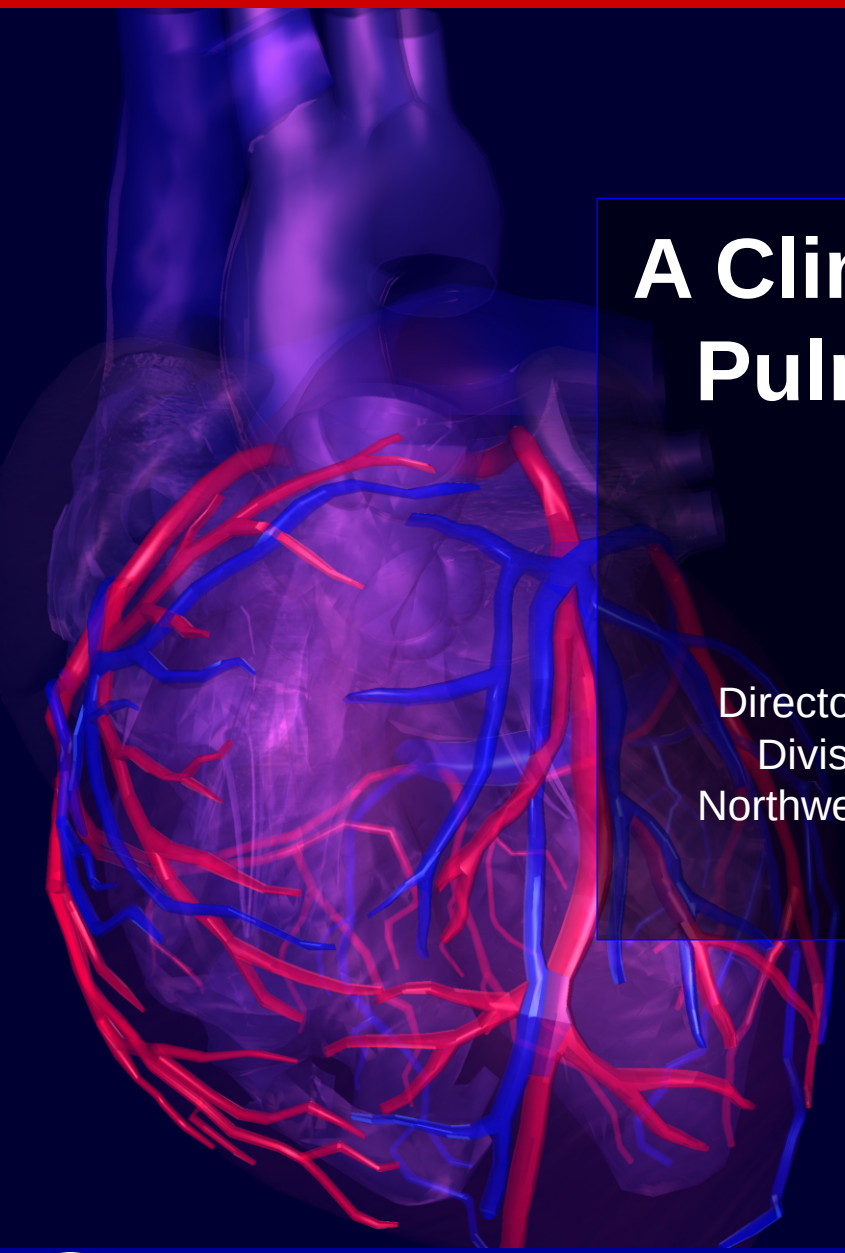


A Clinician's Perspective on Pulmonary Hypertension

FEBRUARY 16, 2016

Sanjiv J. Shah, MD, FASE
Associate Professor of Medicine
Director, Heart Failure with Preserved EF Program
Division of Cardiology, Department of Medicine
Northwestern University Feinberg School of Medicine
sanjiv.shah@northwestern.edu

Close your eyes and think of everything you know about echo evaluation of **pulmonary hypertension**

NOW PRESS THE

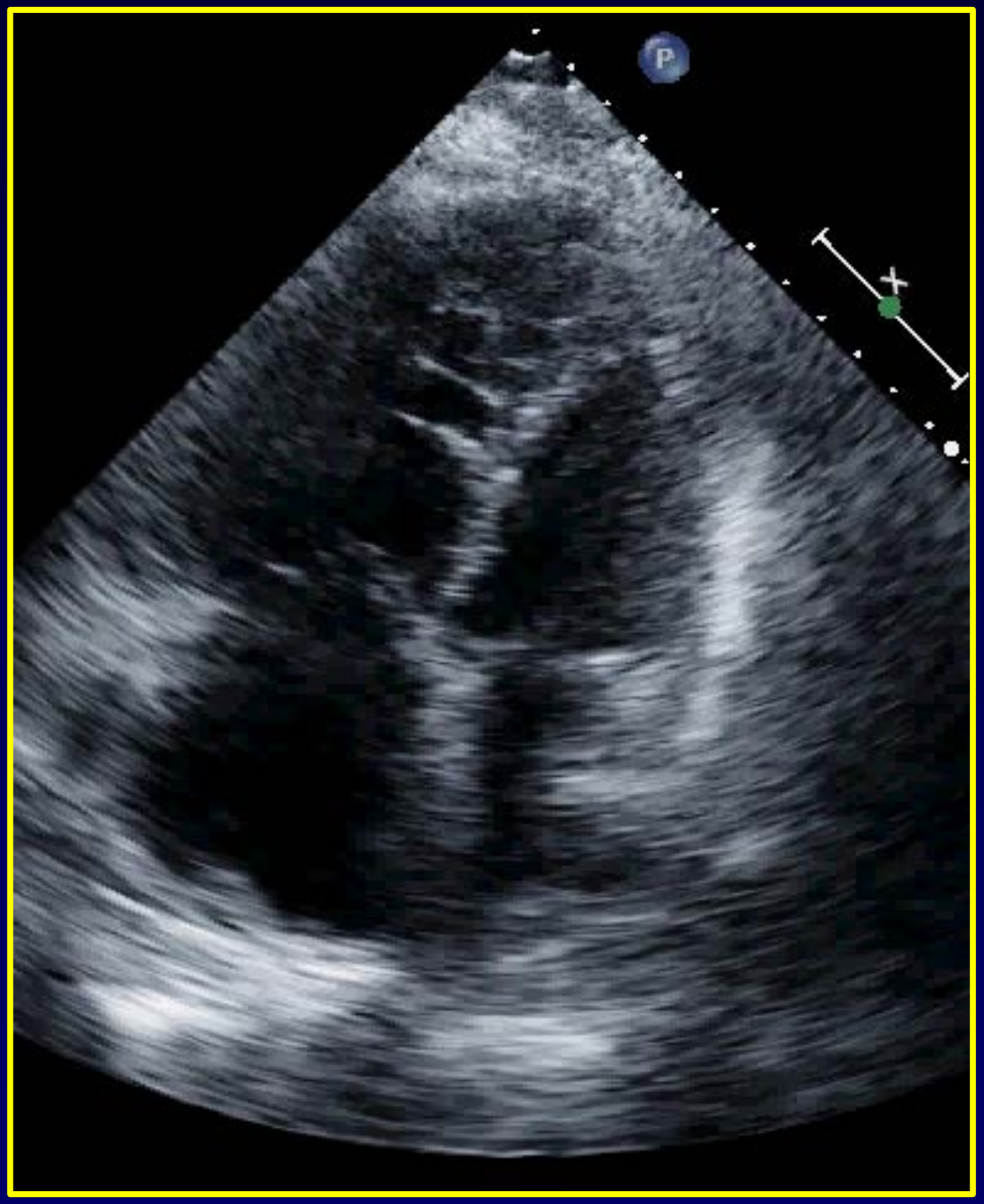
BUTTON!

When using echo to evaluate for pulmonary hypertension, the PA systolic pressure is the *last thing* you should look at!

Learning Objectives

- Define pulmonary hypertension (PH) and its prevalence
- Describe the diagnostic approach to PH
- Discuss role of echo and invasive hemodynamic testing in diagnosis and management of PH

Biventricular HF or PAH??



What I look for on the echo in PH

- Left heart disease causes of PH
- RV size and function function:
  - » RV size (RV basal diameter) and RV wall thickness
  - » RV systolic function (RV s' velocity, TAPSE, global RV function)
  - » Septal flattening: systole, diastole, both?
- Pericardial effusion
- Bubble study to look for intracardiac shunt

What I look for on the echo in PH

- Hemodynamics:
  - » PA systolic pressure (peak TR gradient)
  - » PA diastolic pressure (end-diastolic PR gradient)
  - » RA pressure (IVC size and collapsibility)
  - » LV filling pressure (E/e' ratio [use lateral e'])
  - » Non-invasive PVR: peak TR velocity/RVOT VTI

What I look for on the echo in PH

- PAH vs. PVH:
  - » RVOT notching?
  - » LA/RA ratio?
  - » Interatrial septum bows to left or right?
  - » Lateral e' ratio?
  - » Grade of diastolic function?

Definitions of PH

- *A hemodynamic and pathophysiologic condition*
- PH: <u>not a disease itself</u>
- Pulmonary arterial hypertension (PAH): *a disease of the pulmonary microcirculation*

Galie N, et al. ESC Guidelines on the diagnosis and treatment of PH. Eur Heart J 2009

Hemodynamic Definition of PH/PAH

PH Mean PAP ≥25 mm Hg

PAH Mean PAP ≥25 mm Hg *plus* PCWP/LVEDP ≤15 mm Hg

ACCF/AHA includes PVR >3 Wood Units

Badesch D et al. *J Am Coll Cardiol.* 2009;54:S55-S66.
Galiè N et al. *Eur Heart J.* 2009;30:2493-2537.
McLaughlin VV et al. *J Am Coll Cardiol*. 2009;53:1573-1619.

