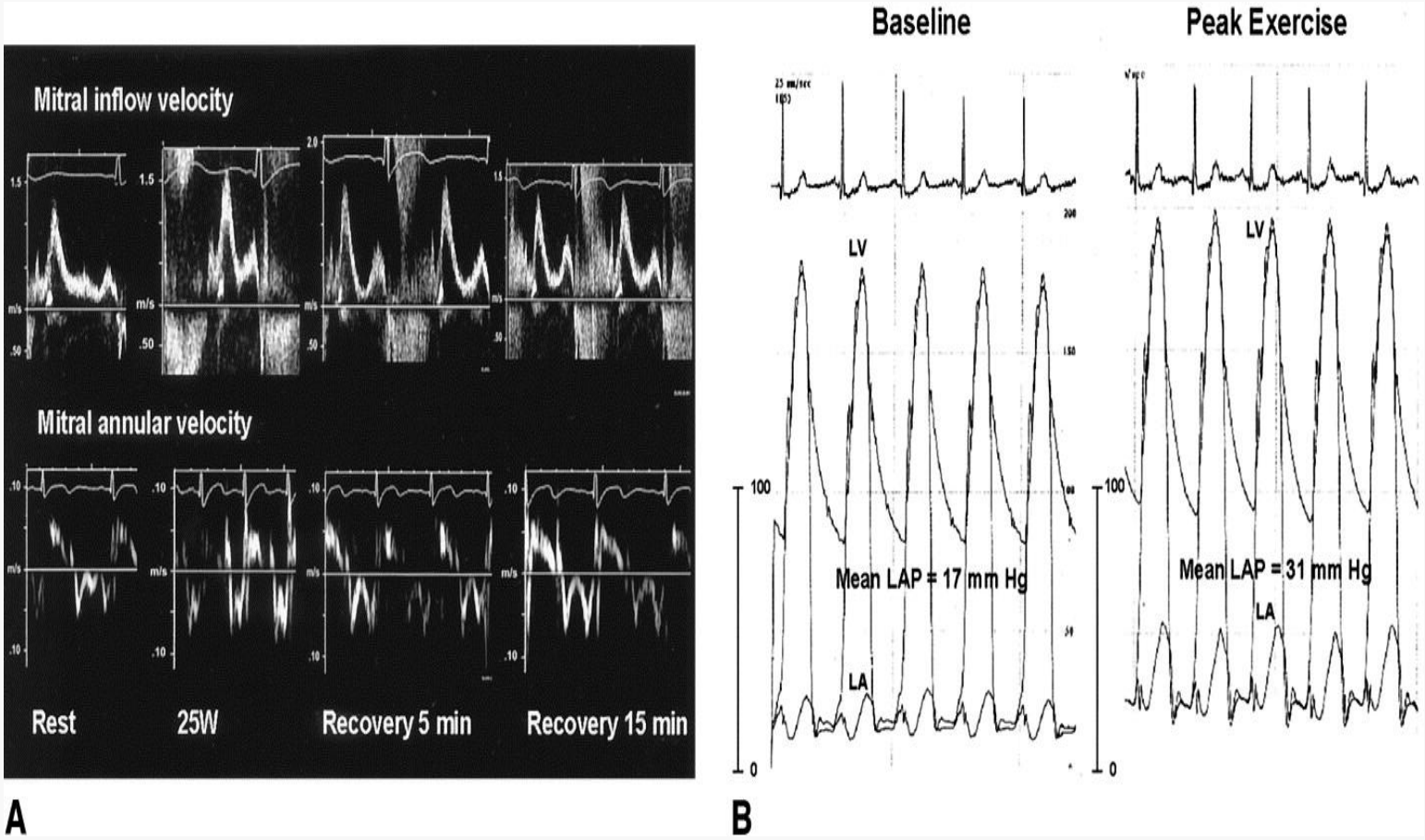
Vejpongsa et al. Sci Rep. **2022;12:3834**

Rationale for Diastolic Stress Test

- Some HFpEF patients have normal LAP at rest
- LAP increases with exercise along with dyspnea
- Diastolic stress test not needed when LAP is already elevated
- TR jet should be acquired and considered with E/e’ ratio to avoid false positive calls

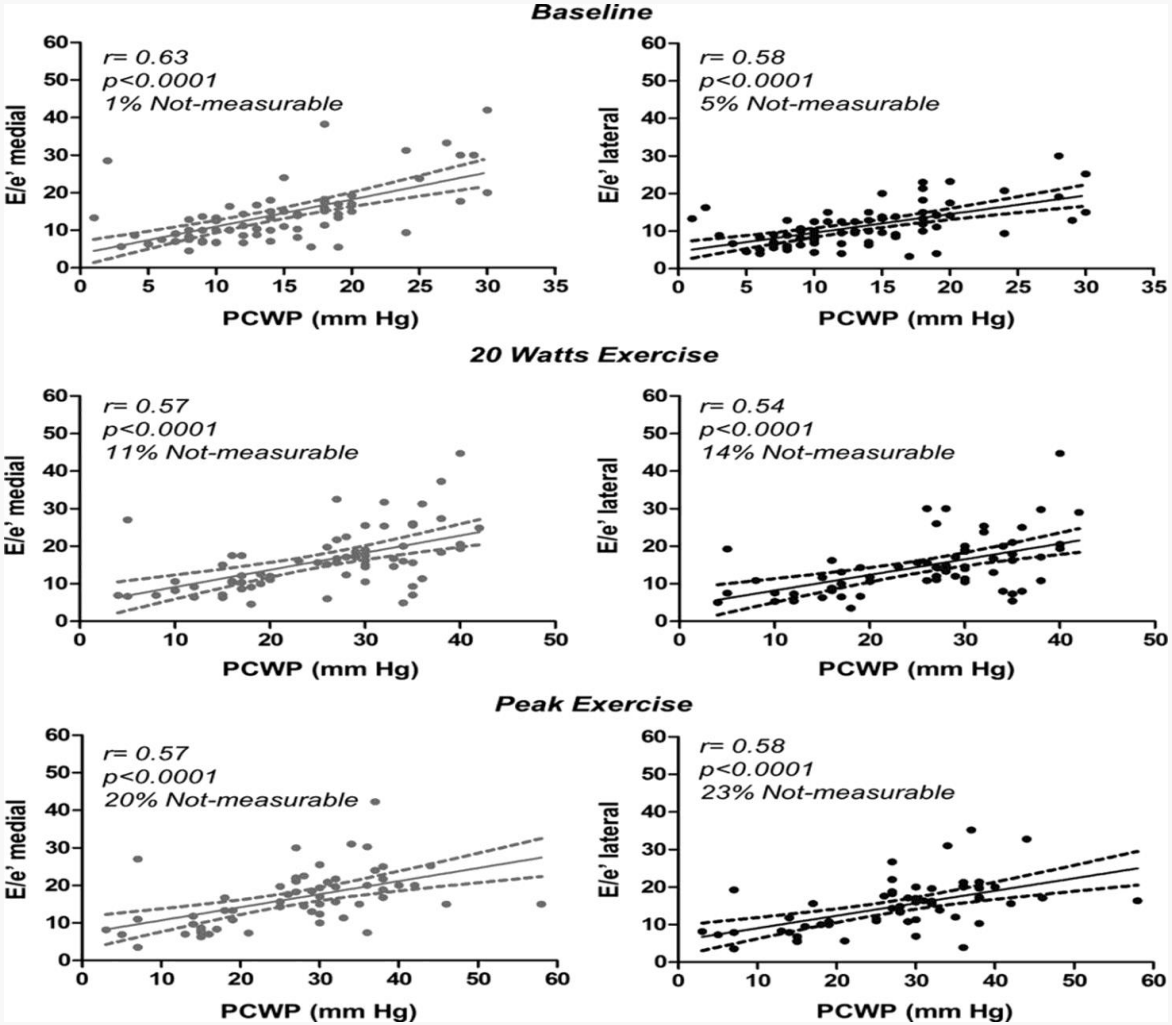
Diastolic Stress Test

First Study on Echo Doppler for LV FP with Exercise using E/e' Ratio



Ha et al. *JASE* 2005;18:63-68

E/e' Versus LV Filling Pressures at Rest and Exercise (N=74)



Obokata et al. *Circulation* 2017;135:825-838

How to Do Diastolic Stress Test

- Exercise for stress and not dobutamine
- Supine bike preferrable over treadmill
- For bike signals acquired at baseline, each stage of exercise, and recovery: 2D protocol, mitral inflow, TD velocities, and peak TR velocity
- For treadmill, baseline and recovery stages are compared for Doppler signals
- If indication chest pain and dyspnea: priority acquisition of 2D signals for wall motion analysis (for treadmill: 2D images within 60 sec of exercise termination)
- TR jet should be acquired and considered with E/e' ratio to avoid false positive calls

