THE RIGHT VENTRICLE IN PULMONARY HYPERTENSION

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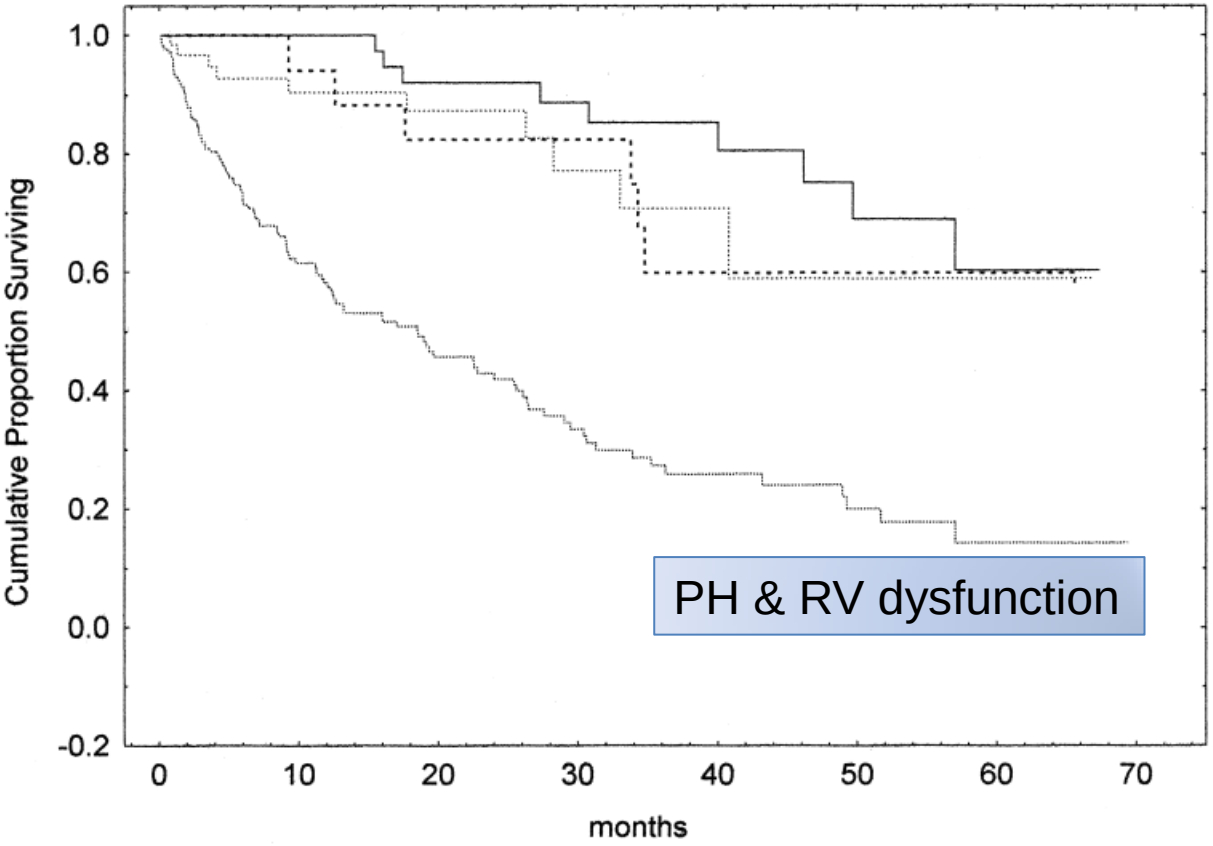
Why the Right Ventricle?

Pulmonary hypertension (PH)

