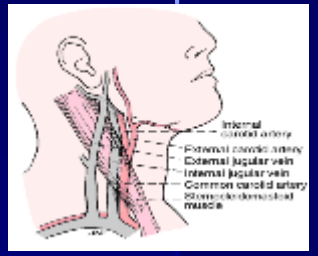
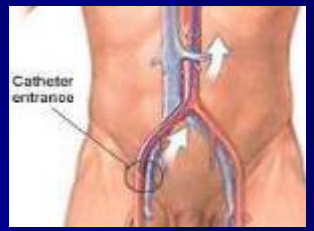
How to interpret right heart catheterization and vasodilation tests

Michele D'Alto
mic.dalto@tin.it

Dpt of Cardiology - Pulmonary Hypertension Unit
Monaldi Hospital – "L. Vanvitelli" University, Naples, Italy

Approach





Approach	Advantages	Disadvantages
Jugular	Easy and safe	Miss PFO
		Cannot perform left heart cath if need
Femoral	Easy and safe	Need fluoro
	Can approach PFO	More difficult rich PA and PAWP
	Can perform left heart cath if need	Bed rest for some time

Any large systemic vein may be used: cephalic, basilic, subclavian

Guidelines for Performing Ultrasound Guided Vascular Cannulation: Recommendations of the American Society of Echocardiography and the Society of Cardiovascular Anesthesiologists

Christopher A. Troianos, MD, Gregg S. Hartman, MD, Kathryn E. Glas, MD, MBA, FASE, Nikolaos J. Skubas, MD, FASE, Robert T. Eberhardt, MD, Jennifer D. Walker, MD, and Scott T. Reeves, MD, MBA, FASE, for the Councils on Intraoperative Echocardiography and Vascular Ultrasound of the American Society of Echocardiography, *Pittsburgh, Pennsylvania; Lebanon, New Hampshire; Atlanta, Georgia; New York, New York; Boston, Massachusetts; and Charleston, South Carolina*

J Am Soc Echocardiogr 2011;24:1291-318

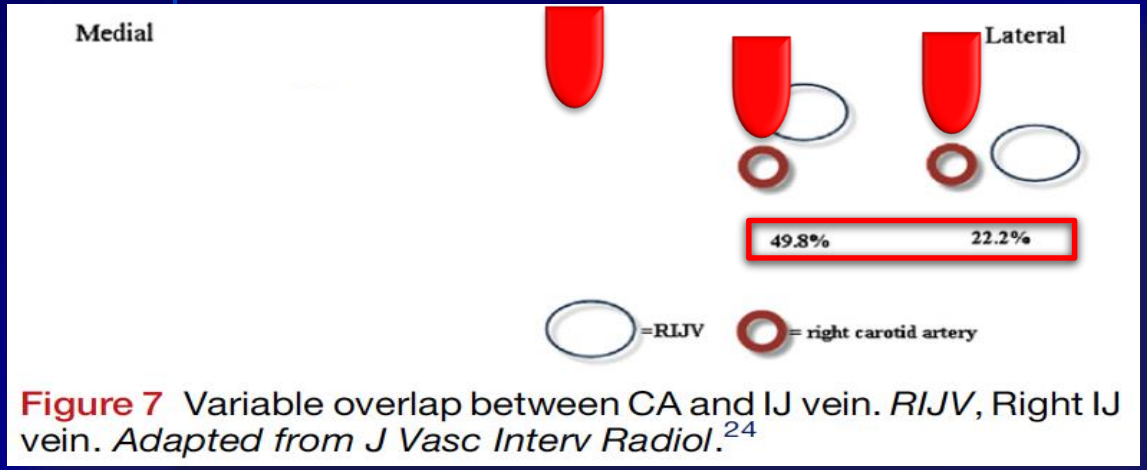
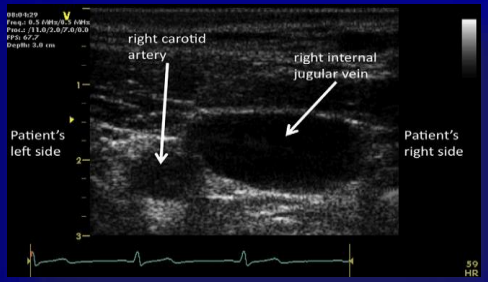
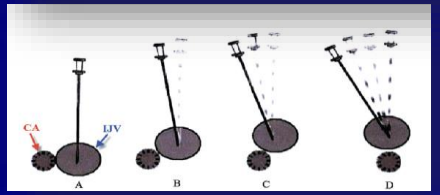
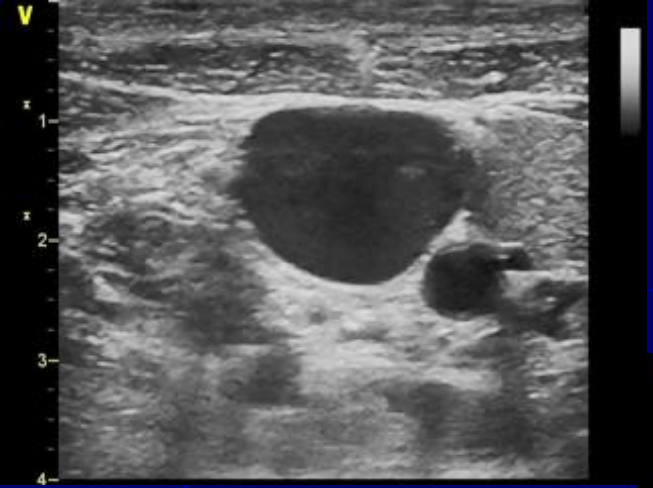