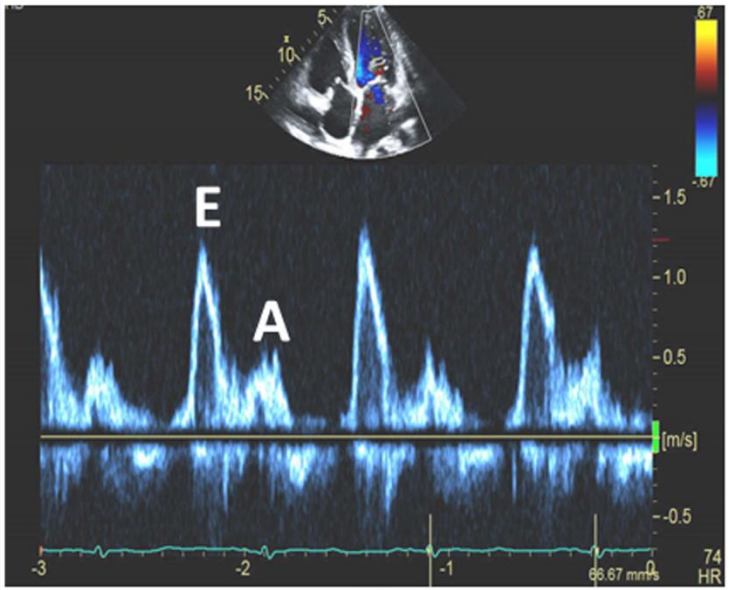
Nagueh et al JASE 2016;29:277-314

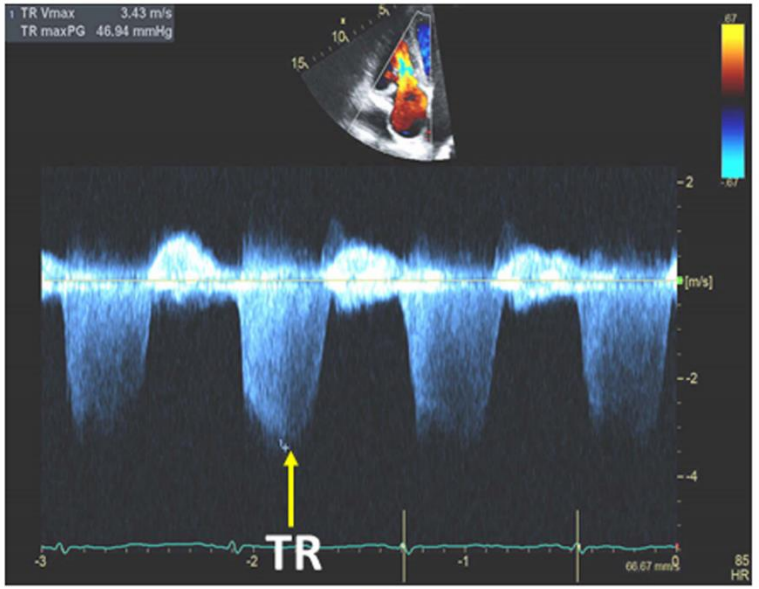
How to Interpret Diastolic Stress Test

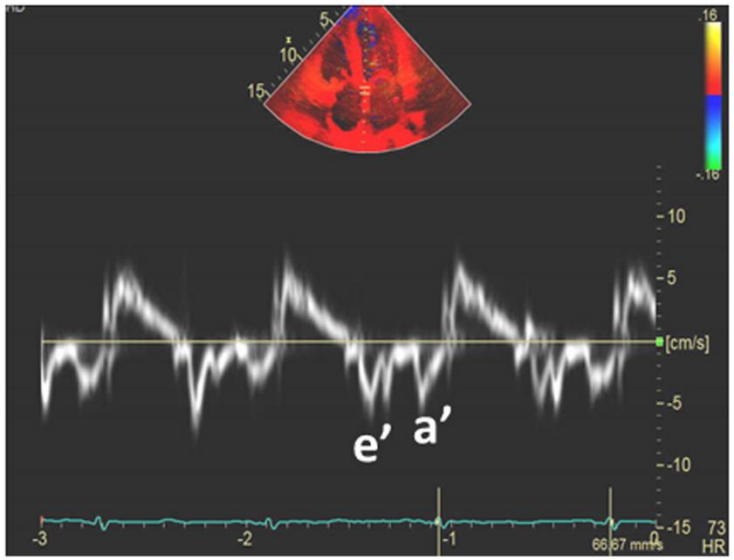
- More experience is needed for satisfactory data acquisition during stress compared to rest
- Test positive with average E/e' ratio >14 or if only septal e' is acquired, septal E/e' ratio >15 + peak TR >2.8 m/s
- TR velocity and PASP can increase in normal subjects and in patients with non cardiac pulmonary hypertension
- Symptomatic patients where diagnostic criteria are not met should be referred for right heart catheterization for PCWP measurements at rest and with graded exercise
- Patients with myocardial disease (for example: diabetes) have reduced augmentation of e' velocity with exercise compared to controls