Right ventricle (RV) function

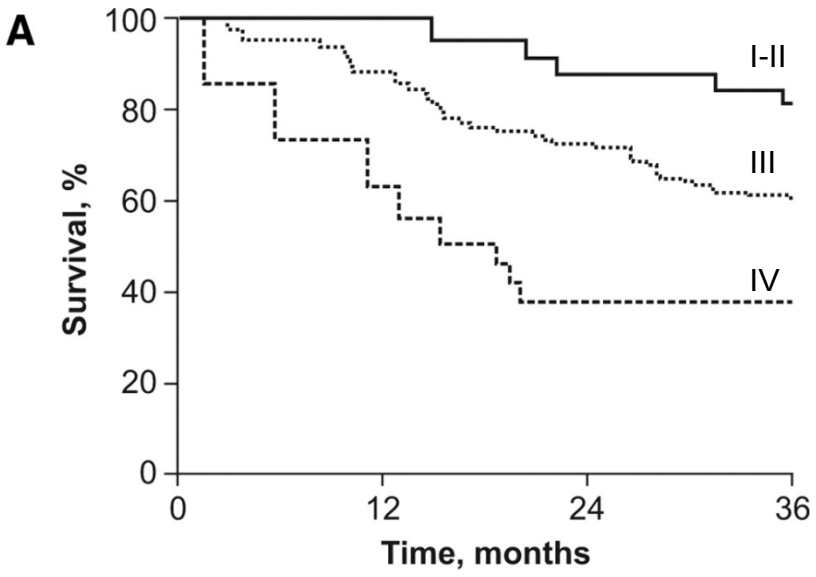
Outcome

RV dysfunction & outcome

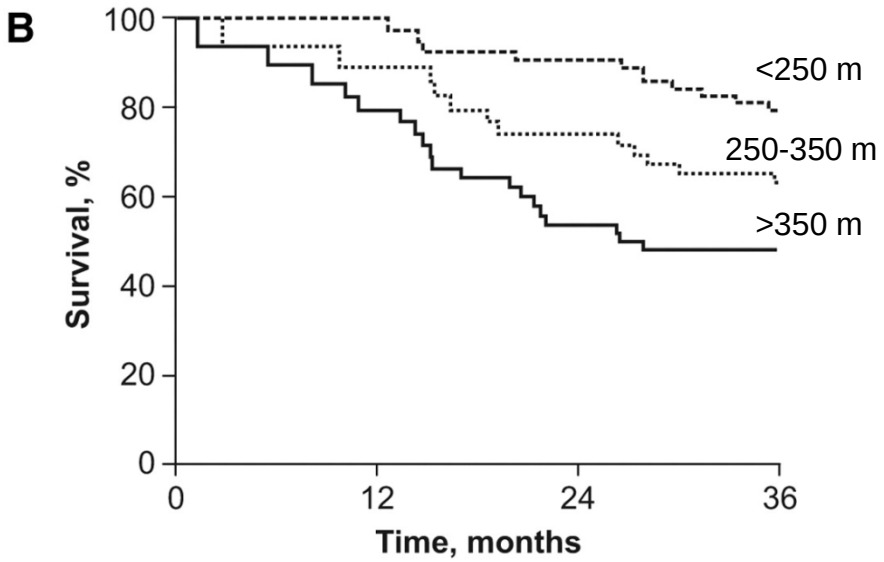


Ghio, *et al. JACC* 2001;37:138-188

RV dysfunction & outcome



NYHA class



6MWD

Humbert, *et al. Circ* 2010;122:156-163

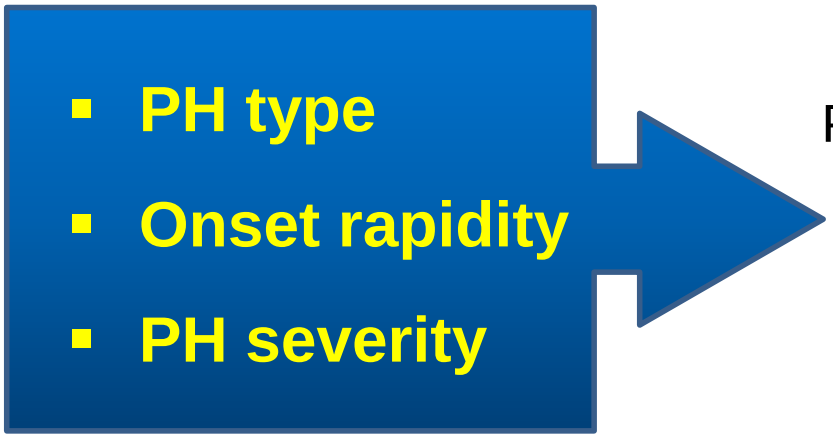
RV dysfunction & outcome

Better prognosis	Determinants of prognosis	Worse prognosis
No	Clinical evidence of RV failure	Yes
Slow	Rate of progression of symptoms	Rapid
No	Syncope	Yes
I, II	WHO-FC	IV
Longer (>500 m)[a]	6MWT	Shorter (<300 m)
Peak O_2 consumption >15 mL/min/kg	Cardio-pulmonary exercise testing	Peak O_2 consumption <12 mL/min/kg
Normal or near-normal	BNP/NT-proBNP plasma levels	Very elevated and rising
No pericardial effusion TAPSE[b] >2.0 cm	Echocardiographic findings[b]	Pericardial effusion TAPSE[b] <1.5 cm
RAP <8 mmHg and CI ≥2.5 L/min/m^2	Haemodynamics	RAP >15 mmHg or CI ≤2.0 L/min/m^2