Revised (2013) Categories of PH

1. PAH

- Idiopathic PAH
- Heritable
- Drug- and toxin-induced
- Persistent PH of newborn
- Associated with:
  - CTD
  - HIV infection
  - Portal hypertension
  - Congenital heart disease (shunts)
  - Schistosomiasis

1'. PVOD and/or PCH
1". Persistent PH of newborn

2. PH Owing to Left Heart Disease

- Systolic dysfunction
- Diastolic dysfunction
- Valvular disease
- Congenital left heart disease, cardiomyopathies

3. PH Owing to Lung Diseases and/or Hypoxia

- COPD
- ILD
- Other pulmonary diseases with mixed restrictive and obstructive pattern
- Sleep-disordered breathing
- Alveolar hypoventilation disorders
- Chronic exposure to high altitude
- Developmental abnormalities

4. CTEPH

5. PH With Unclear Multifactorial Mechanisms

- Hematologic disorders
- Systemic disorders, sarcoid
- Metabolic disorders
- Others

Simonneau G et al. *J Am Coll Cardiol.* 2013

5

KEY LESSONS

Lesson #1

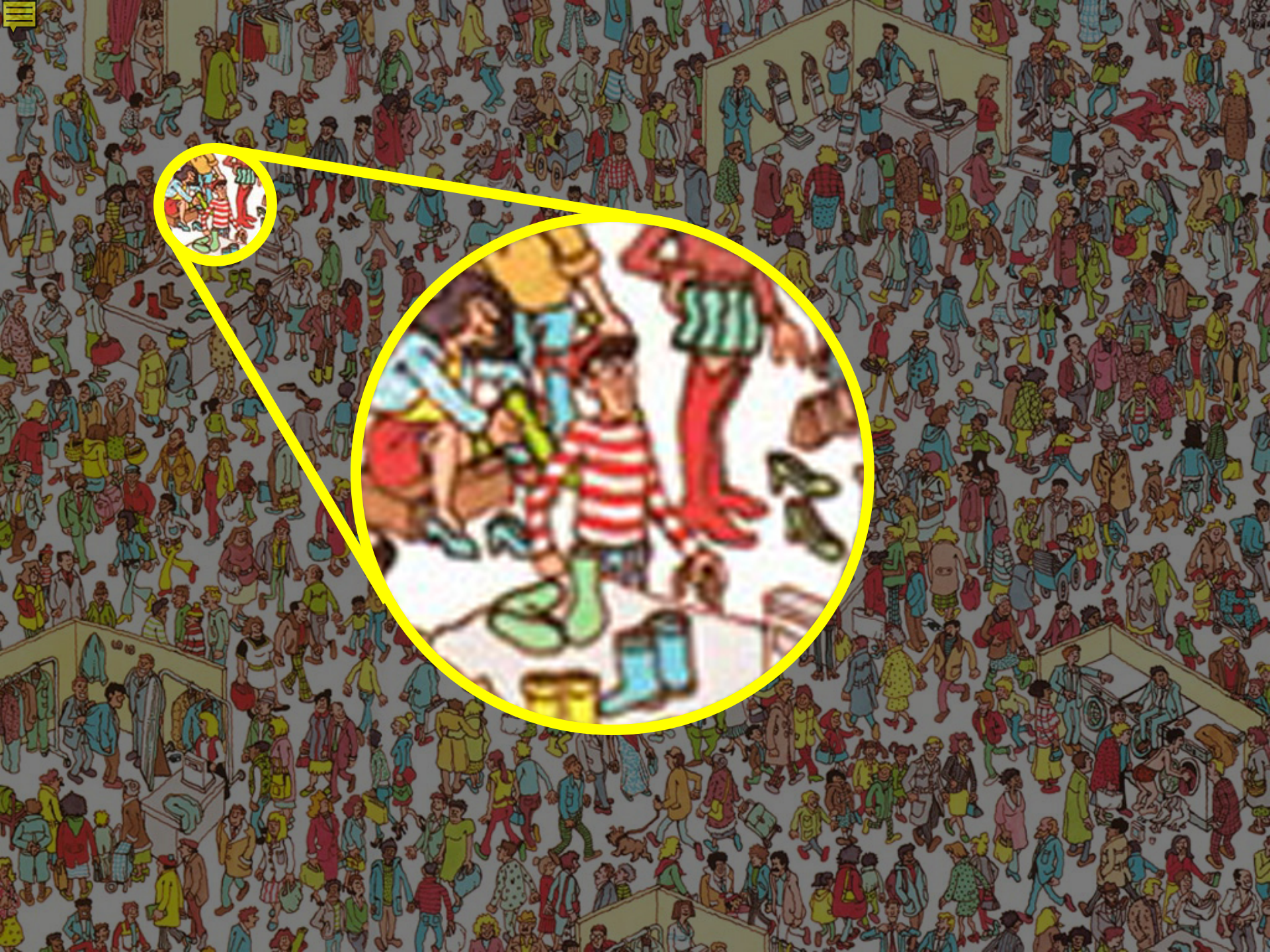
PH is common

Which of the following statements is **TRUE**?

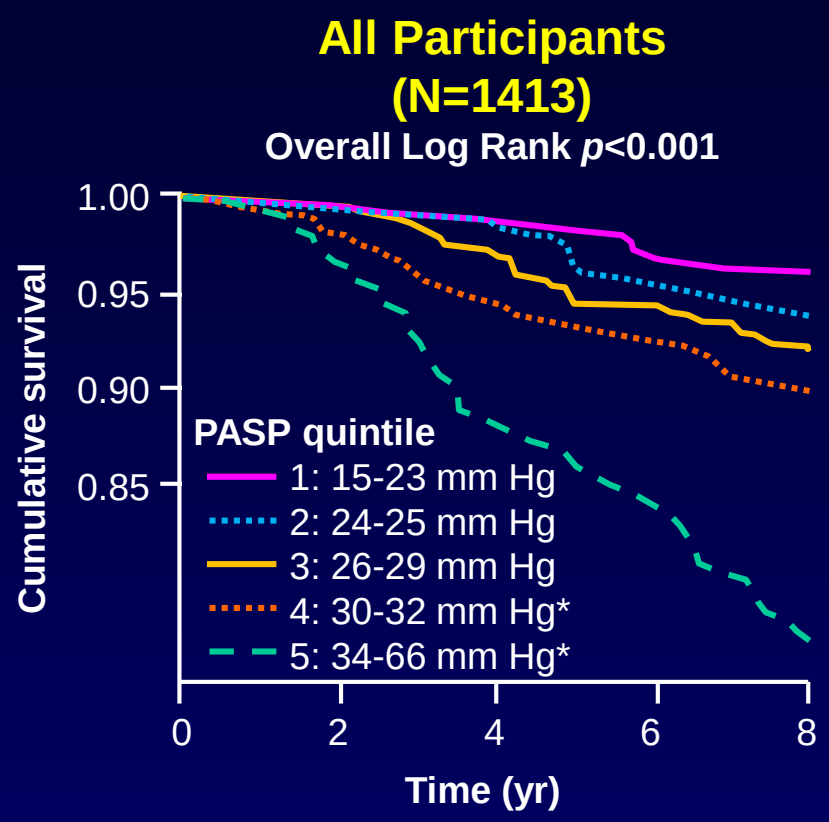
1. Pulmonary hypertension is rare
2. Left heart disease is the #1 cause of PH
3. Elevated PVR is a marker of increased mortality but elevated PASP is not
4. Prevalence of PH is decreasing

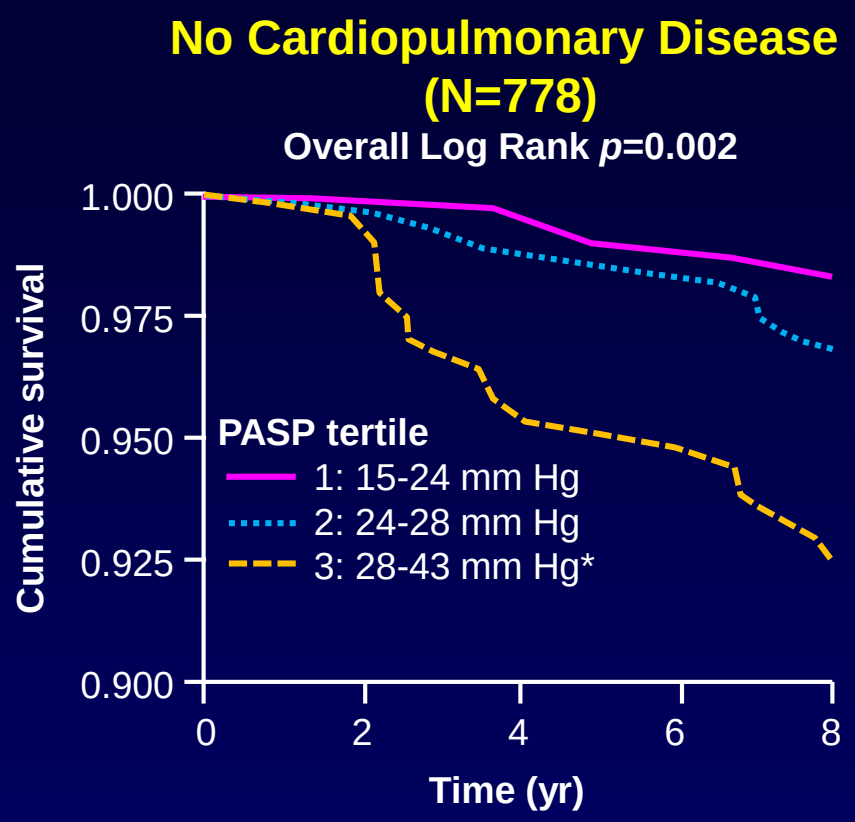
Which of the following statements is **TRUE**?

1. Pulmonary hypertension is rare
2. Left heart disease is the #1 cause of PH
3. Elevated PVR is a marker of increased mortality but elevated PASP is not
4. Prevalence of PH is decreasing



PH in the Community: PASP and Survival





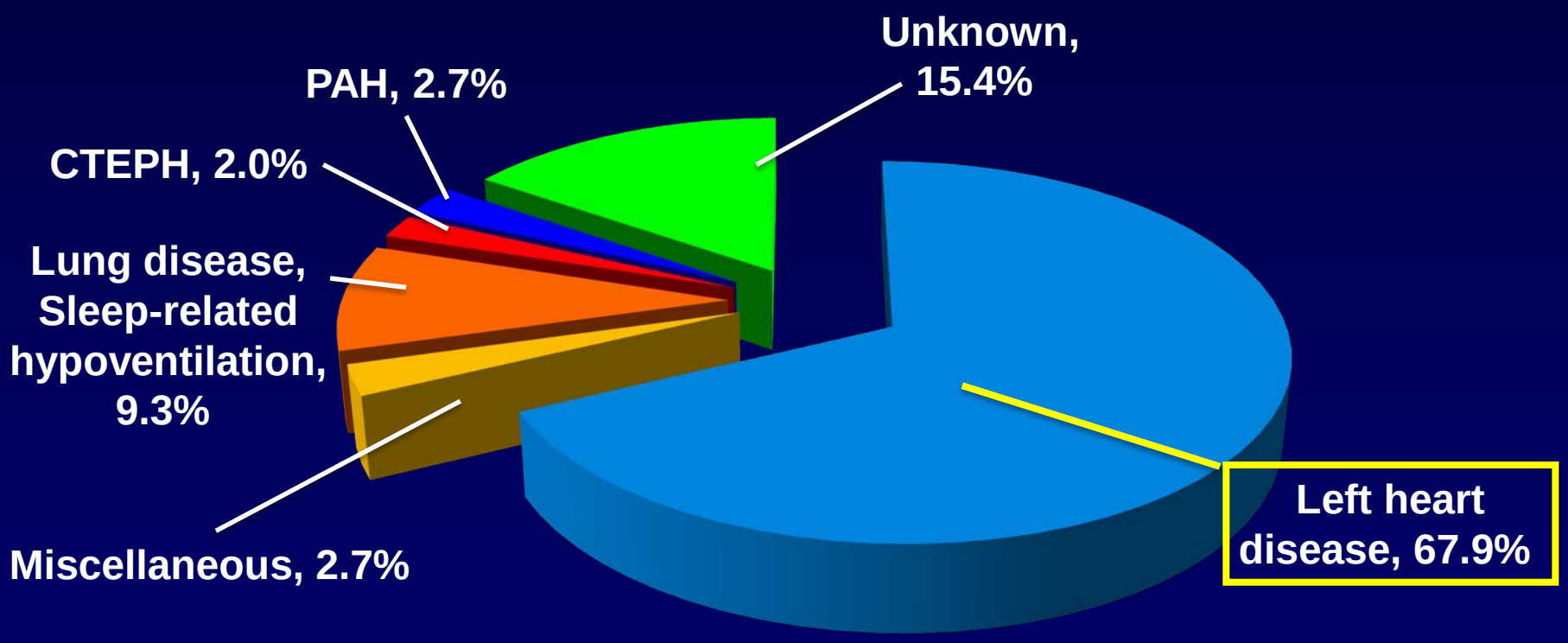
Up to 20% of the US population has echo evidence of PH

*Bonferroni-adjusted $p<0.05$ in pairwise comparison with lowest tertile.