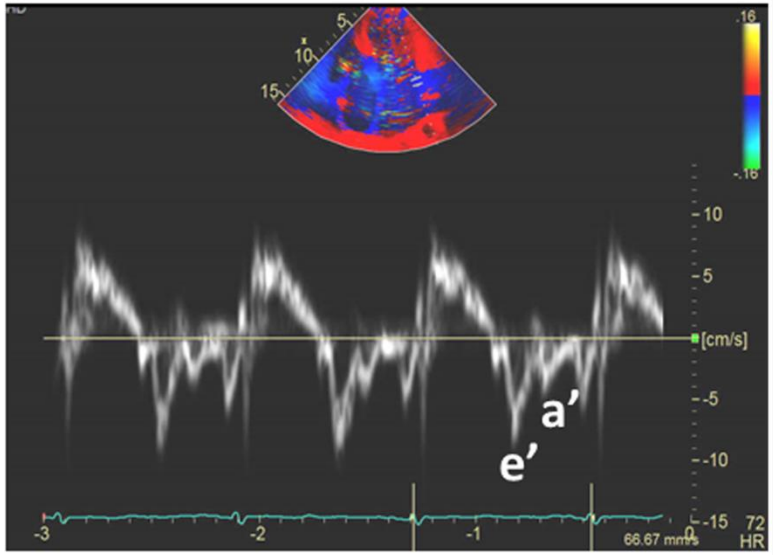
Nagueh et al JASE 2016;29:277-314

Findings at Rest in Patient with HFpEF

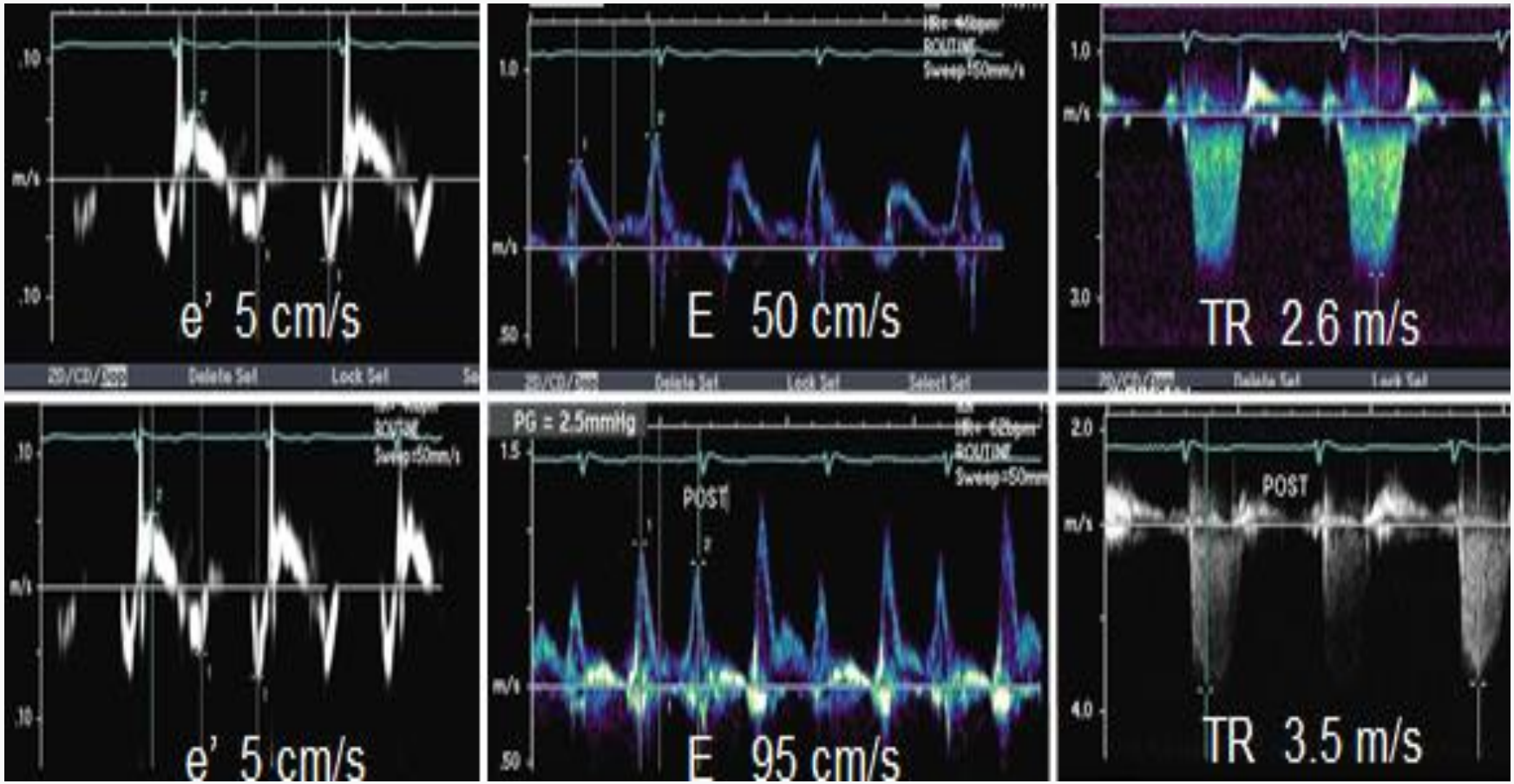






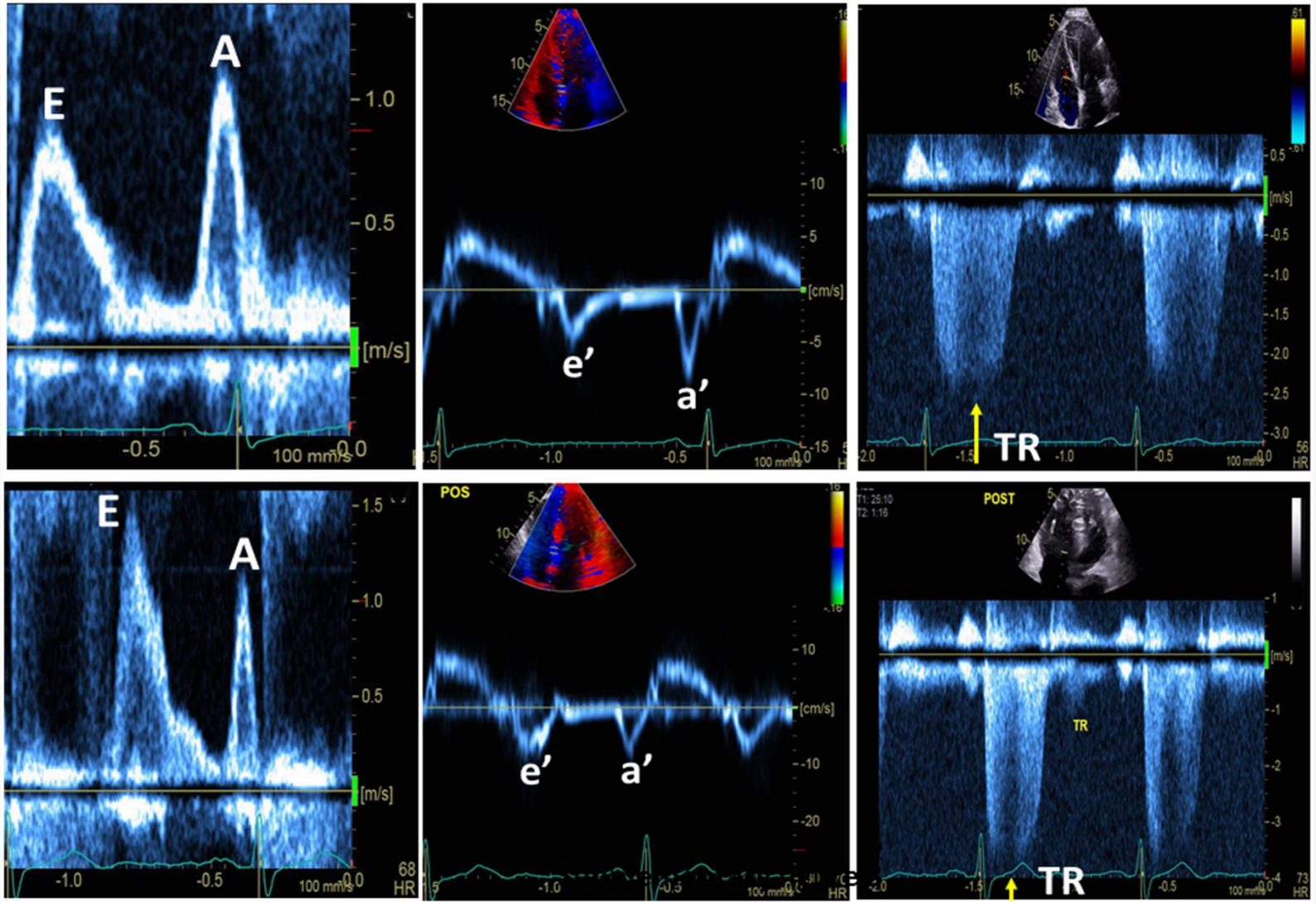


Positive Diastolic Stress Test-Example 1



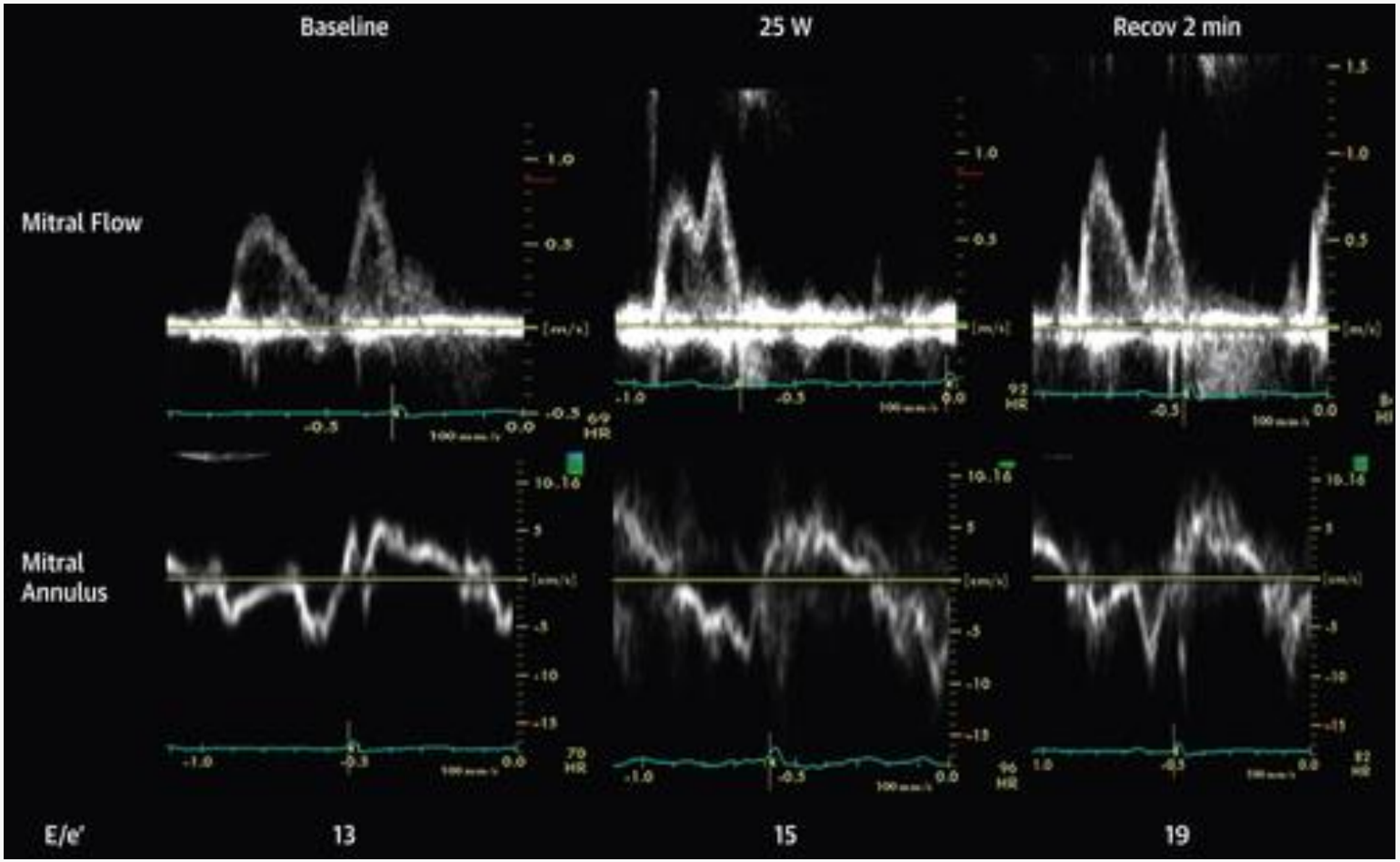
Nagueh et al JASE 2016;29:277-314

Diastolic Stress Test –Example 2



Nagueh Cardiovasc Res. 2021;117:999-1014

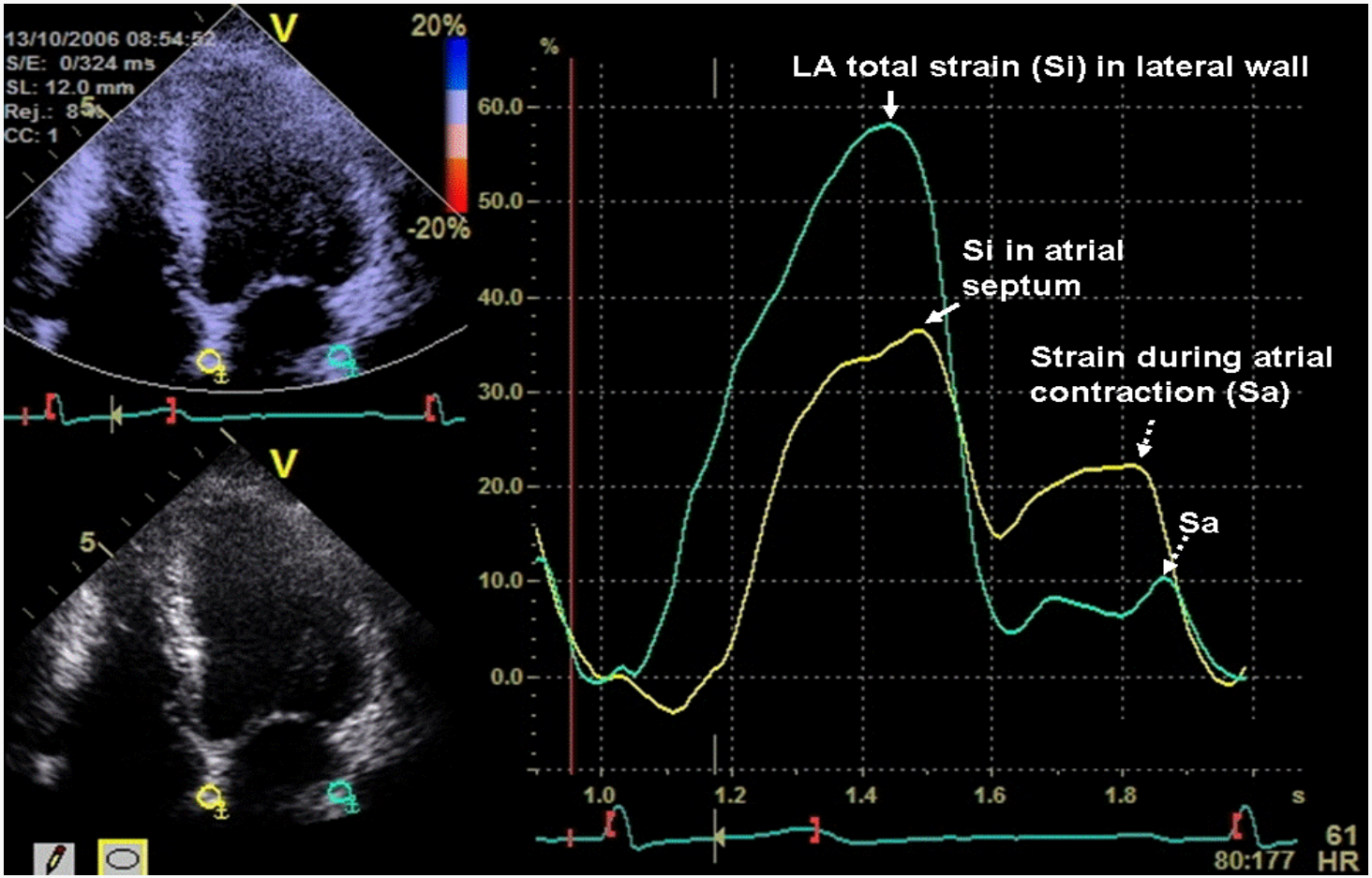
Positive Diastolic Stress Test-Example 3