Galie *et al. Eur H J 2009*;30:2493-2537

RV response to PH

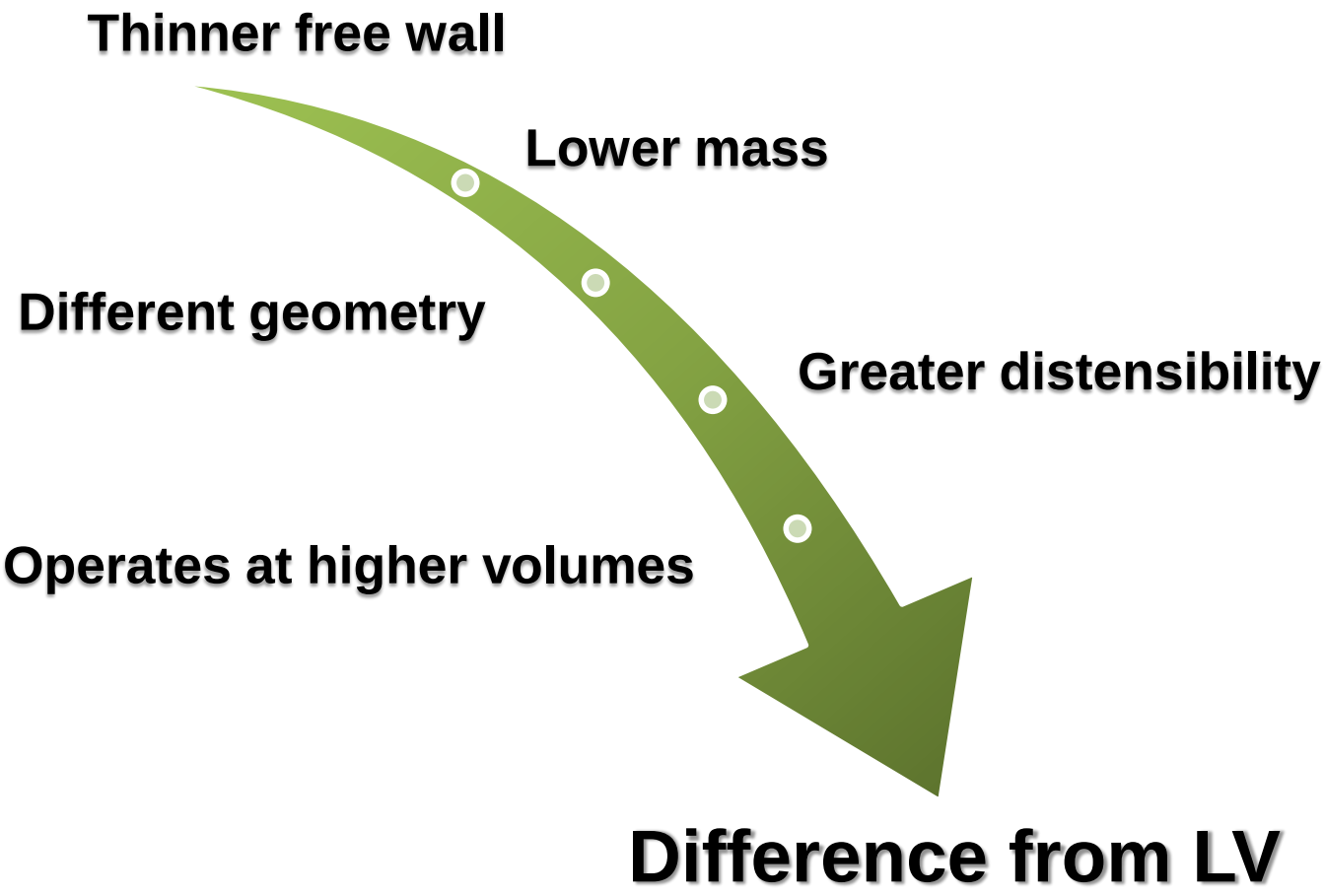
- **Variable**
- **Depends on:**