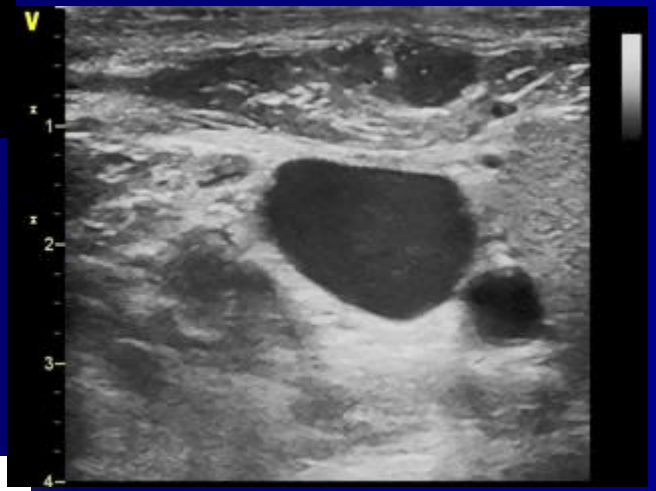
Figure 7 Variable overlap between CA and IJ vein. *RIJV*, Right IJ vein. *Adapted from J Vasc Interv Radiol*.[24]

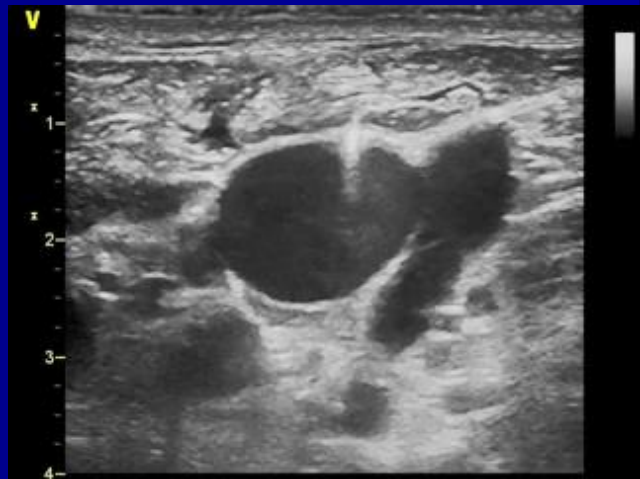




It is the recommendation of the council that individuals gain the requisite knowledge, develop the required dexterity, and perform **10 ultrasound-guided vascular access procedures under supervision** to demonstrate competence to independently practice this technique.







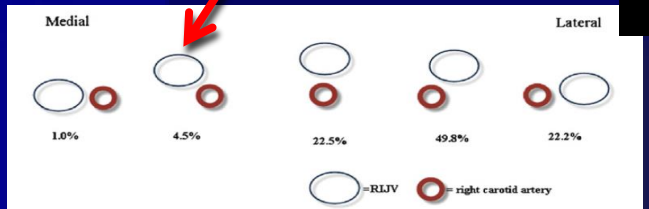


Figure 7 Variable overlap between CA and IJ vein. *RIJV*, Right IJ vein. *Adapted from J Vasc Interv Radiol*.[24]

ACCF/AHA 2009 Expert Consensus Document on Pulmonary Hypertension

A Report of the American College of Cardiology Foundation Task Force on Expert Consensus Documents and the American Heart Association

Developed in Collaboration With the American College of Chest Physicians, American Thoracic Society, Inc., and the Pulmonary Hypertension Association

WRITING COMMITTEE MEMBERS
Vallerie V. McLaughlin, MD, FACC, FAHA, FCCP, Chair*; Stephen L. Archer, MD, FACC, FAHA†;

Circulation 2009;119:2250-94

CHD

diagnosis

prognosis

therapy

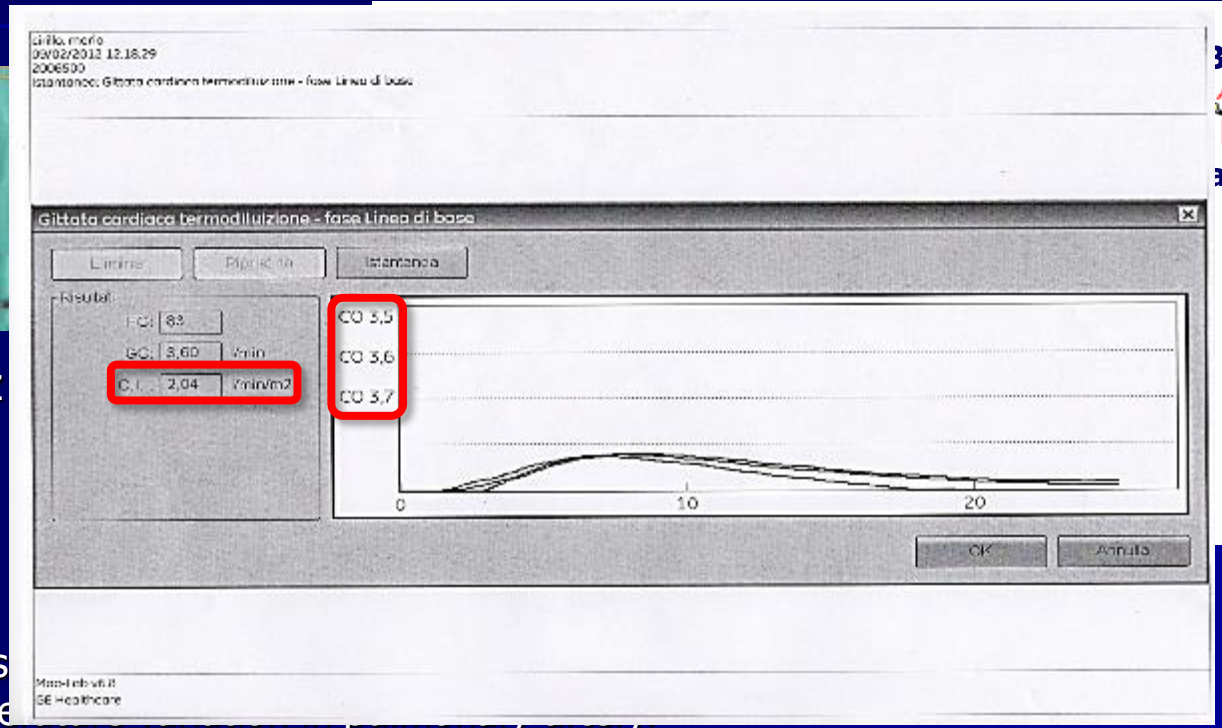
Table 6. Essential Components of Invasive Hemodynamic Assessment