Jong-Won Ha et al. *J Am Coll Cardiol Img* 2019; 13:272-282

Other Indices of LV Filling Pressure Which I Consider

LA Strain



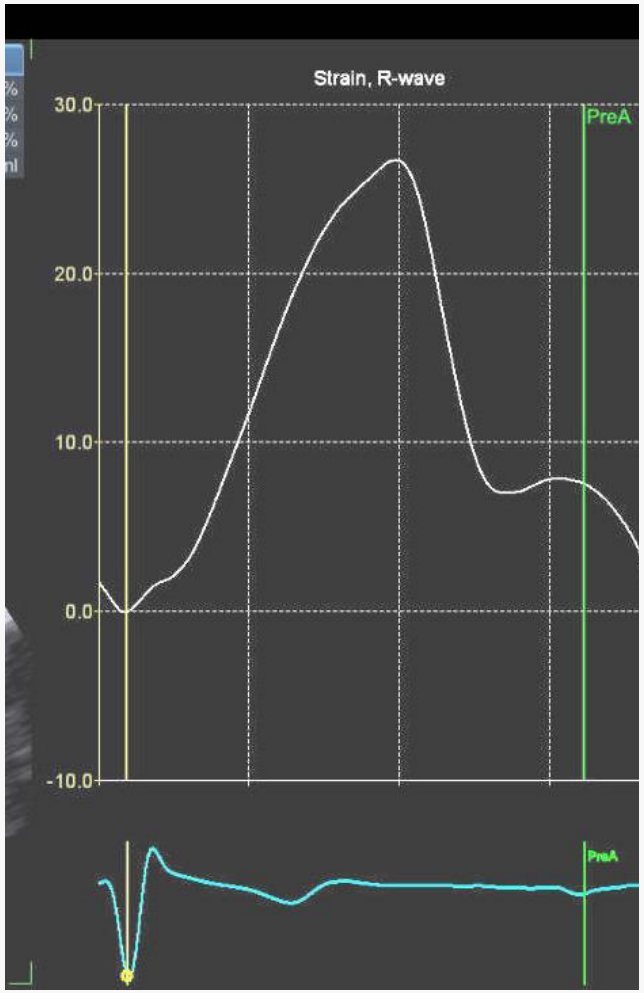
Kurt et al Circ Cardiovasc Imging 2009;2:10-15

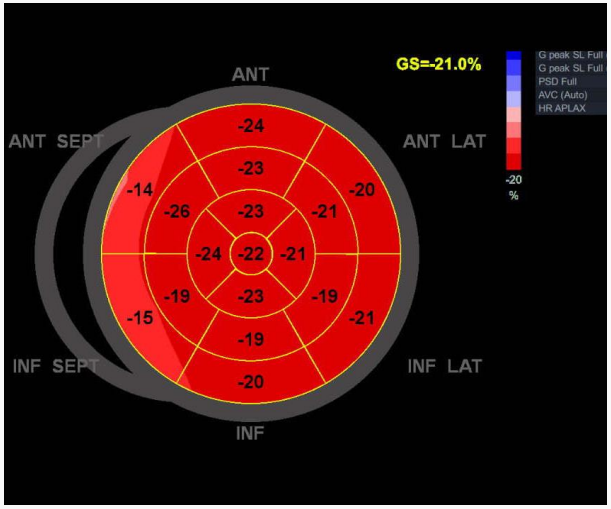
Normal Values of LA Strain (N=1765 Subjects)

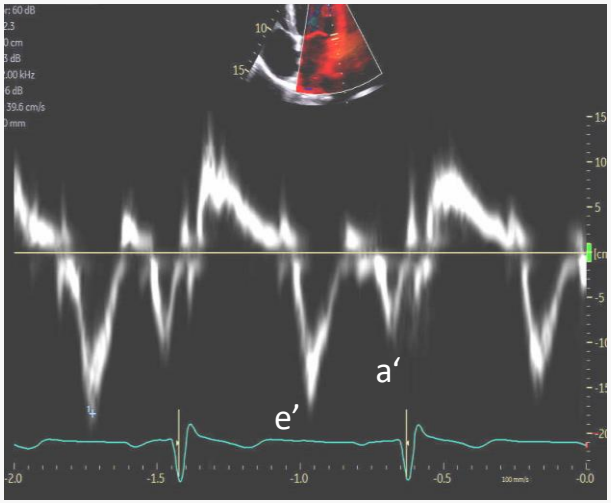
	Men 18-40 yrs	Men 41-65 yrs	Men >65 yrs	Women 18-40 yrs	Women 41-65 yrs	Women >65 yrs
LA reservoir Strain (%)	25–63	23–61	24–57	29–62	22–56	21-56
LA conduit Strain (%)	18-50	12-43	10-36	19-52	12-42	9-36
LA pump Strain (%)	2-23	5–28	9–32	2–21	6–28	7-30