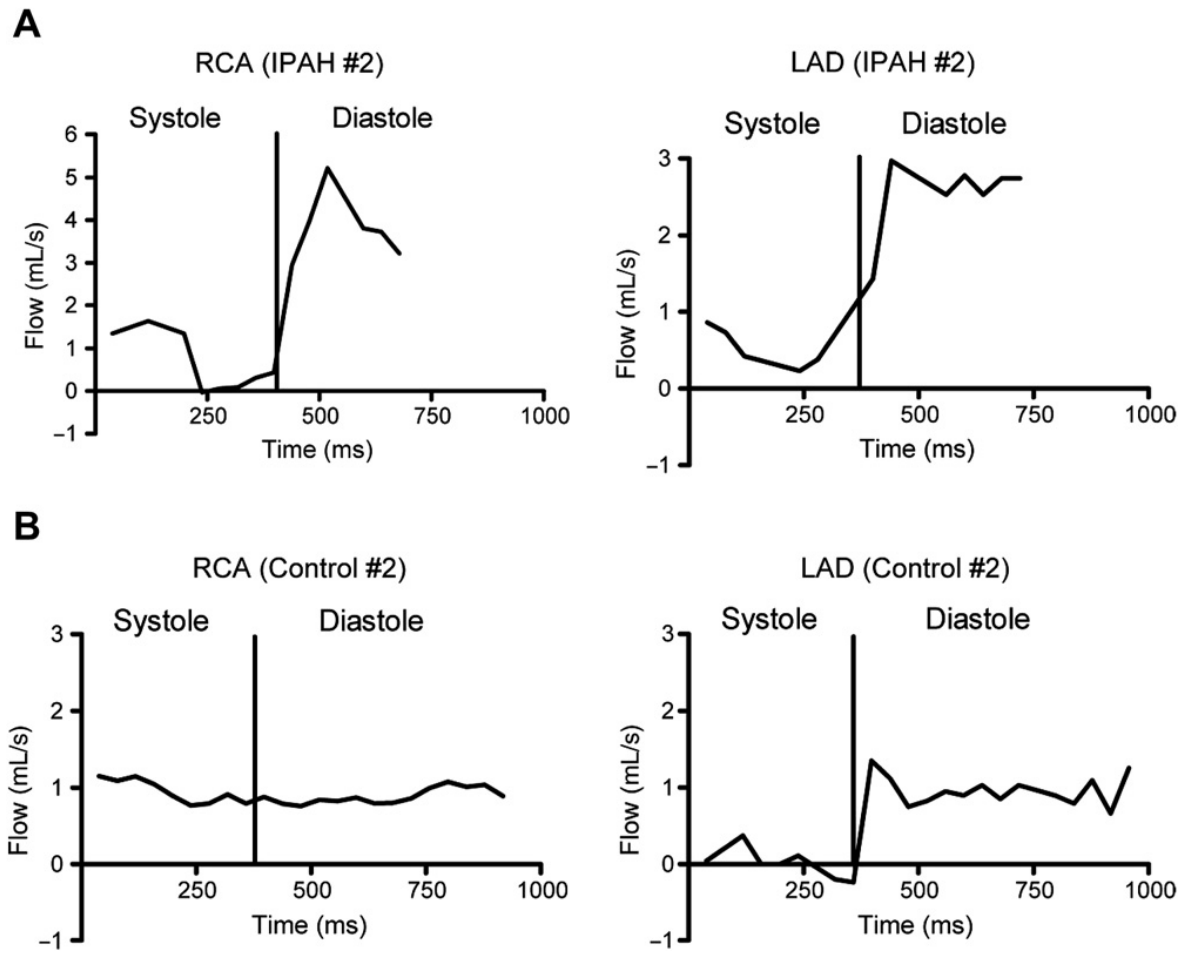
Prediction of future dysfunction

LIMITED

RV Chamber characteristics

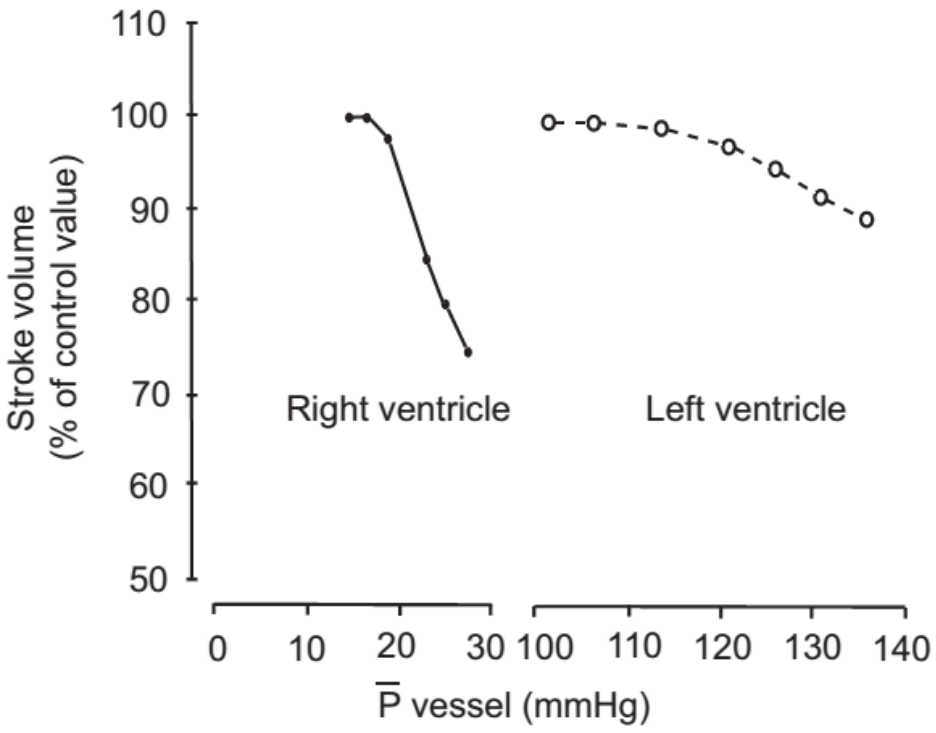


RV response in PH