Oxygen saturations (SVC, IVC, RV, PA, SA)
Right atrial pressure
Right ventricular pressure
Pulmonary artery pressure, systolic, diastolic, mean
Pulmonary arterial wedge pressure, left atrial pressure, or left ventricular end-diastolic pressure
Cardiac output/index
Pulmonary vascular resistance
Systemic blood pressure
Heart rate
Response to acute vasodilator

IVC indicates inferior vena cava; PA, pulmonary artery; RA, right atrium; RV, right ventricle; SA, systemic artery; and SVC, superior vena cava.

Cardiac output: thermodilution

Swan-Ganz catheter



Balloon

al lumen

Cold s

Tempe

Lower temperature reduction… higher cardiac output.

Cardiac output (CO) by Fick principle

Adolph Fick (1829–1901) mathematician, physicist and physiologist.

The Fick method (described by Adolph Fick in 1870) for measuring pulmonary blood flow:

In the absence of a significant intracardiac shunt, the pulmonary and systemic blood flows are equal.

Fick equation:

$$\textbf{CO (L/min)} = \frac{\textbf{O}_2\ \textbf{consumption (mL/min)}}{\textbf{Δ arterio-venous O}_2}$$

$$\text{QP (L/min)} = \frac{O_2 \text{ consumption (mL/min)}}{\text{Pulmonary vein } O_2 - \textbf{Pulmonary artery O}_2}$$

Recommendations for vasoreactivity testing

Idiopathic, hereditary and anorexigen-related PAH

Drug	Route	Half-life	Dose range[d]	Increments[e]	Duration[f]	Class[a]	Level[b]	Ref[c]
Nitric oxide	Inh	15–30 sec	10–20 ppm	-	5 min[g]	I	C	4, 5
Epoprostenol	i.v.	3 min	2–12 ng/kg/min	2 ng/kg/min	10 min	I	C	4, 6
Adenosine	i.v.	5–10 sec	50–350 µg/kg/min	50 µg/kg/min	2 min	IIa	C	7
Iloprost	Inh	30 min	5–20 µg	-	15 min	IIb	C	8

A positive response to vasoreactivity testing is defined as a reduction of mean PAP $\geq$10 mmHg to reach an absolute value of mean PAP $\leq$40 mmHg with an increased or unchanged cardiac output	I	C

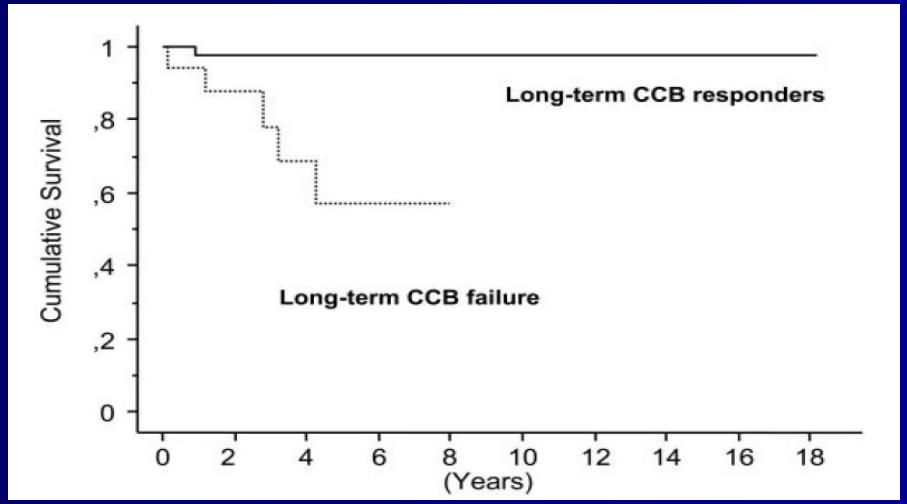
→ High dose CCB

Survival in IPAH with CCB

Long-Term Response to Calcium Channel Blockers in Idiopathic Pulmonary Arterial Hypertension

Olivier Sitbon, MD; Marc Humbert, MD, PhD; Xavier Jaïs, MD; Vincent Ioos, MD; Abdul M. Hamid, MD; Steeve Provencher, MD; Gilles Garcia, MD; Florence Parent, MD; Philippe Hervé, MD; Gérald Simonneau, MD

Circulation 2005;111:3105-3111



Conclusions—Long-term CCB responders represent <10% of IPAH patients evaluated in a pulmonary vascular referral center. During acute vasodilator testing, these patients showed significantly lower levels of both mean PAP and PVR, which reached near-normal values. (***Circulation*. 2005;111:3105-3111.**)