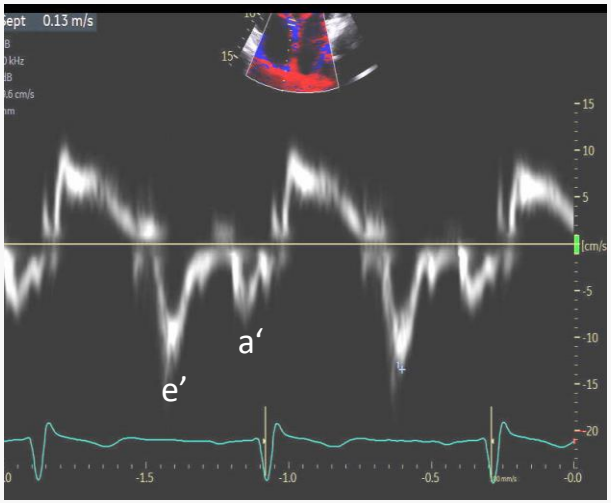
Singh et al JASE 2022;35:154-164

LA Strain in a Normal Subject



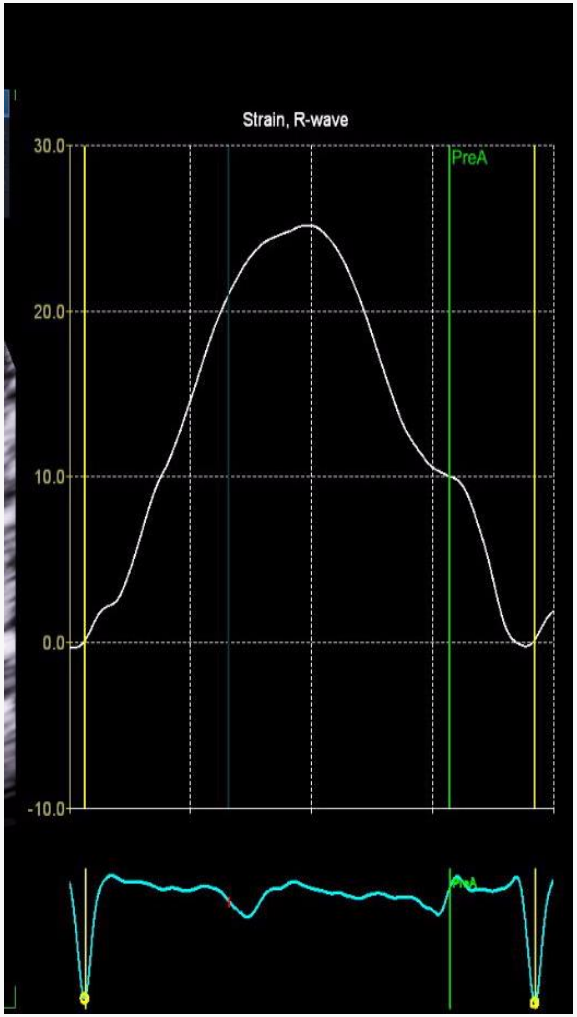


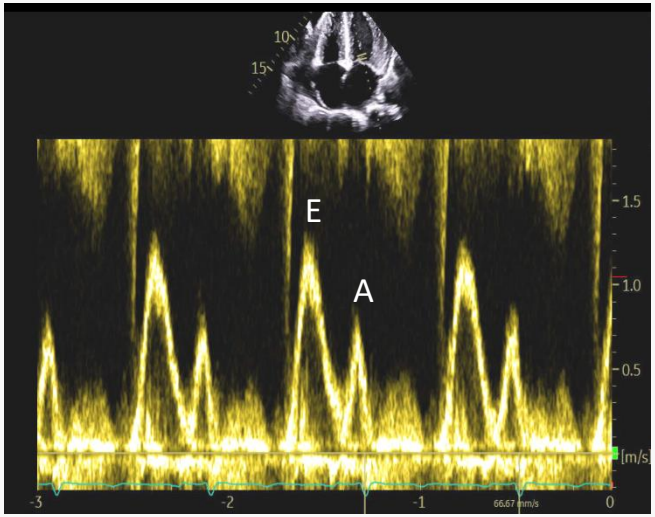


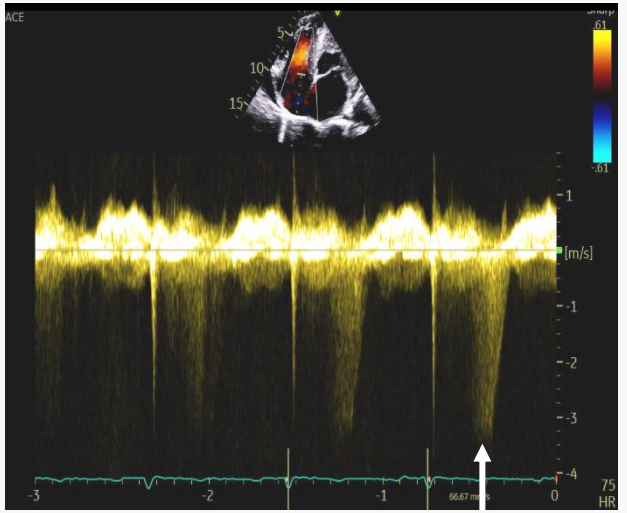


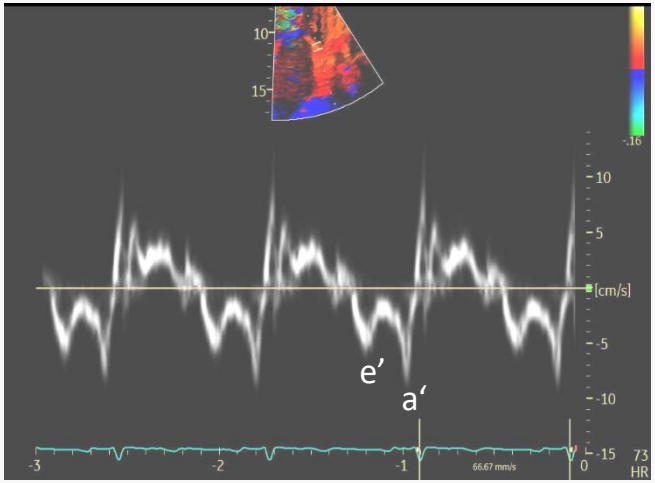
Nagueh and Khan JACC CV Img 2023

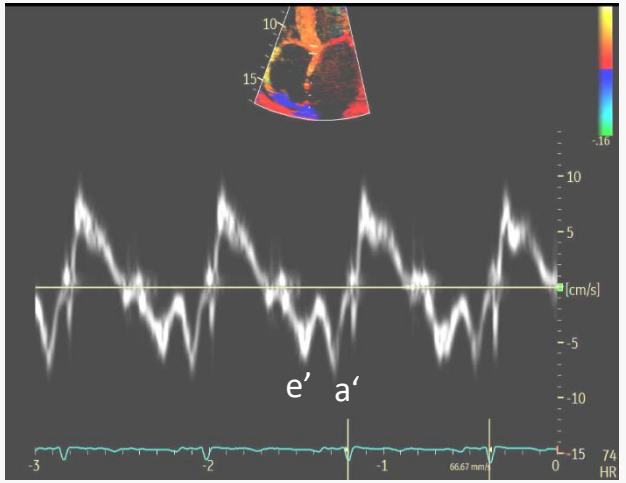
LA Strain in HFpEF Patient











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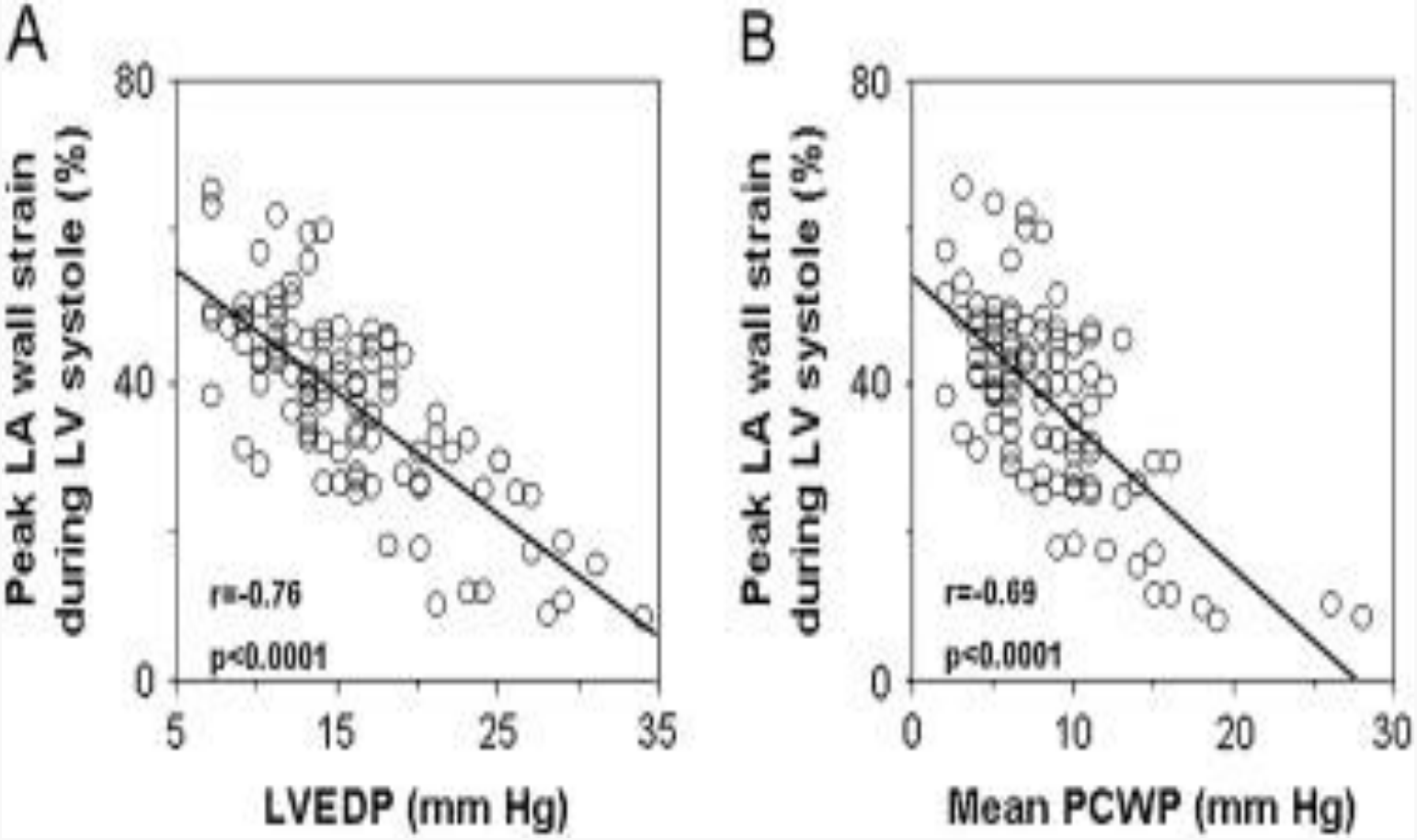
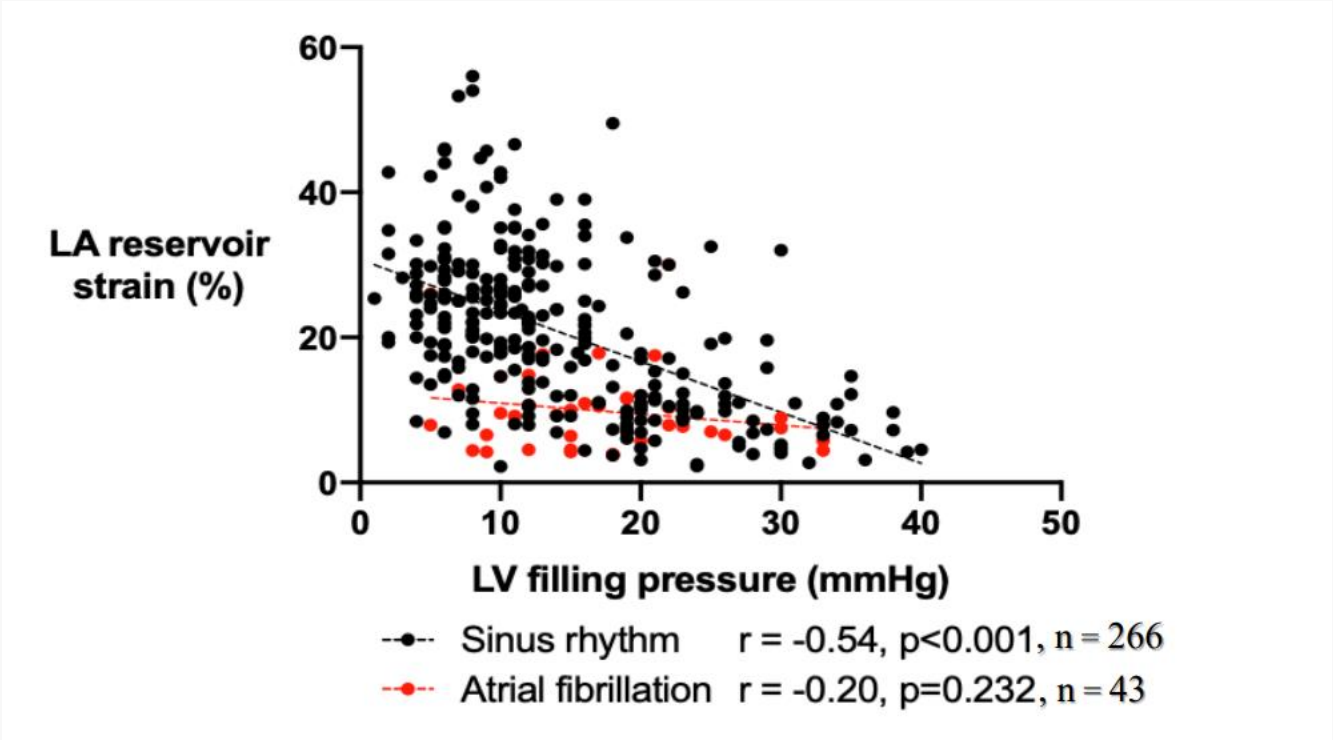
Peak LA Systolic Strain and LV Filling Pressures