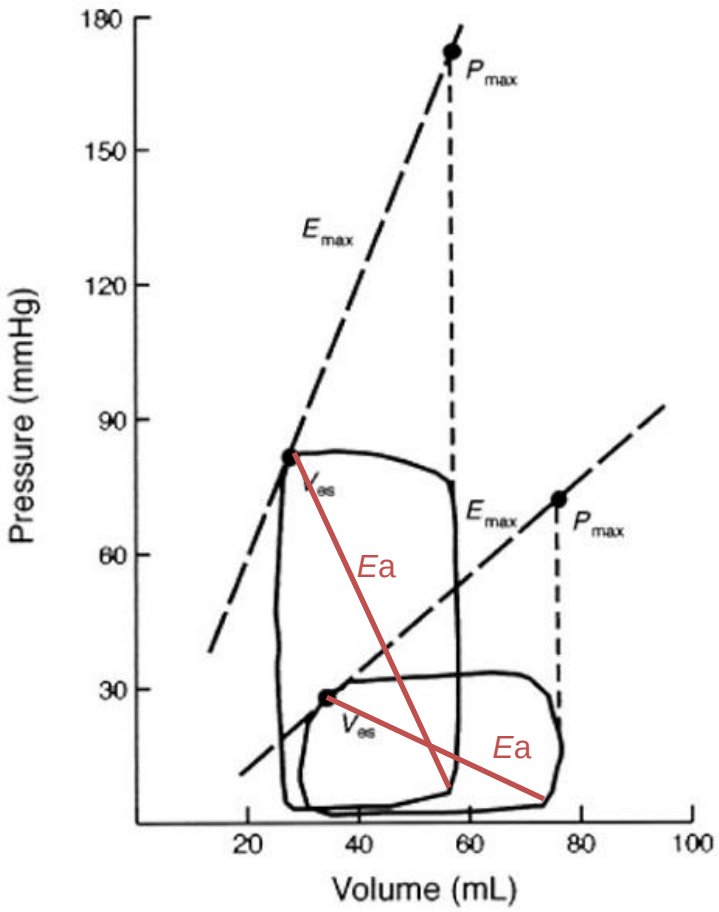


Wolferen *et al. Eur Heart J* 2008; 29:120-7

RV response to PH



Haddad *et al. Circulation* 2008; 117:1436-48.