Lam CSP et al. *Circulation*. 2009;119:2663-2670.

Epidemiology of PH by Echo

- Single echo lab / Australian community of 165,450
- Etiology of PH noted on echocardiogram

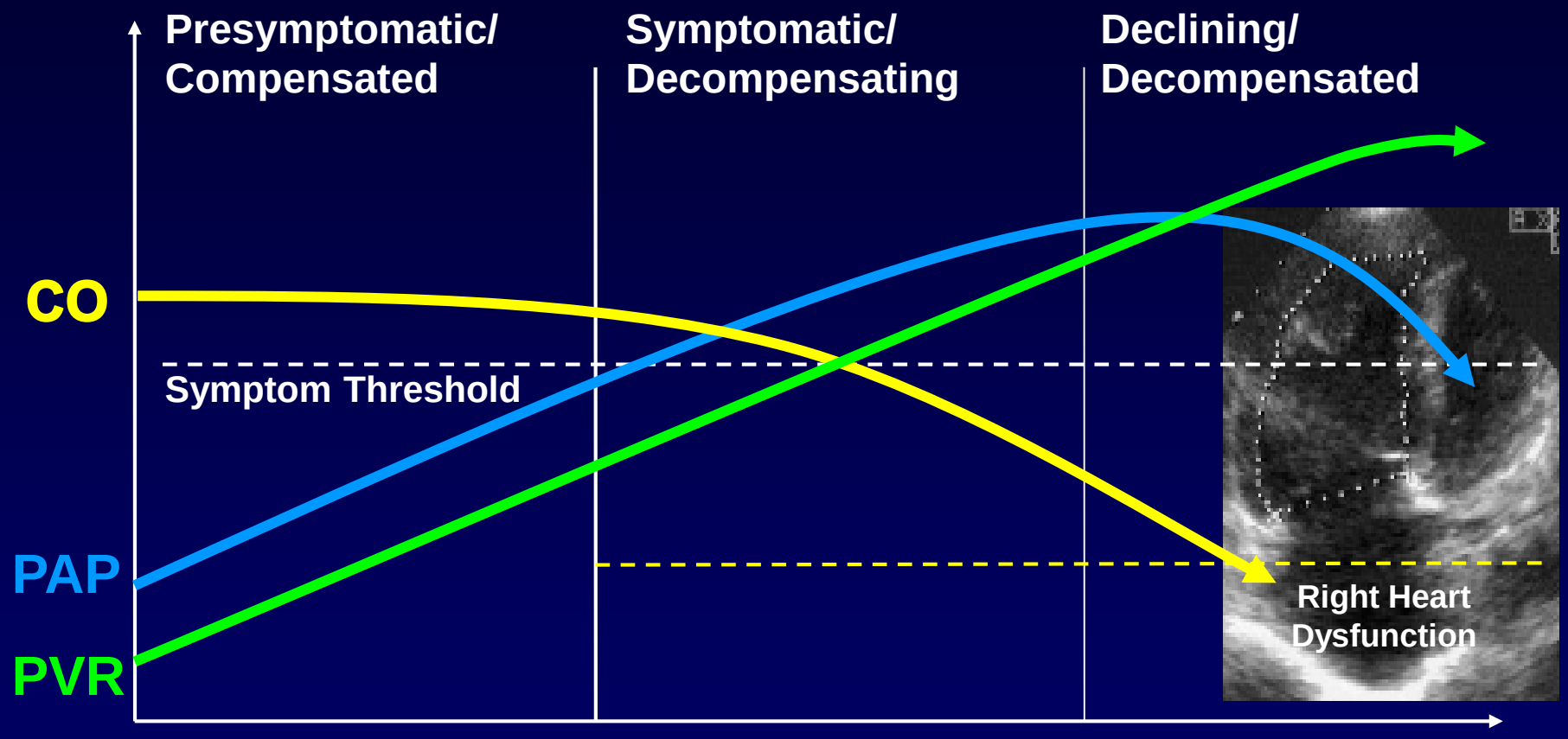


N=936 of 10,314 patients with echo PASP >40 mm Hg.
Strange G et al. *Heart*. 2012;98:1805-1811.

Lesson #2

WHO Group I PAH is rare but deadly—make the dx early

Schematic Progression of PAH



$$CO = \frac{TPG}{PVR}$$

TPG=transpulmonary gradient.

Lesson #3

Know the clinical clues for PH in the dyspneic patient

Is There a Reason to Suspect PAH?

Risk Factors

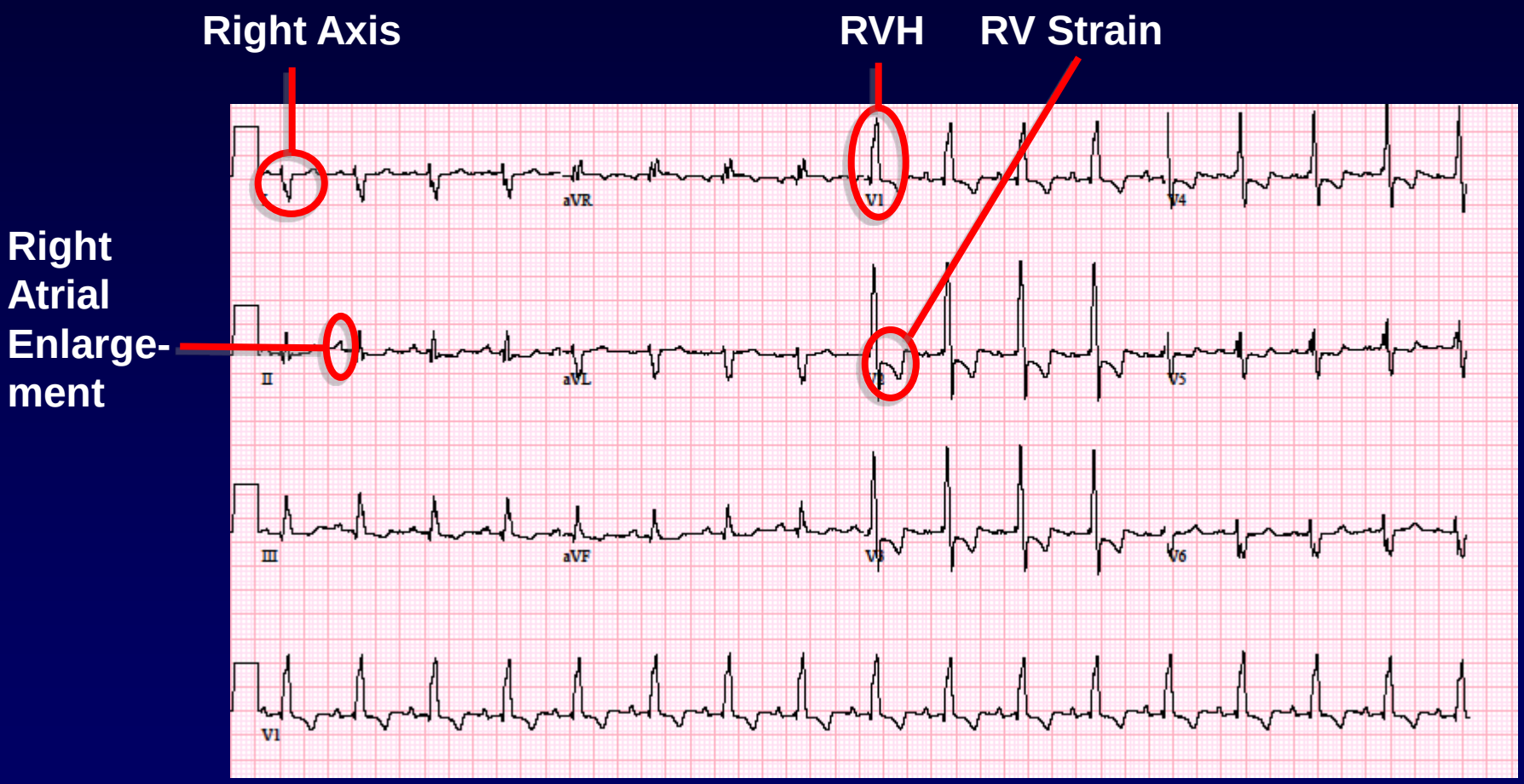
- Family history
- Connective tissue disease
- Congenital heart disease
- Portal hypertension—liver transplant candidate
- Environmental/drug factors
- HIV
- Lung disease / OSA
- Chronic PE

Is There a Reason to Suspect PAH?
Clinical Presentation

History	Exam (PH)	Exam (RV Failure)
• Dyspnea (86%) • Fatigue (27%) • Chest pain (22%) • Edema (22%) • **Syncope (17%)** • Dizziness (15%) • Cough (14%) • Palpitations (13%)	• **Loud P2 (listen at apex)** • **RV lift (left parasternal – fingertips)** • RV S3, S4 • Systolic murmur (TR; ⇧with inspiration) • Diastolic murmur (PR)	• **JVD; increased A wave, V wave;** hepatojugular reflex • Pulsatile liver • Hepatomegaly • Edema • Ascites • **Low BP, low PP, cool extremities**

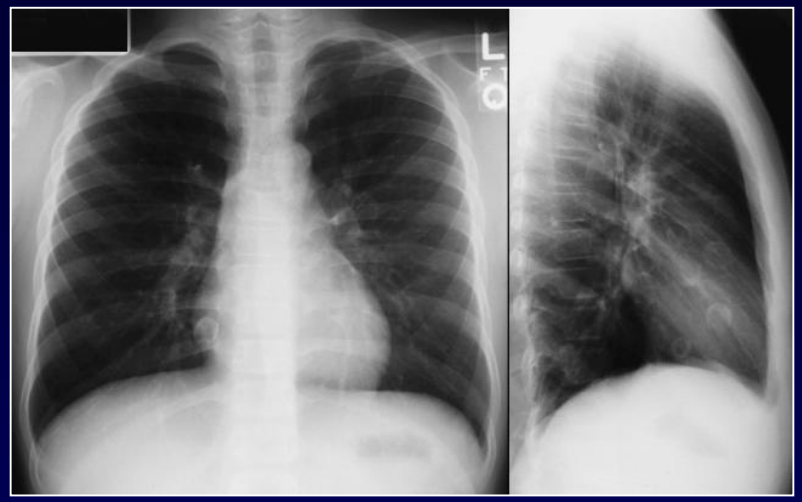
REVEAL. Brown LM et al. *Chest.* 2011;140:19-26.
Adapted from McLaughlin VV et al. *J Am Coll Cardiol*. 2009;53:1573-1619.