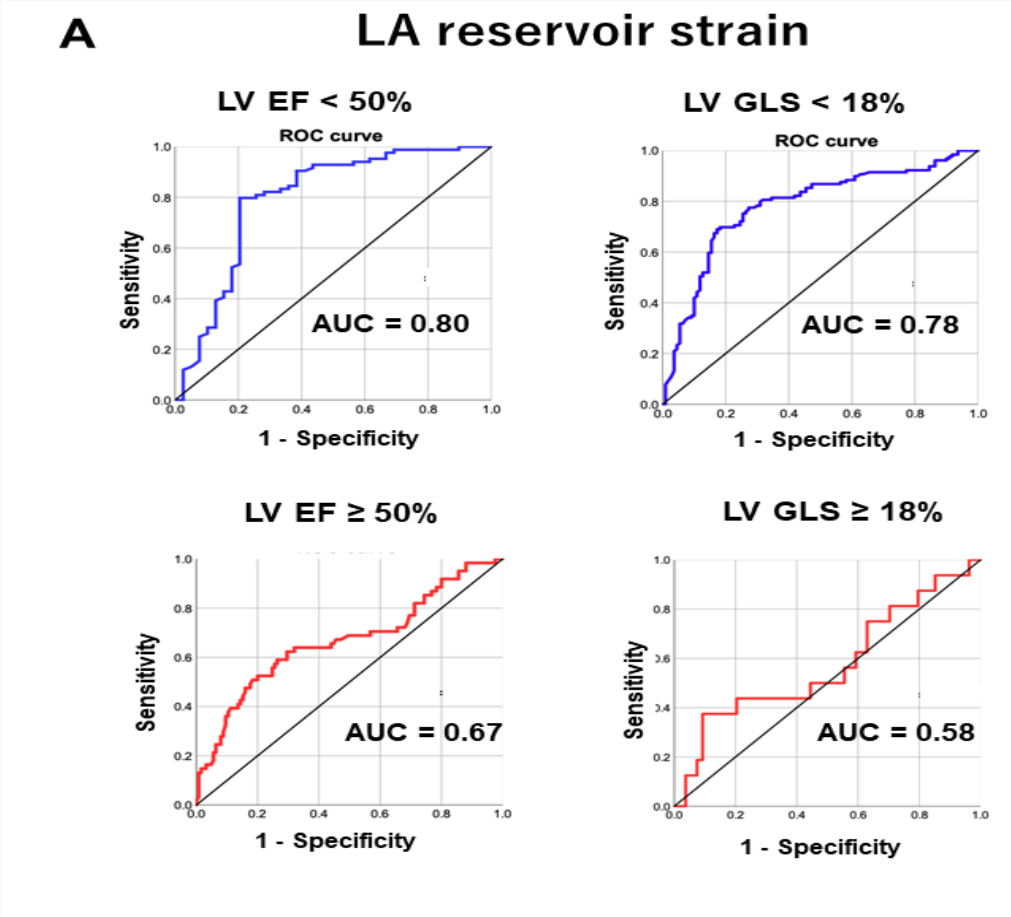


Wakami et al. JASE 2009;22:847-851



Inoue et al. European Heart Journal CV Img 2021

Accuracy of LA Reservoir Strain Depends on LV Systolic Function



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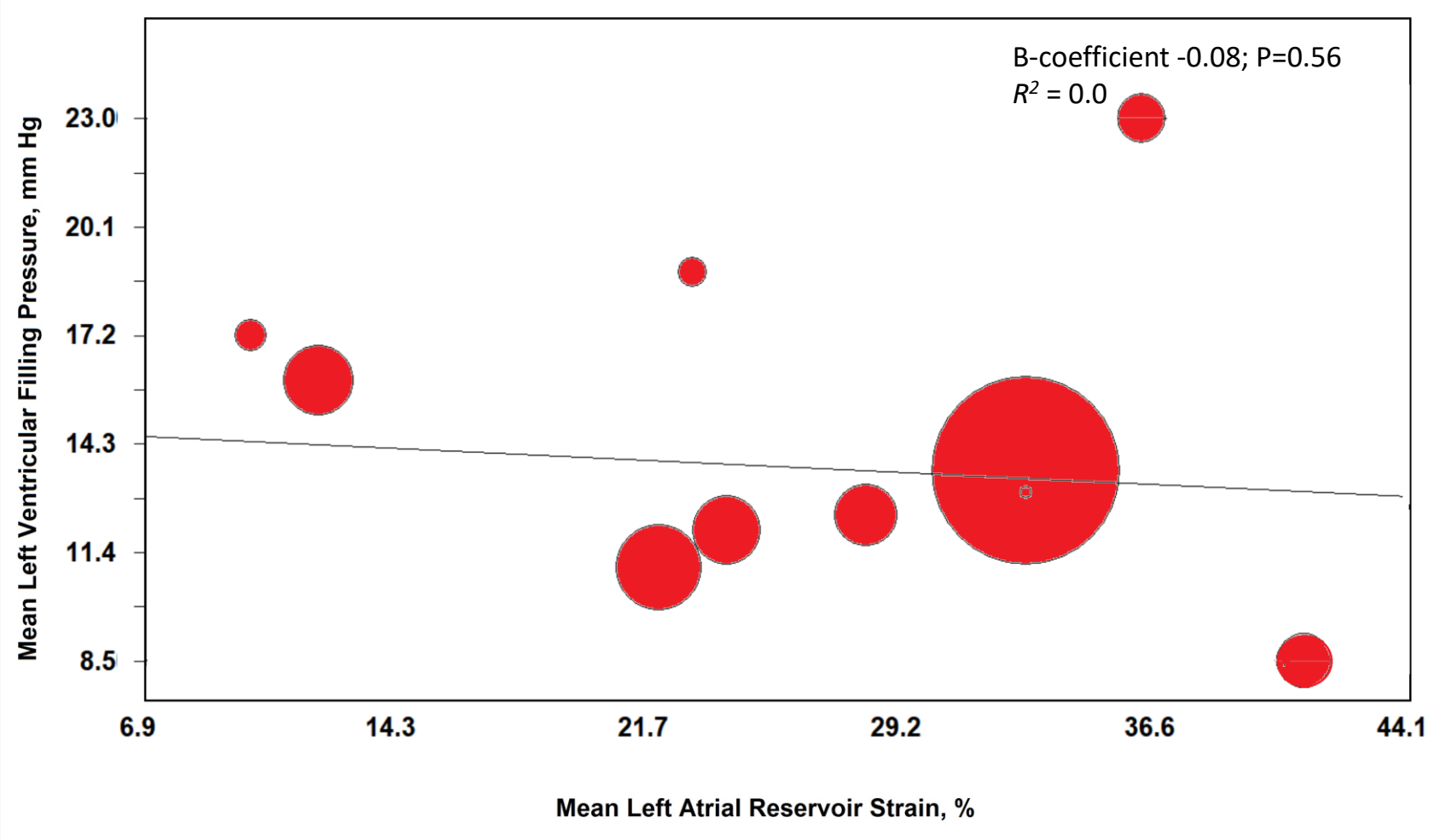
Meta regression plot of correlation between mean LA reservoir strain (%) and mean LV filling pressure (mm Hg) in patients with normal LV EF