Additional use of "vasoreactivity testing"

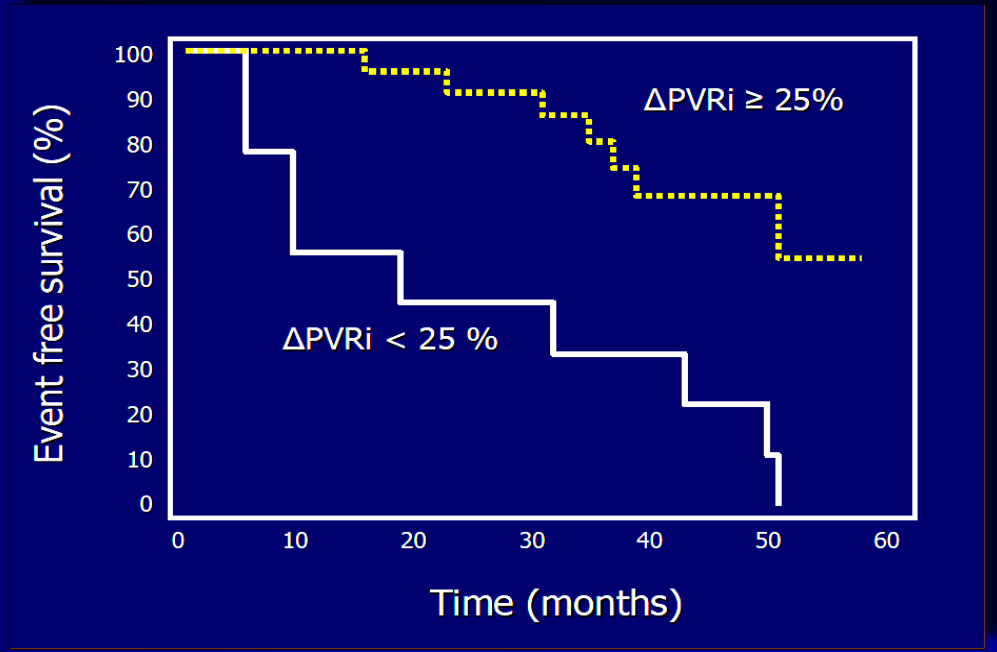
Prognosis in CHD-PAH

Pulmonary vasoreactivity predicts long-term outcome in patients with Eisenmenger syndrome receiving bosentan therapy

Michele D'Alto,[1] Emanuele Romeo,[1] Paola Argiento,[1] Giuseppe Santoro,[1] Berardo Sarubbi,[1] Giampiero Gaio,[1] Christian Mélot,[2] Maria Giovanna Russo,[1] Robert Naeije,[3] Raffaele Calabrò[1]

Heart 2010;96:1475-1479

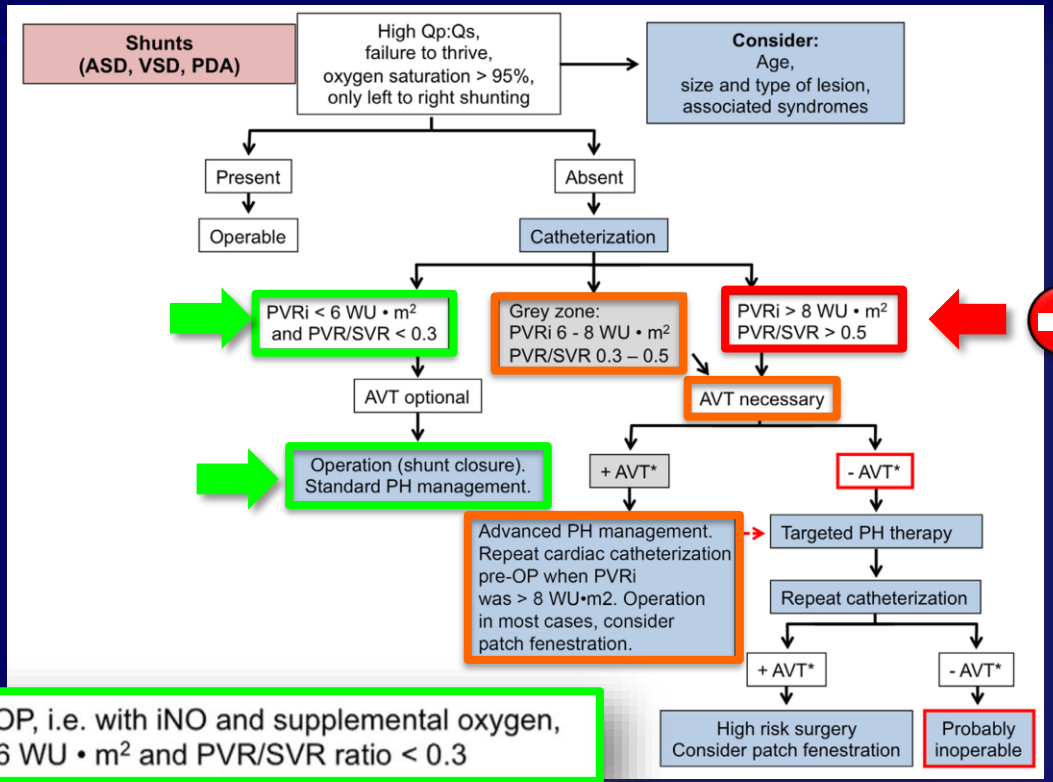
- 38 Eisenmenger patients
- ΔPVRi <25% showing a positive predictive value (for clinical worsening) 100% and a negative predictive value 75.9%.