Is There a Reason to Suspect PAH?
ECG

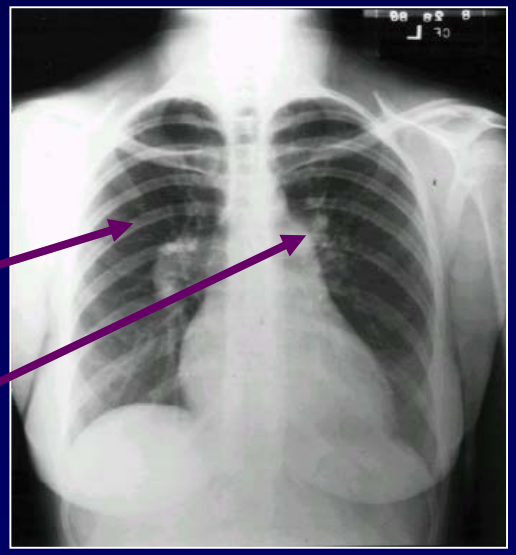


Is There a Reason to Suspect PAH?
Chest X-ray

Normal



Abnormal



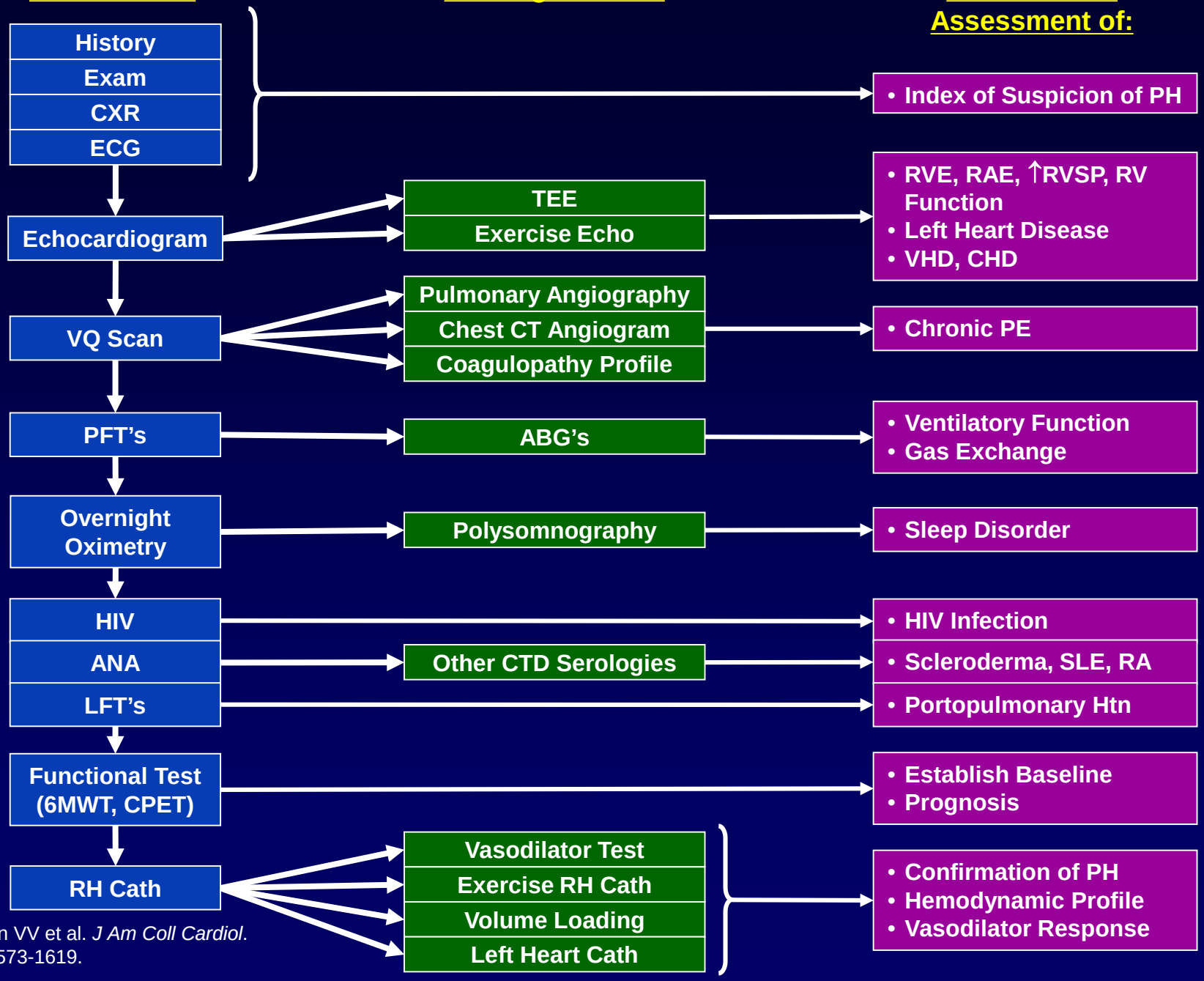
Peripheral hypo-vascularity (pruning)

Prominent central pulmonary artery

RV enlargement into retrosternal clear space

Adapted from McLaughlin VV et al. *J Am Coll Cardiol*. 2009;53:1573-1619.

ACCF/AHA Diagnostic Algorithm



McLaughlin VV et al. *J Am Coll Cardiol*. 2009;53:1573-1619.

Lesson #4

PASP is the last thing you should look at on echo when evaluating for PH

What is the most important echo finding in a patient with suspected or known PH?

1. PA systolic pressure
2. RA pressure
3. RV size and function
4. Severity of tricuspid regurgitation
5. M-mode of pulmonic valve

What is the most important echo finding in a patient with suspected or known PH?

1. PA systolic pressure
2. RA pressure
3. RV size and function
4. Severity of tricuspid regurgitation
5. M-mode of pulmonic valve

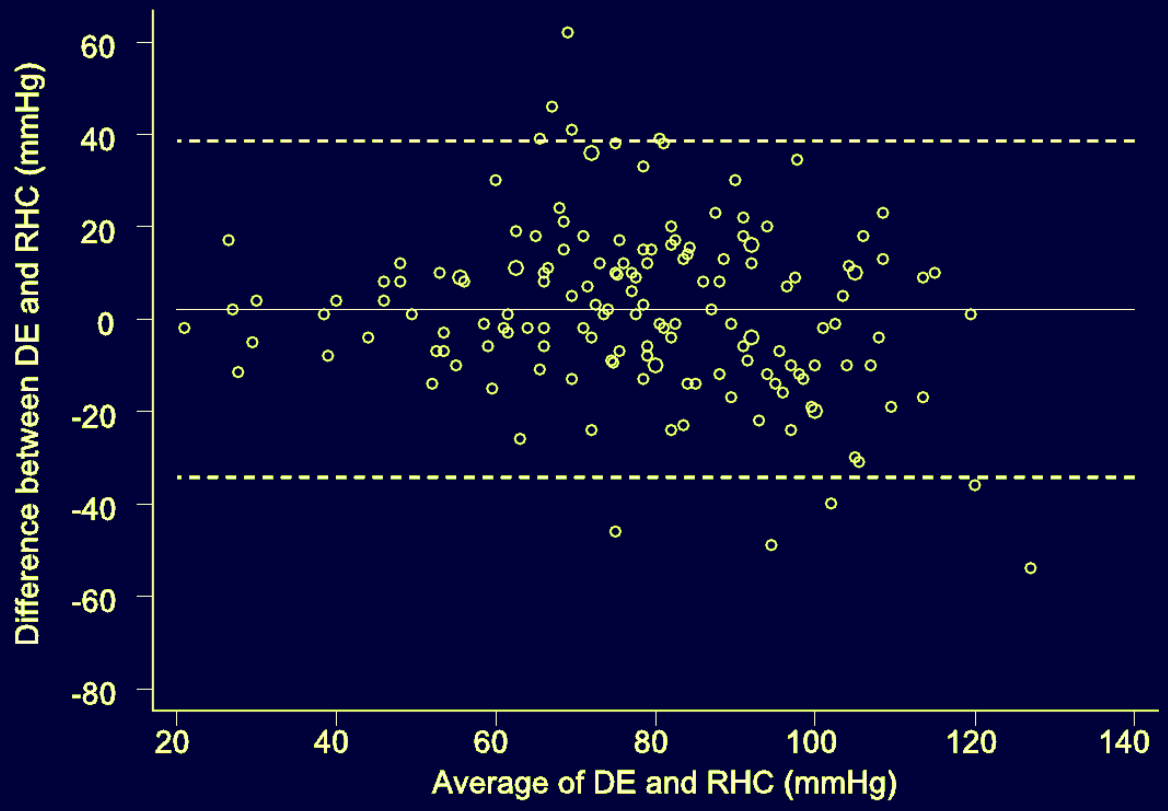
Which of the following is a cause of PASP *over-estimation* on echo?

1. Anemia
2. Poor acoustic windows
3. Poor Doppler alignment with the TR jet
4. LV diastolic dysfunction
5. None of the above: PASP on echo is *under-estimated*, not over-estimated

Which of the following is a cause of PASP *over-estimation* on echo?