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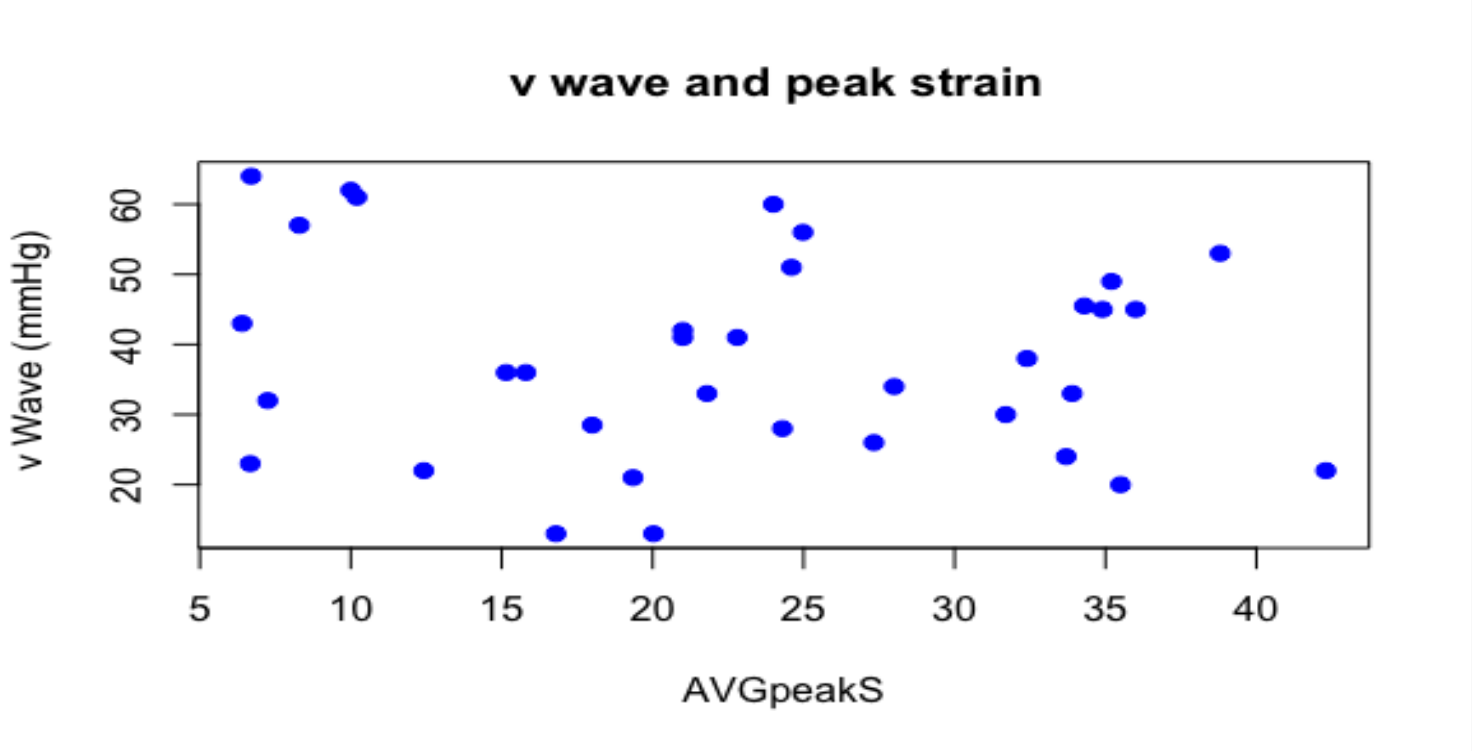
LA Strain Versus LA Pressure in Severe MR



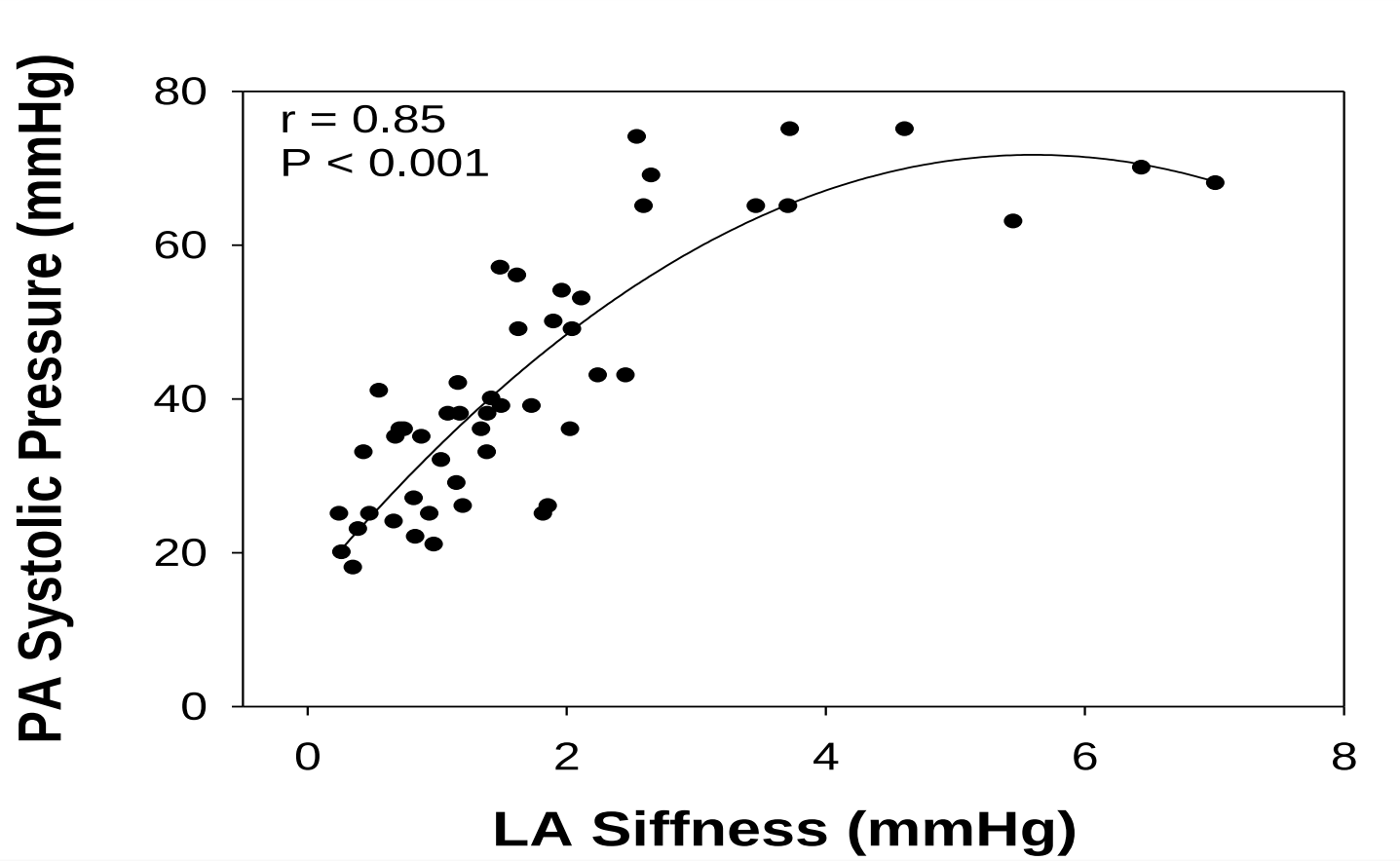
Avenatti et al Am J Cardiol Jul 5. pii: S0002-9149(18)31323-7. doi: 10.1016/j.amjcard.2018.06.031

LA stiffness

- **LA Strain is a measure of LA volume change**
- **LA stiffness derived as: ratio of PCWP (LAP) to LA_S OR**
- **Ratio of E/e' to LA_S**

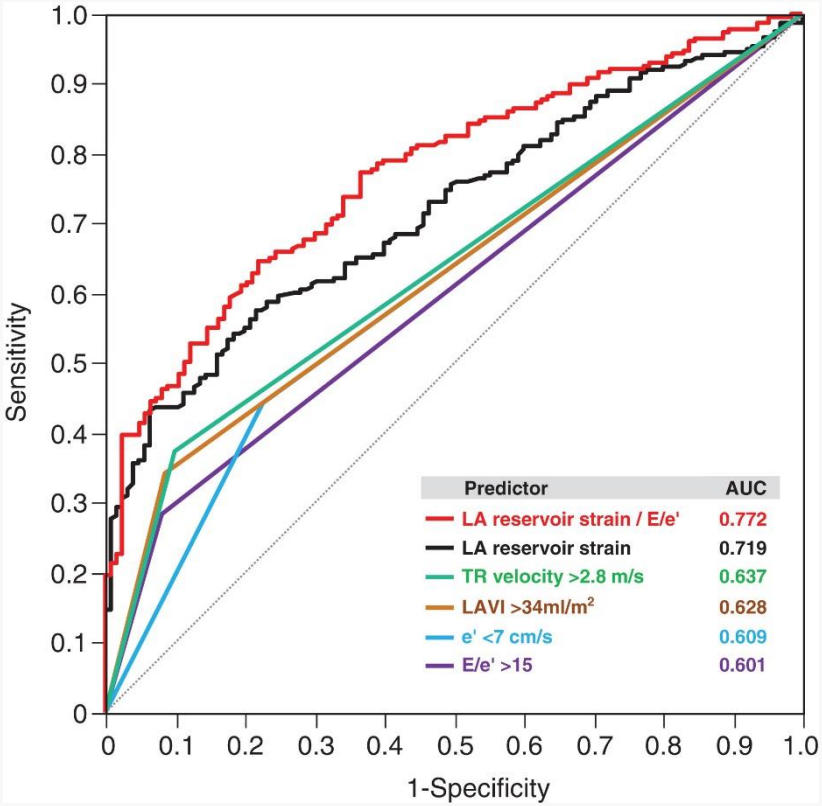
Kurt et al Circ Cardiovasc Imaging 2009;2:10-15