"Pulmonary vasoreactivity" is a significant predictor of clinical worsening in CHD-PAH

Additional use of "vasoreactivity testing"

To close or not to close an ASD?



* Positive AVT pre OP, i.e. with iNO and supplemental oxygen, PVRi decreases < 6 WU • m² and PVR/SVR ratio < 0.3

Hansmann G, et al. J Heart Lung Transplant 2019;38:879–901

Additional use of "vasoreactivity testing"

Decision making for heart transplantation

The 2016 International Society for Heart Lung Transplantation listing criteria for heart transplantation: A 10-year update

Mandeep R. Mehra, MD (Chair), Charles E. Canter, MD, Margaret M. Hannan, MD, Marc J. Semigran, MD, Patricia A. Uber, PharmD, David A. Baran, MD, Lara Danziger-Isakov, MD, MPH, James K. Kirklin, MD, Richard Kirk, MD, Sudhir S. Kushwaha, MD, Lars H. Lund, MD, PhD, Luciano Potena, MD, PhD, Heather J. Ross, MD, David O. Taylor, MD, Erik A.M. Verschuuren, MD, PhD, Andreas Zuckermann, MD and on behalf of the International Society for Heart Lung Transplantation (ISHLT) Infectious Diseases, Pediatric and Heart Failure and Transplantation Councils

J Heart Lung Trans 2018; 35(1);1-28

Additional use of "vasoreactivity testing"

Decision making for heart transplantation

A vasodilator challenge* should be administered when the pulmonary artery systolic pressure is ≥ 50 mm Hg and either the transpulmonary gradient is ≥ 15 or the pulmonary vascular resistance (PVR) is > 3Wood units while maintaining a systolic arterial blood pressure > 85 mm Hg (**Class I, Level of Evidence: C**).

When an acute vasodilator challenge is unsuccessful, hospitalization with continuous hemodynamic monitoring should be performed, as often the PVR will decline after 24 to 48 hours of treatment consisting of diuretics, inotropes and vasoactive agents such as inhaled nitric oxide (**Class I, Level of Evidence: C**).

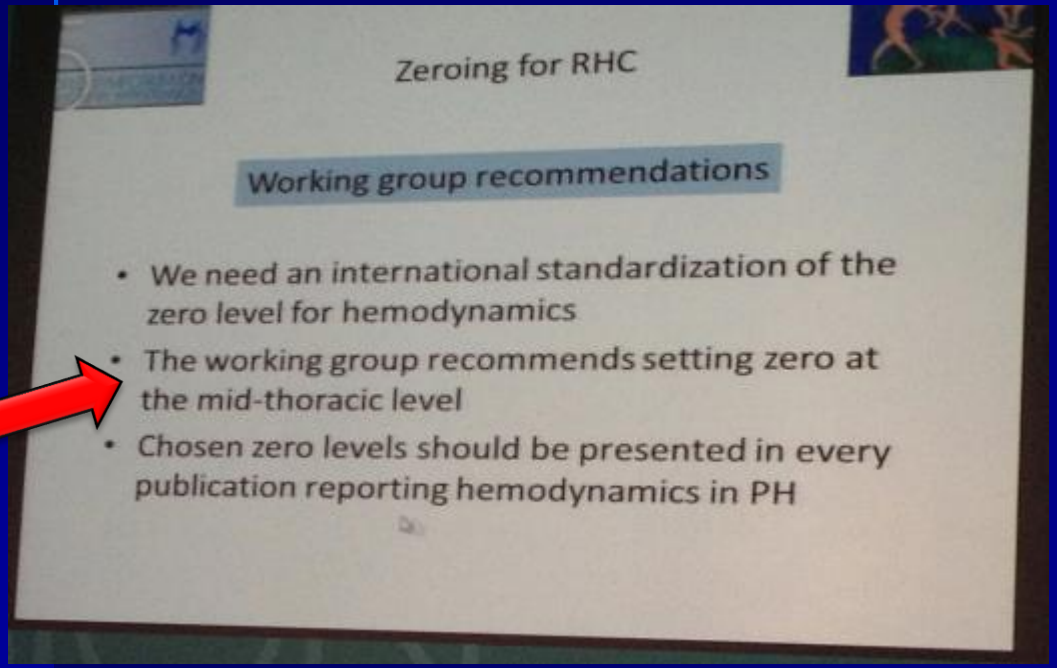
If medical therapy fails to achieve acceptable hemodynamics, and if the left ventricle cannot be effectively unloaded with mechanical adjuncts, including an intra-aortic balloon pump (IABP) and/or left ventricular assist device (LVAD), it is reasonable to conclude that the pulmonary hypertension is irreversible (**Class IIb, Level of Evidence: C**).

* Intravenous nitrates (or inhaled nitric oxide)

WORLD SYMPOSIUM ON PULMONARY HYPERTENSION

NICE ACROPOLIS, Nice February 27-28 / March 1, 2013

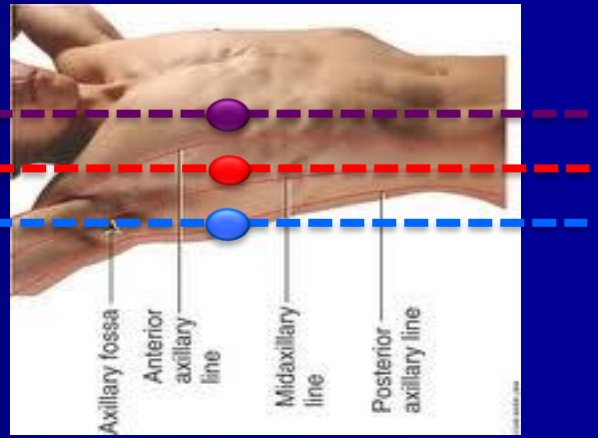
Caveat!