1. Anemia
2. Poor acoustic windows
3. Poor Doppler alignment with the TR jet
4. LV diastolic dysfunction
5. None of the above: PASP on echo is *under-estimated*, not over-estimated

PA systolic pressure: echo vs invasive



N=160 consecutive patients with known or suspected PH

High correlation (r=0.7, p<0.001)

But…poor agreement

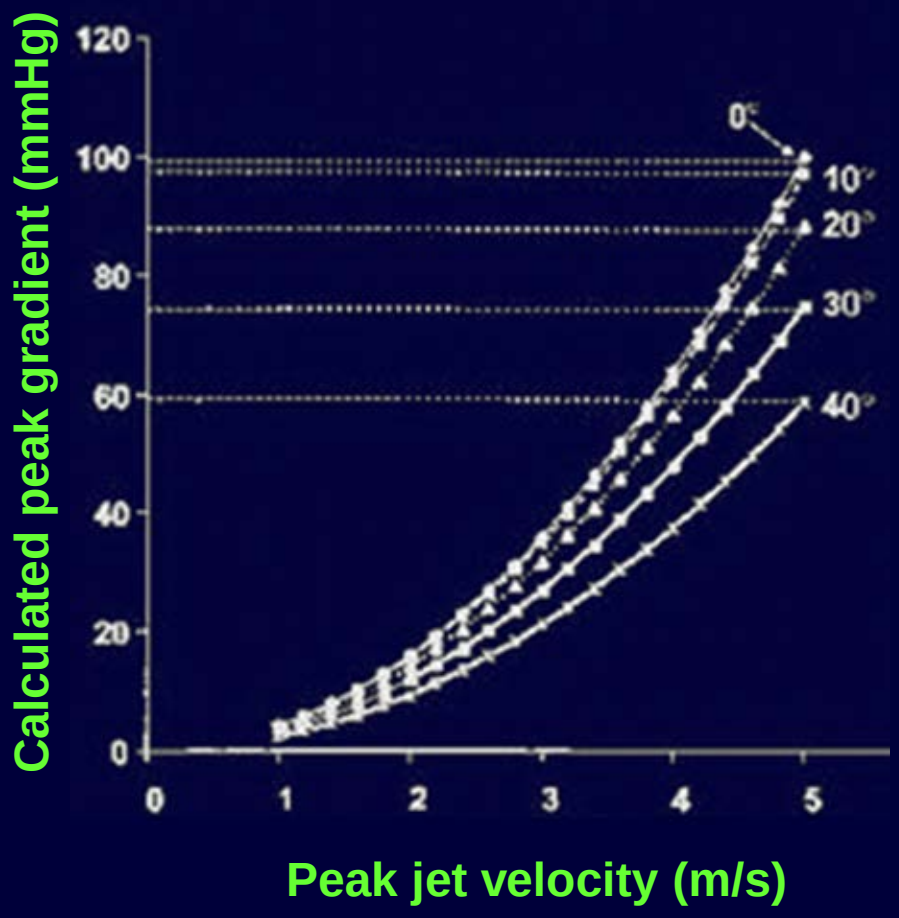
Rich J, Shah SJ, et al. Chest 2010

Problems with Doppler PASP

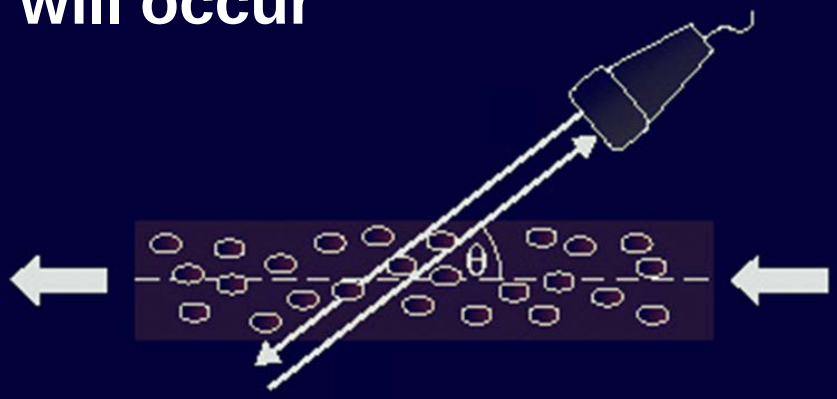
- Ultrasound / Doppler:
  - » Poor acoustic windows
  - » Inter-observer variability (under- and over-measured)
  - » Poor Doppler beam alignment
- Bernoulli:
  - » Viscosity (affected by RBC deformity, anemia, hypoxemia)
  - » Pressure-recovery phenomenon
- Other causes of elevated PASP besides ↑PVR
  - » Elevated left atrial pressure
  - » Elevated cardiac output
  - » Elevated systemic blood pressure

Shah SJ. Pulmonary Hypertension. *JAMA* 2012

Pitfalls of measuring PASP

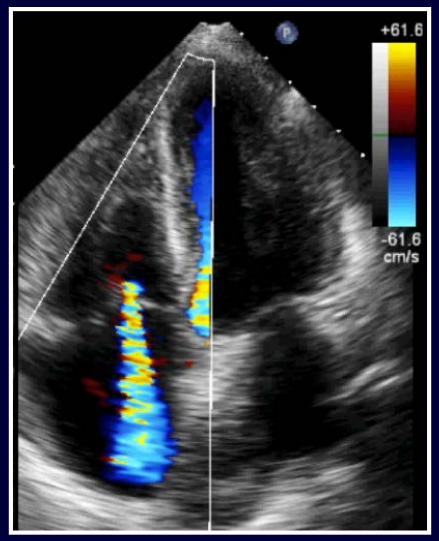


As angle (θ) between Doppler beam and blood flow increases, underestimation of peak gradient (e.g., PASP) will occur



Armstrong WF, Ryan T. Feigenbaum's Echocardiography, 7th Edition.

Bernoulli equation



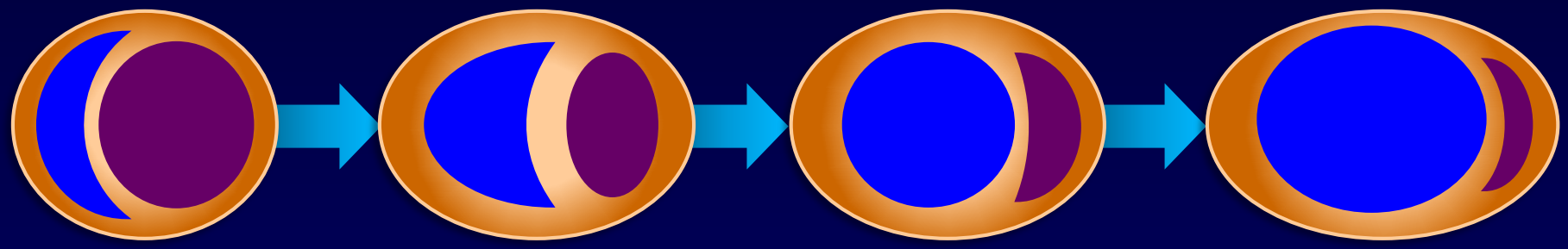
- $P_1 - P_2 = \boxed{\tfrac{1}{2}\rho\,(v_2^2 - v_1^2)} + \boxed{\rho \int (dv/dt)\cdot ds} + \boxed{R(v)}$

  CONVECTIVE ACCELERATION — FLOW ACCELERATION — VISCOUS FRICTION

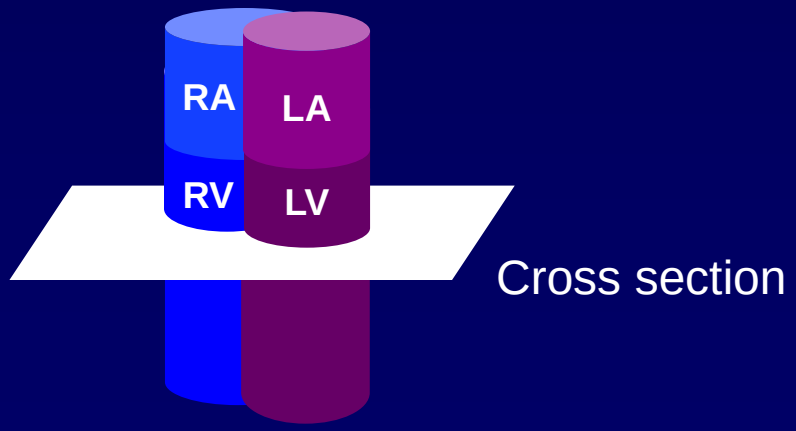
- RV-RA gradient = $\Delta P = 4(v_{TR})^2$

The Right Ventricle in PAH

- RV pressure/volume overload
- RV failure



Progressive structural changes in the RV due to poor adaptation to increasing PVR



Echocardiography in PH

Strengths

- Best screening tool for PH
- Inexpensive, portable, readily available, non-invasive, no radiation
- Allows for serial assessment
- Provides clues to other diagnoses (eg, left heart disease, congenital heart disease)

Limitations

- **Experienced techs/MDs essential**
- Imaging quality suboptimal in patients with poor windows (eg, lung disease, obesity)
- **Right ventricle not imaged adequately in some labs**
- TR jet inadequate to determine RVSP in 10%–25% of patients

McLaughlin VV et al. *J Am Coll Cardiol*. 2009;53:1573-1619.
Bossone E et al. *Chest.* 2005;127:1836-1843.
Brecker SJ. *Br Heart J.* 1994;72:384-389.

Essential Components of the Echocardiogram in PH

- Doppler estimate of RVSP
- Assess biventricular size and systolic function
- Look for interventricular septal shift
- Discriminate between pulmonary arterial and pulmonary venous causes of PH (if possible)
- Assess for congenital heart shunt lesions
- Document pericardial effusion

Bossone E et al. *Chest.* 2005;127:1836-1843.
McLaughlin VV et al. J *Am Coll Cardiol*. 2009;53:1573-1619.

Which of the following echo signs favors PAH in a patient with PASP 80 mmHg?

1. Elevated TR velocity/RVOT ratio
2. Reduced septal e’ velocity
3. PASP > 60 mmHg
4. Severe RV enlargement
5. Grade I diastolic dysfunction

Which of the following echo signs favors PAH in a patient with PASP 80 mmHg?

1. Elevated TR velocity/RVOT ratio
2. Reduced septal e’ velocity
3. PASP > 60 mmHg
4. Severe RV enlargement
5. Grade I diastolic dysfunction

Key Features of PAH on Echo

- Enlarged RV with normal or small LV
- RA, RV, and PA enlargement
- RV dysfunction
- Increased PASP
- Notching of the RV outflow due to reflected pressure wave (due to stiff pulmonary arteries)
- **Mitral E/A wave ratio <1.0**

Bossone E et al. *Chest.* 2005;127:1836-1843.
McLaughlin VV et al. J *Am Coll Cardiol*. 2009;53:1573-1619.