Relation of Invasively Derived LA Stiffness to PA Systolic Pressure



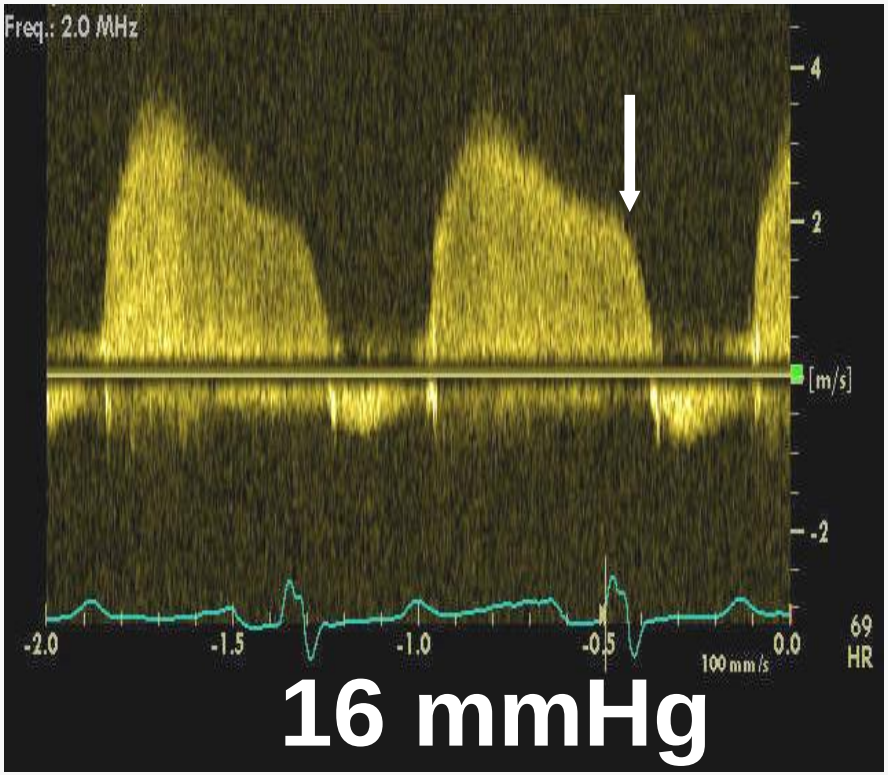
Kurt et al Circ Cardiovasc Imaging 2009;2:10-15

Accuracy of Noninvasively Derived LA Stiffness in Identifying Patients with HFpEF



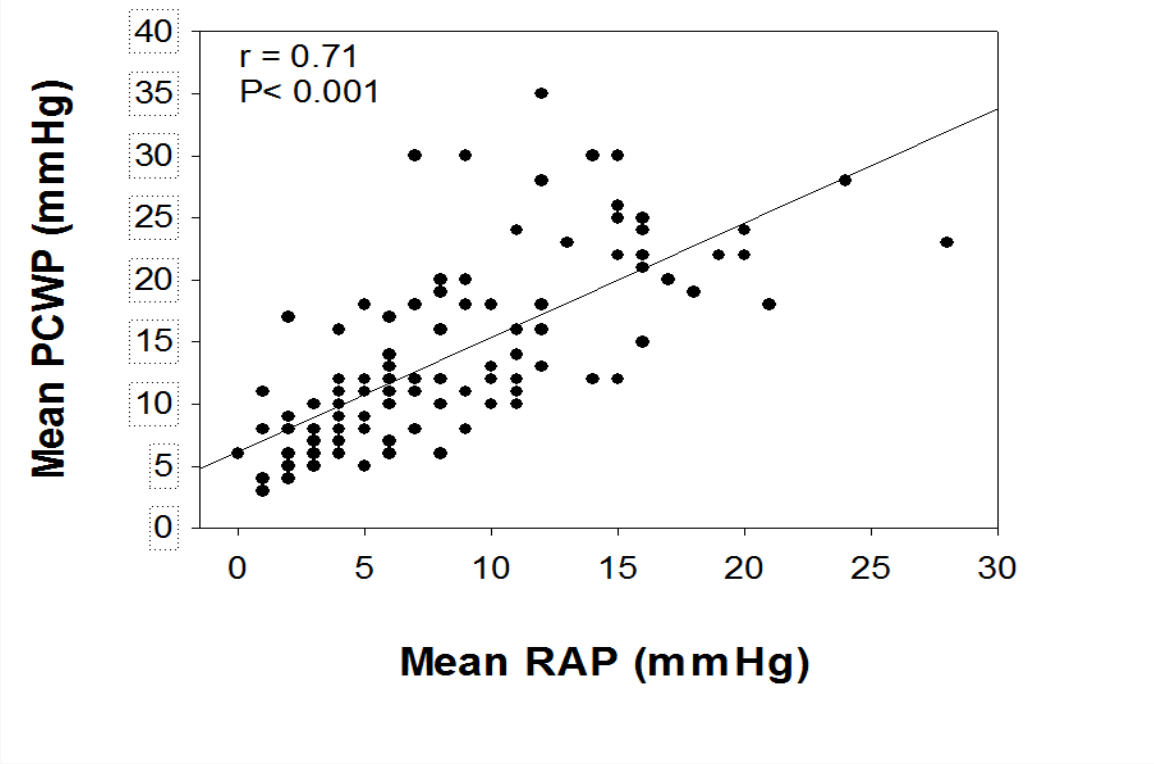
Reddy et al European Journal of Heart Failure 2019;21:891-900

Calculation of PA Diastolic Pressure



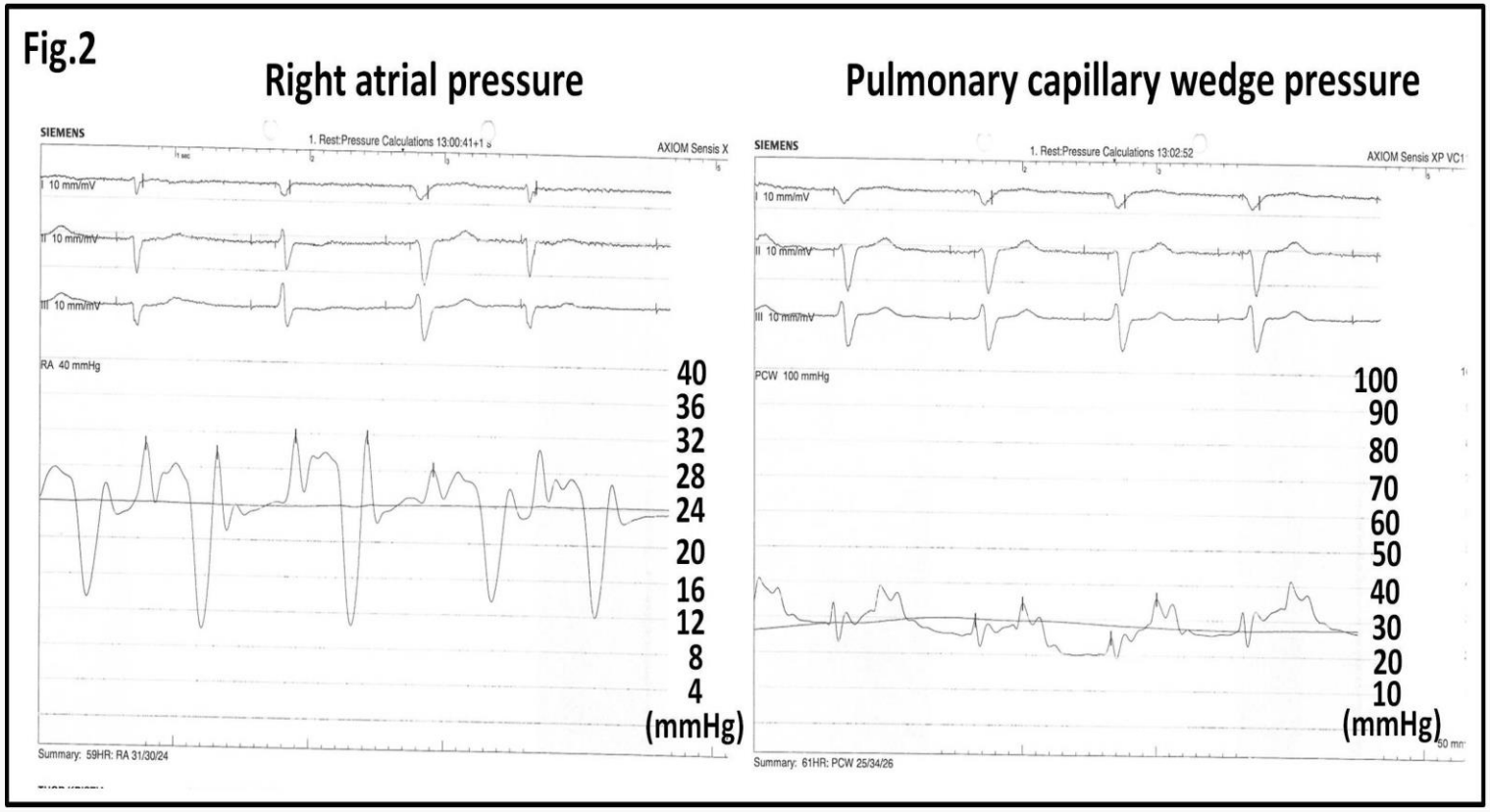
4 $(V)^2$ of end diastolic PR velocity = PAD – RAP
4 $(2)^2$ or 16 = PAD – RAP
PAD = at least 16 mmHg (+RAP)

Mean RAP Versus Mean PCWP in Patients with Normal LV EF



Nagueh et al. JASE 2018;31:799-806

Mean RAP Versus Mean PCWP in Patient with HFpEF



Nagueh et al. JASE 2018;31:799-806

Conclusions

- Clinical context and vital signs
- 2D findings (LV volumes, mass index, EF, and LV GLS
- Acquire mitral inflow, MA TD velocities, peak TR velocity, pulmonary veins, RAP, PR jet and LARS
- Careful scrutiny of Doppler signals and commonsense approach with guidelines application
- When needed, recommend diastolic stress test or cardiac catheterization