Caveat: zero setting at mid-thoracic level!

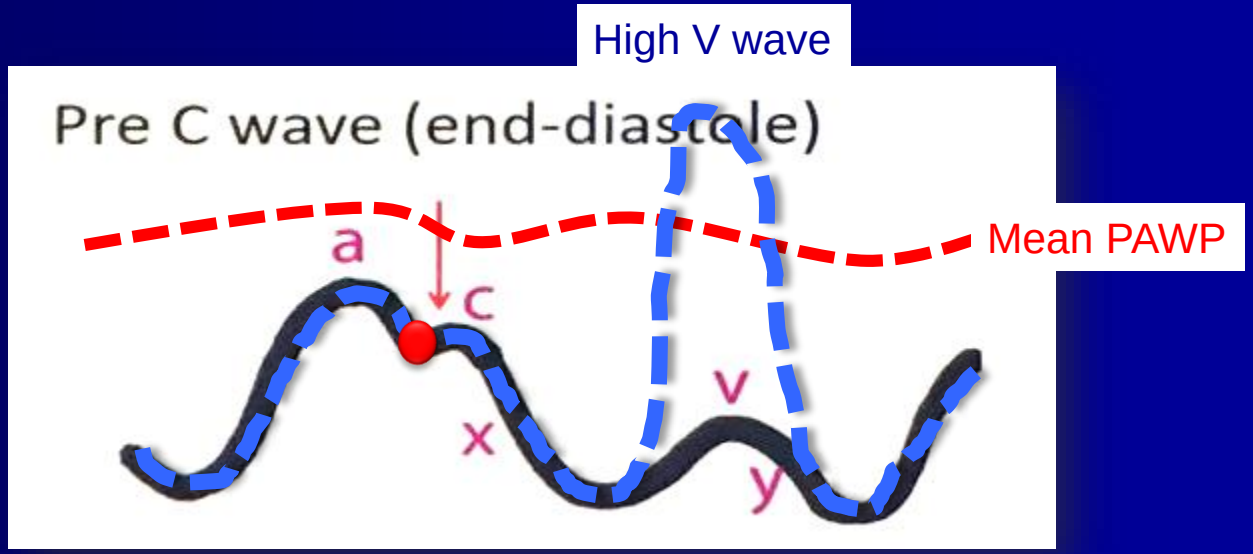
1 mmHg = 13 mmH_2O = 1.3 cmH_2O

- **-10 mmHg** = -13 cmH_2O
- **+10 mmHg** = +13 cmH_2O



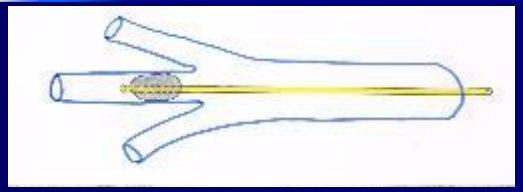
Ideal zero line

Caveat: exclude very high V wave!

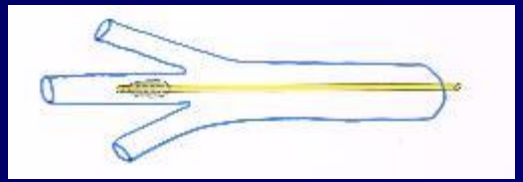


Mean PAWP > end-diastolic PAWP = LVEDP
(possible negative DPG!)

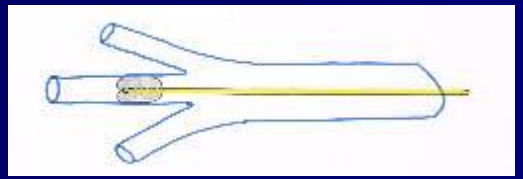
Caveat: avoid PAWP over-estimation



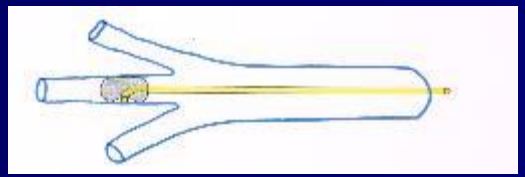
ideal



over-wedge
(PAP vs PAWP)



over-wedge
(intra-baloon
pressure)