Lesson #5

Definitive diagnosis of PH requires invasive hemodynamic testing

Importance of Right Heart Cath

⇧PVR

⇧PADP-PCWP

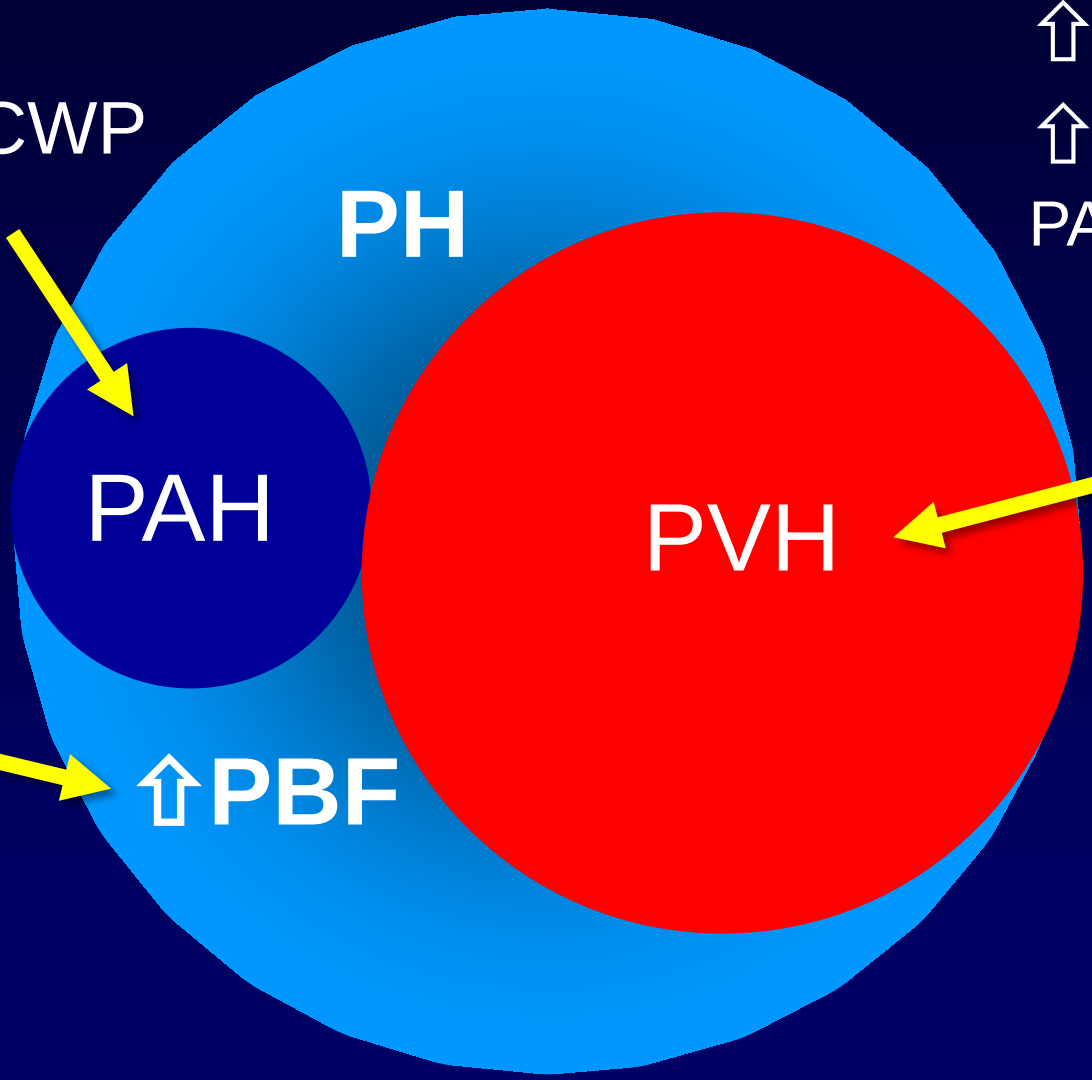
PAH (Group 1)
Hypoxic/Lung
CTEPH

⇧PCWP

⇧LVEDP

PADP~PCWP

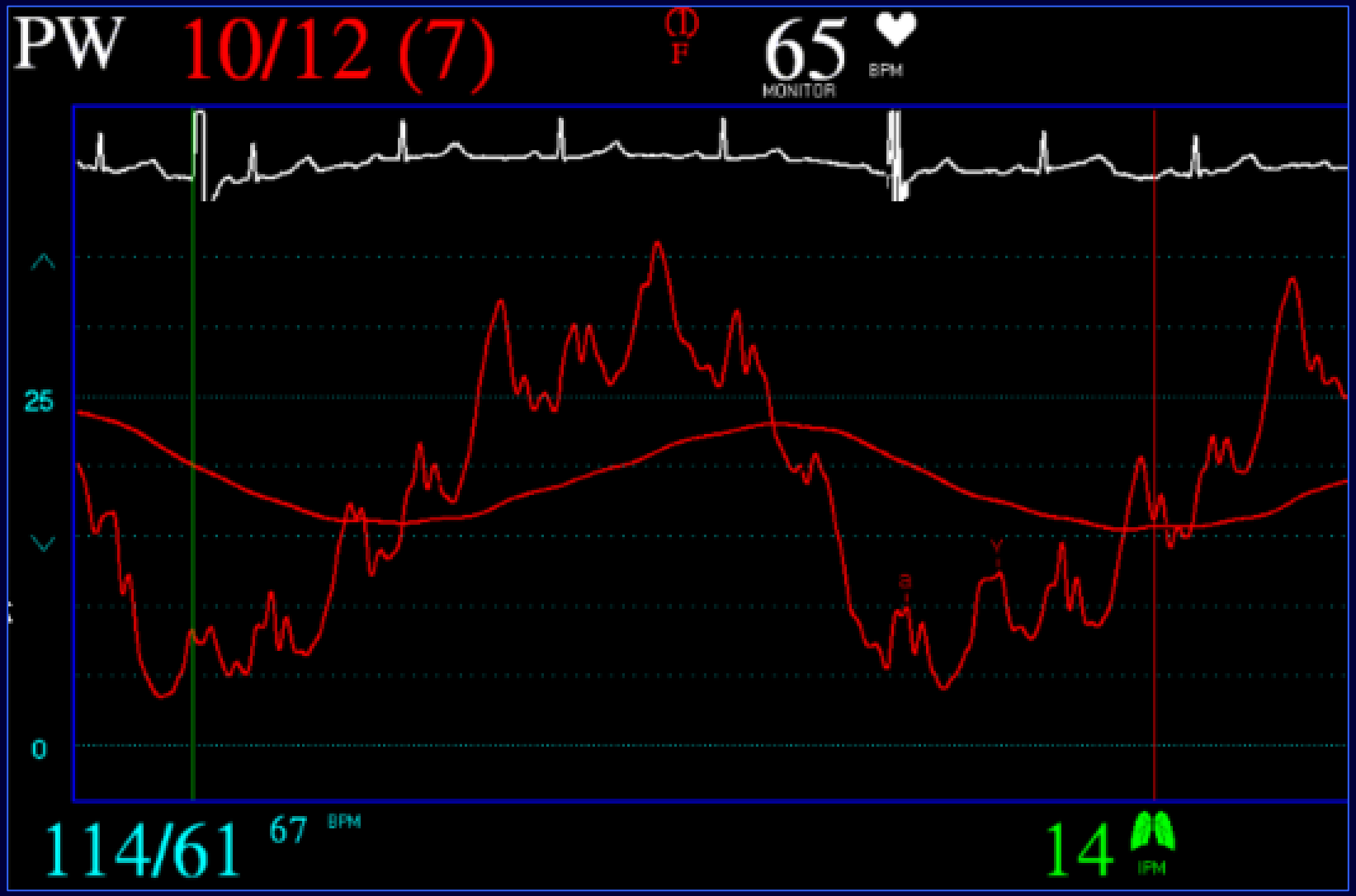
LH Disease
PV Obstruction



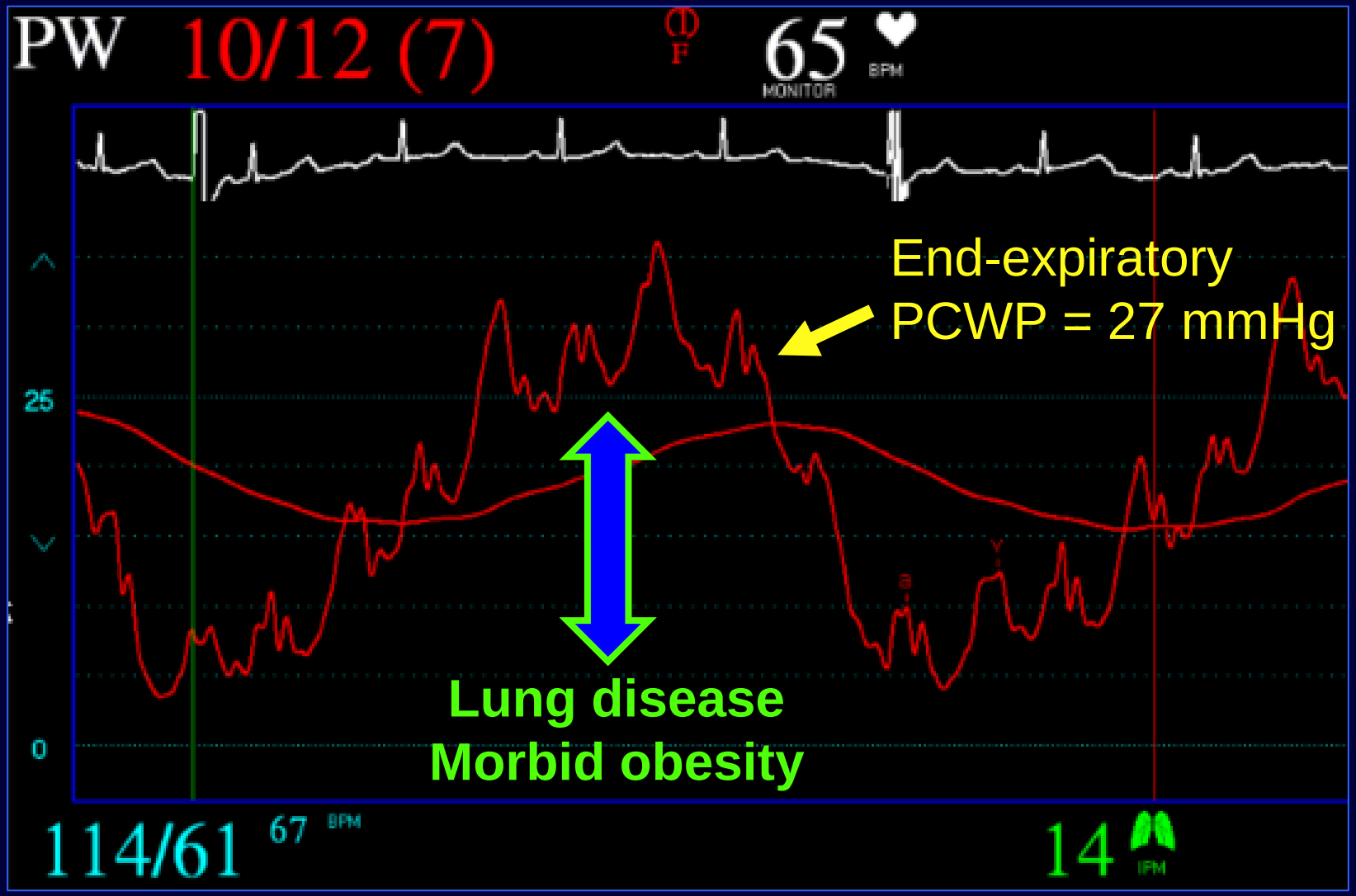
⇧CO

Fever
Thyrotoxicosis
Anemia
Pregnancy

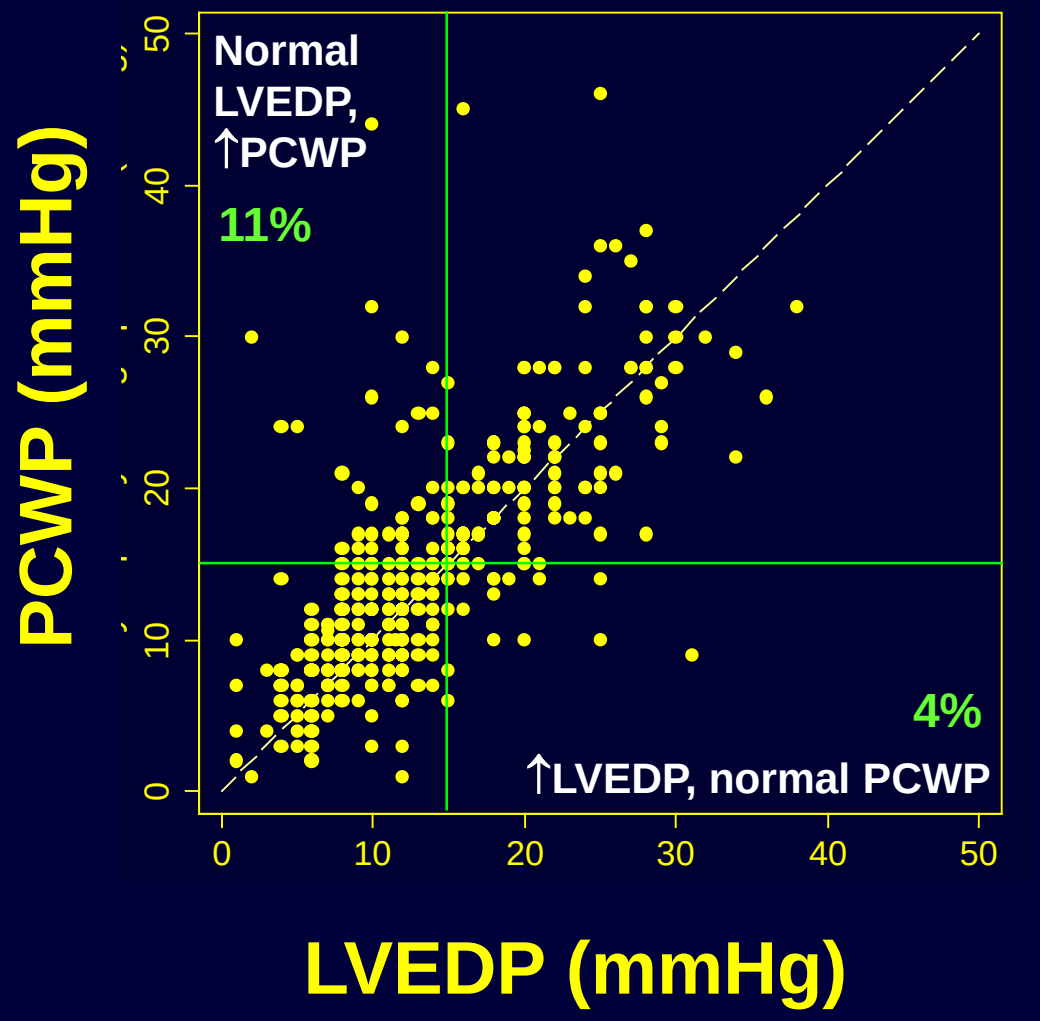
Respiratory variation in PCWP



Respiratory variation in PCWP



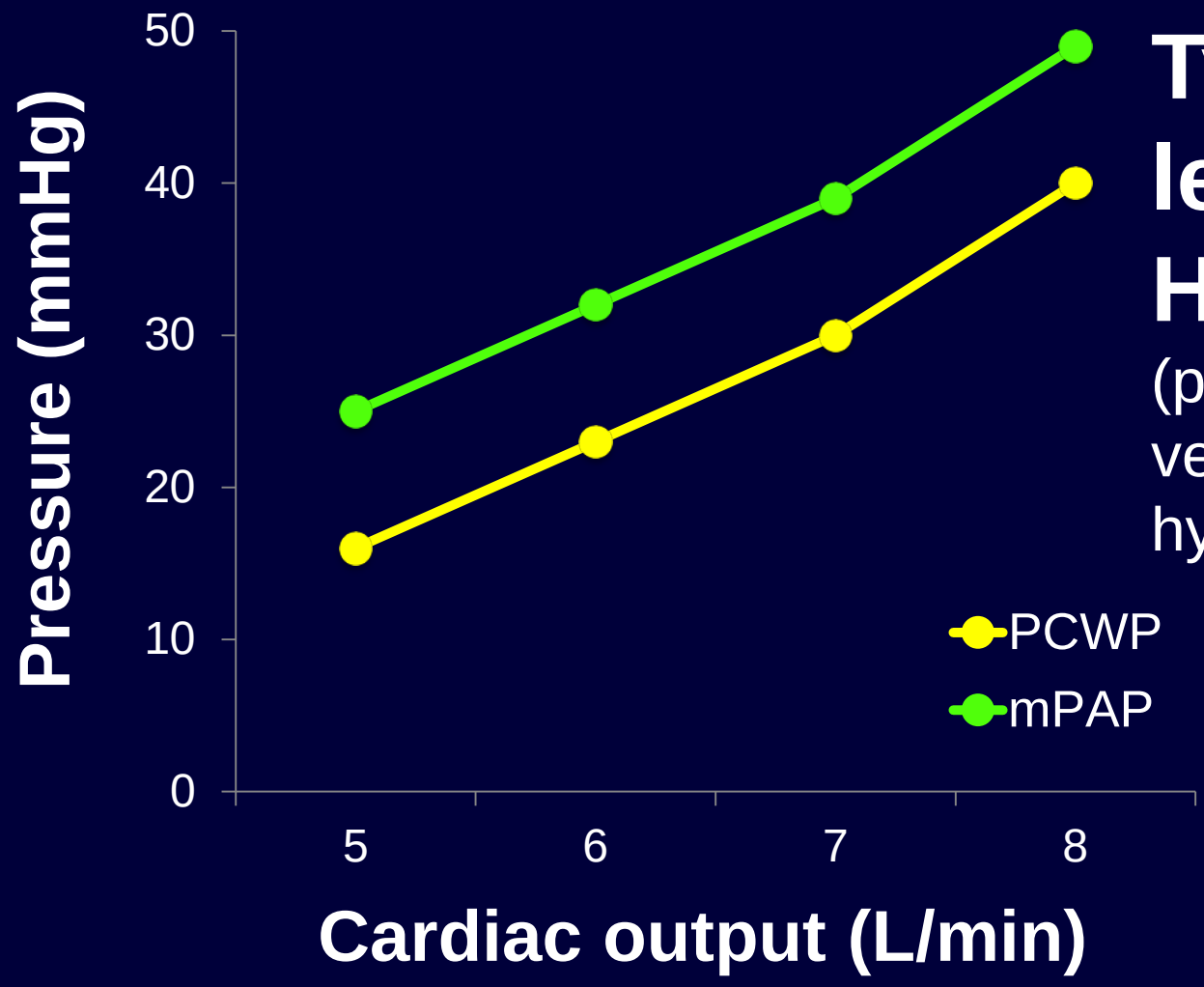
PCWP ≠ LVEDP in some cases



N=420 pts with mPAP>25 *(all patients underwent right and left heart cath)*

Presence of hypoxemic lung disease was the best predictor of PCWP-LVEDP discrepancy