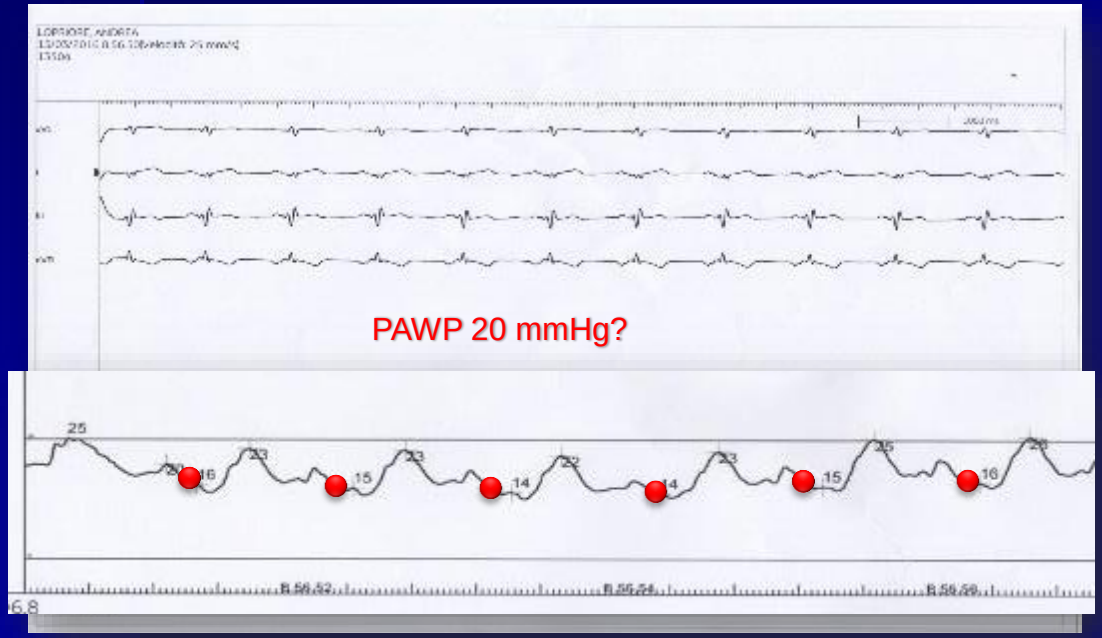


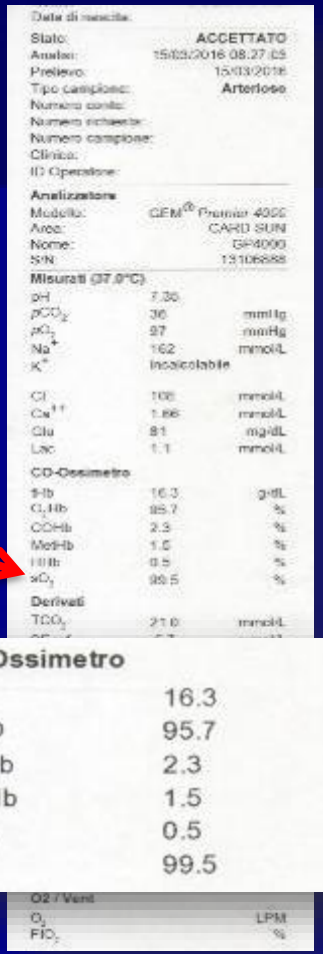
over-wedge
(vessel wall
pressure)

D'Alto M, Heart Fail Clin 2018;14:467-477

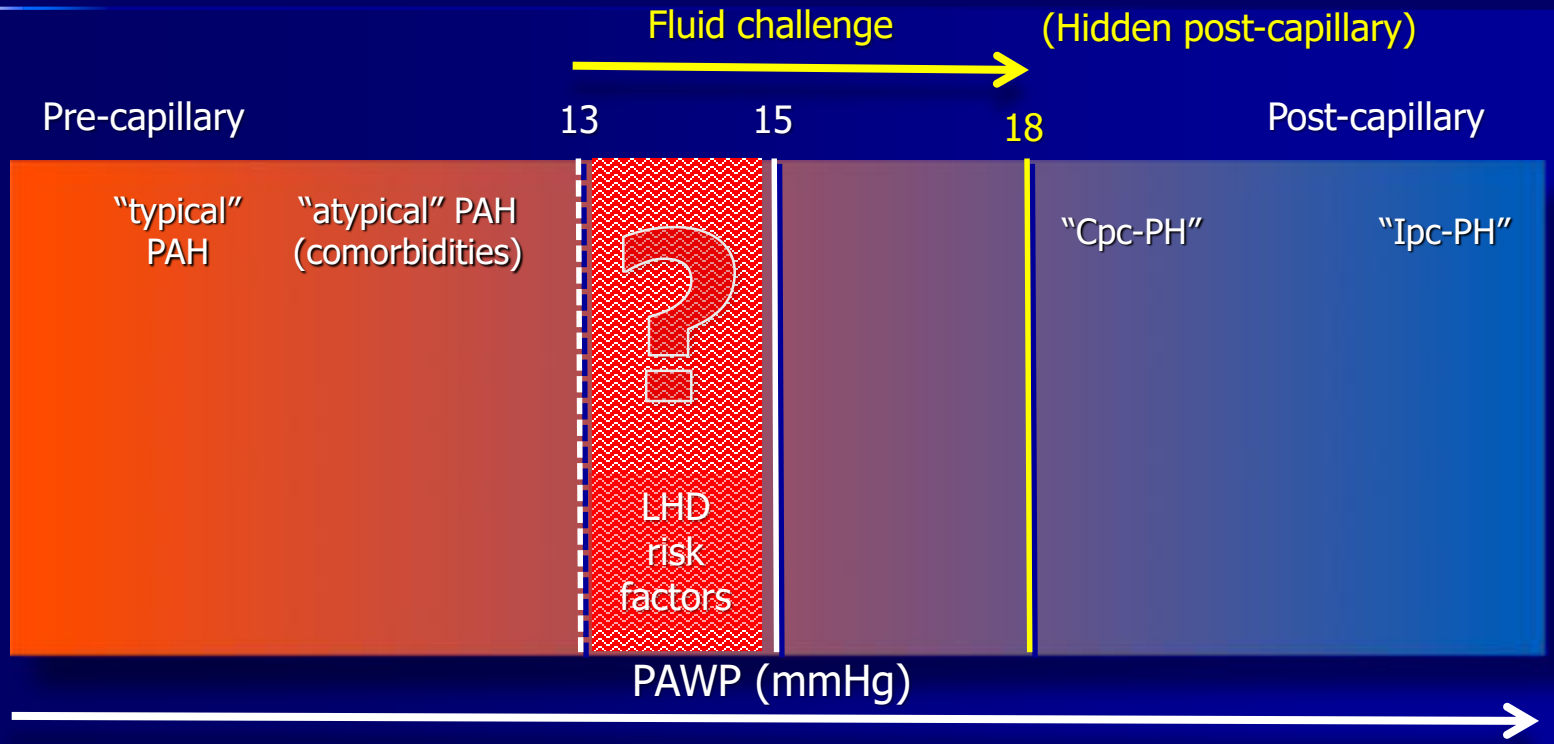
Caveat: “difficult” PAWP trace: true or false?

57 yo male
Moderate mitral valve insufficiency
Suspected pulmonary hypertension





Haemodynamic definition of PH: certainties and doubts



Courtesy S. Rosenkranz, modified

Change in PAWP under saline loading

212 pts
7 mL/kg
(~500cc)

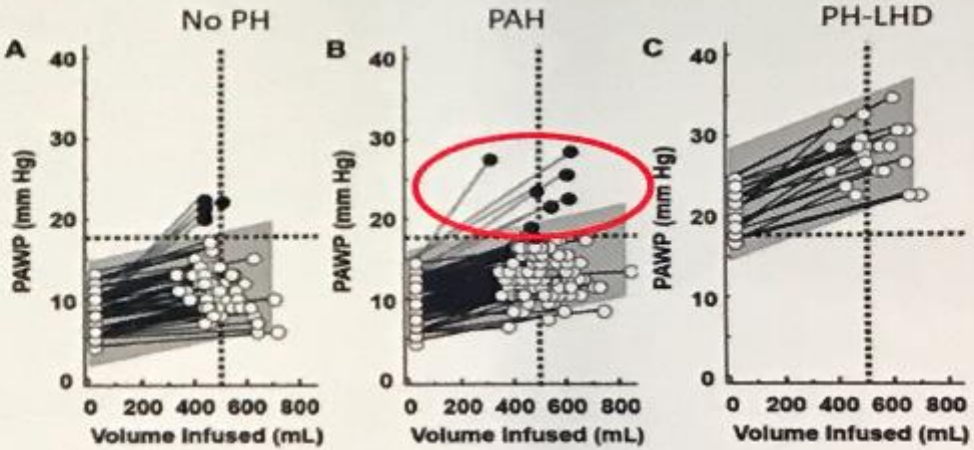


Figure 1 – *Individual increases in PAWP as a function of volume of rapidly infused saline 7 mL/kg in control subjects with no pulmonary hypertension (PH) (A), patients with precapillary PH (B), and patients with postcapillary PH (C). ● = patients with hidden left-sided heart disease defined by means of a fluid-challenge-induced increase in PAWP > 18 mm Hg. The shaded area corresponds to quadratic fits of the pooled PAWP responses. The horizontal dotted lines correspond to a predefined upper limit of normal of 18 mm Hg for PAWP after fluid challenge. The vertical dotted line corresponds to 500 mL of infused saline. PAWP = pulmonary wedge pressure.*

7% of those previously diagnosed with PAH had PAWP > 18mmHg after fluid bolus

D'Alto M et al. CHEST 2017; 151(1):119-126

TF 9 Proposal for fluid loading test

- A PAWP ≤ 15 mmHg continues to define pre-capillary PH
- In patients with a PAWP between 13 and 15 mmHg and high/intermediate probability of PH HFpEF, a fluid loading challenge should be considered with 500 ml of saline over 5 minutes
- A PAWP of > 18 mmHg immediately after fluid administration is considered abnormal
- However, how this should impact management is unknown
- If PAH specific therapies are initiated in patients with "abnormal" response, caution should be exercised, including close monitoring of response and side effects

Complications of Right Heart Catheterization Procedures in Patients With Pulmonary Hypertension in Experienced Centers

Marius M. Hoeper, MD,* Stephen H. Lee, MD,† Robert Voswinckel, MD,‡ Massimiliano Palazzini, MD,§ Xavier Jais, MD,‖ Alessandro Marinelli, MD,§ Robyn J. Barst, MD,¶ Hossein A. Ghofrani, MD,‡ Zhi-Cheng Jing, MD,‖ Christian Opitz, MD,# Hans-Juergen Seyfarth, MD** Michael Halank, MD,†† Vallerie McLaughlin, MD,‡‡ Ronald J. Oudiz, MD,§§ Ralf Ewert, MD,‖‖ Heinrike Wilkens, MD,¶¶ Stefan Kluge, MD,## Hinrich-Cordt Bremer, MD,*** Eva Baroke,* Lewis J. Rubin, MD†

J Am Coll Cardiol 2006;48:2546 –52

5-year retrospective and 6-month prospective evaluation of SAE related to RHC in patients with PH (**total 7,218 RHC**).

The most frequent complications were related to **venous access** (e.g., hematoma, pneumothorax), followed by **arrhythmias**.

Four fatal events were recorded, resulting in an overall procedure-related **mortality of 0.055% (1/1,805 RHC)**.

Conclusions

- The **gold standard** for the evaluation of the functional state of the pulmonary circulation is a **right heart catheterization**
- Pulmonary vascular pressures and flow measurements should be done by **expert physicians** (not only cath placement but also waveform interpretation and understanding pathophysiology).
- **RHC** is an essential tool for **diagnosis and follow-up** but it is a **part of a complex diagnostic algorithm**.
- A **deep knowledge of the disease** is a key point in RHC execution and interpretation.
- RHC is a **safe** procedure in the **expert centers**.