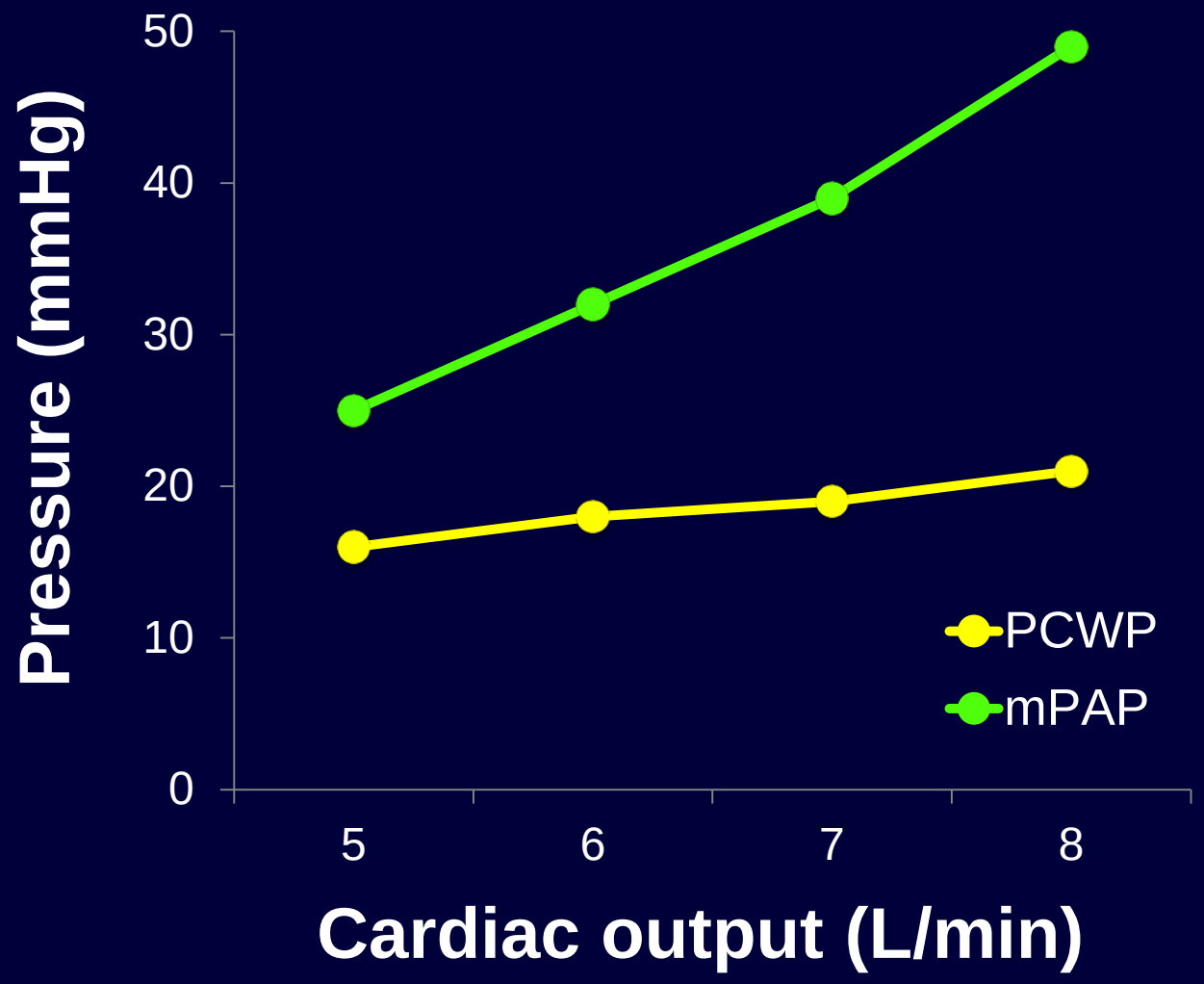
Exercise hemodynamics



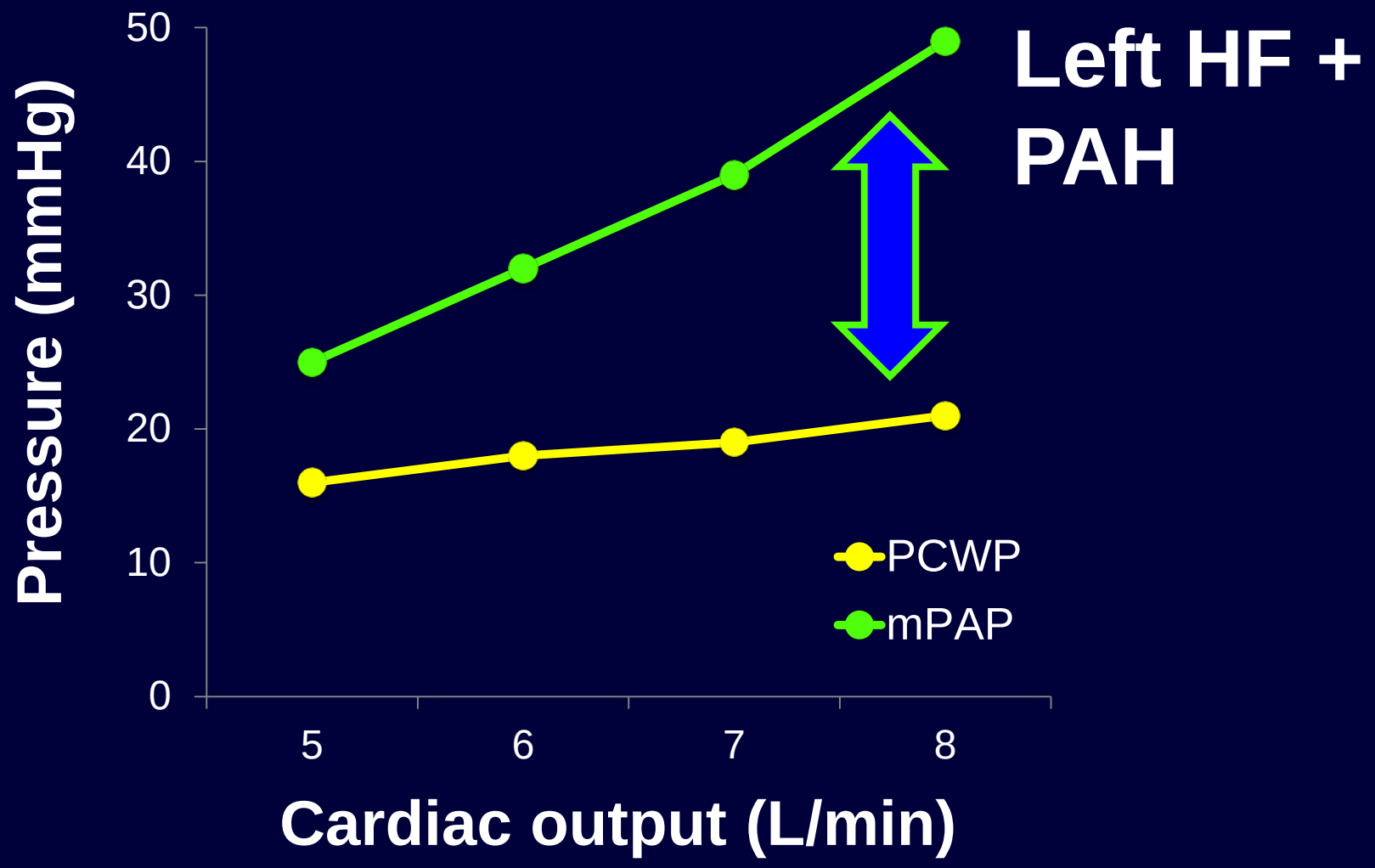
Typical left-sided HF

(pulmonary venous hypertension)

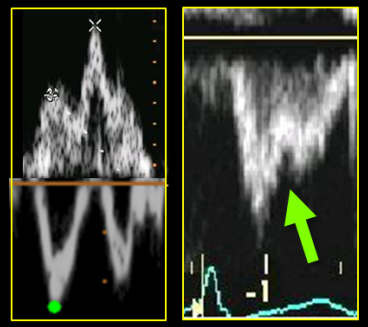
Exercise hemodynamics

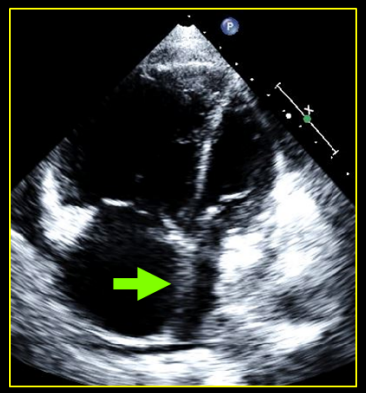


Exercise hemodynamics

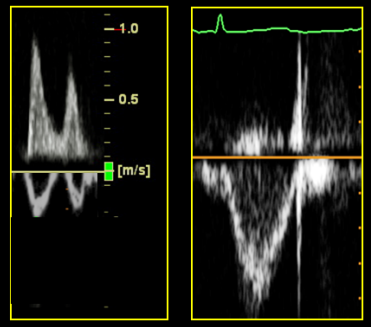


E/A = 0.5
Lateral E/e' = 5

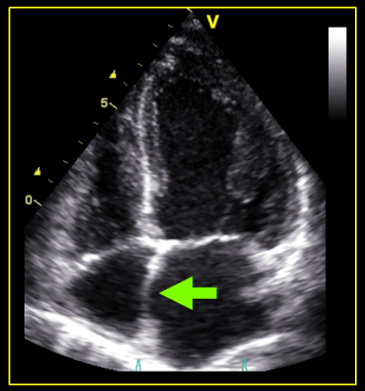




Parameter	PAH	PVH
RV size	Enlarged	May be enlarged
LA size	Small	Large
RA/LA size ratio	Increased	Normal (LA > RA size)
Interatrial septum	Bows from right to left	Bows from left to right
RVOT notching	Common	Rare
E/A ratio	<< 1	> 1
Lateral e'	Normal	Decreased
Lateral E/e'	< 8	> 10
Aortic pressure	Normal/Low	Normal/High
PCWP	≤ 15 mmHg	> 15 mmHg
PADP-PCWP	> 7 mmHg	< 5 mmHg



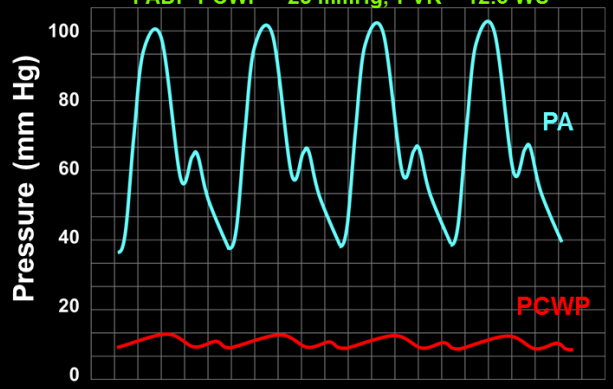
E/A = 1.4
Lateral E/e' = 20



PULMONARY ARTERIAL HYPERTENSION

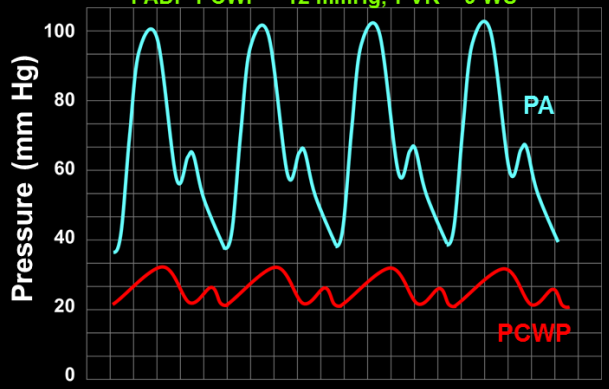
PULMONARY VENOUS HYPERTENSION

mPAP = 60 mmHg, PCWP = 10 mmHg, CO = 4 L/min
PADP-PCWP = 28 mmHg, PVR = 12.5 WU



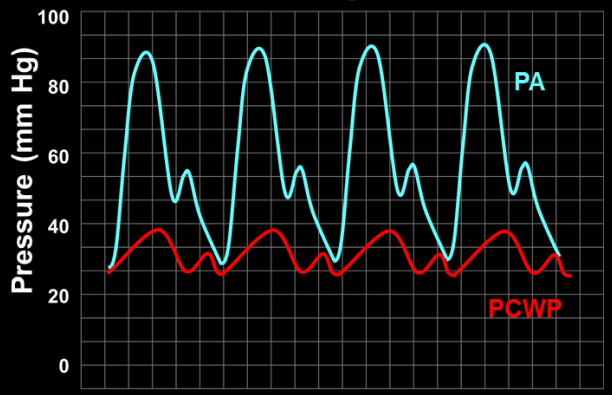
Pre-capillary PH

mPAP = 60 mmHg, PCWP = 24 mmHg, CO = 4 L/min
PADP-PCWP = 12 mmHg, PVR = 9 WU



Combined pre- and post-capillary PH

mPAP = 48 mmHg, PCWP = 38 mmHg, CO = 4 L/min
PADP-PCWP = 0 mmHg, PVR = 2.5 WU



Post-capillary PH

Take Home Points: 5 Lessons

1. PH is common, but most often due to left heart disease: *selective pulmonary vasodilators are not proven in these patients*
2. PAH is rare but deadly: outcomes have improved but diagnosis must be made earlier
3. Know the PH clinical clues in the dyspneic patient
4. Look beyond PA pressure to the RV to evaluate size/function
5. Definitive diagnosis of PH requires heart cath but don’t forget to integrate echo findings


thank you!