Naeije *et al. Eur Heart J 2007;9,H5–H9*.

RV afterload

- **PVR**
  - used in clinical practice as equivalent for afterload
  - may not reflect its complex nature
- **Pulmonary arterial system**

• Low impedance / high distensible
  - High compliance
  - Low resistance
  - Low peripheral pulse wave reflection coefficient

Pulmonary circulation

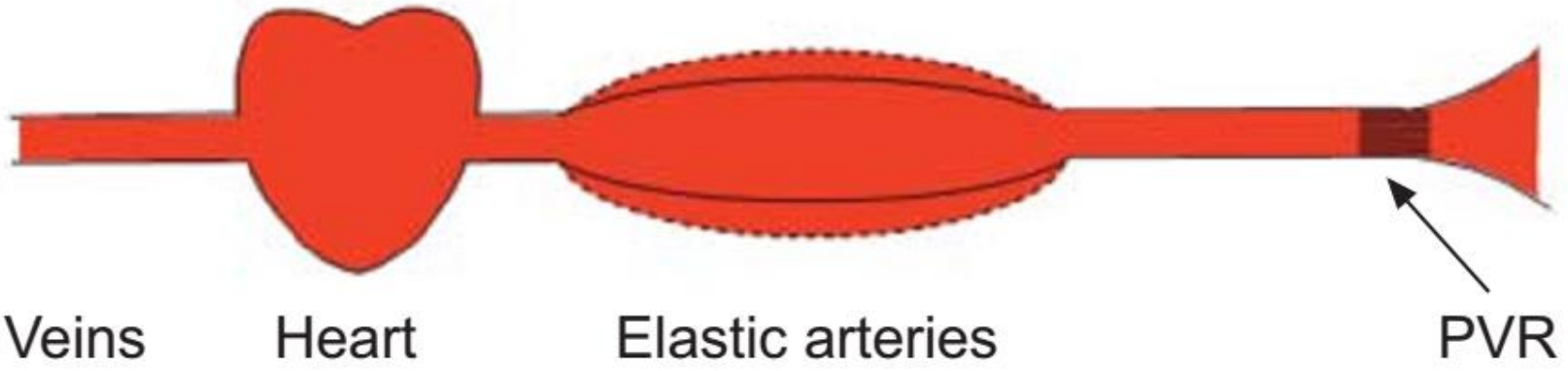
Systemic circulation

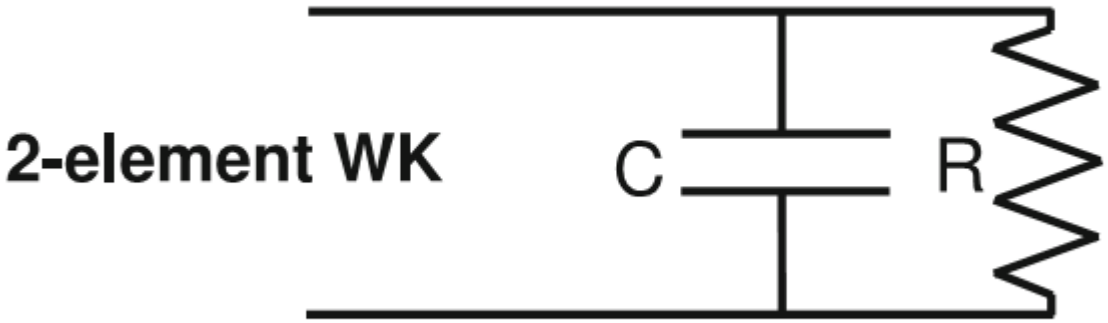
- **Resistance**
  - small arteries
  - arterioles
- **Compliance**
  - aorta

Pulmonary circulation

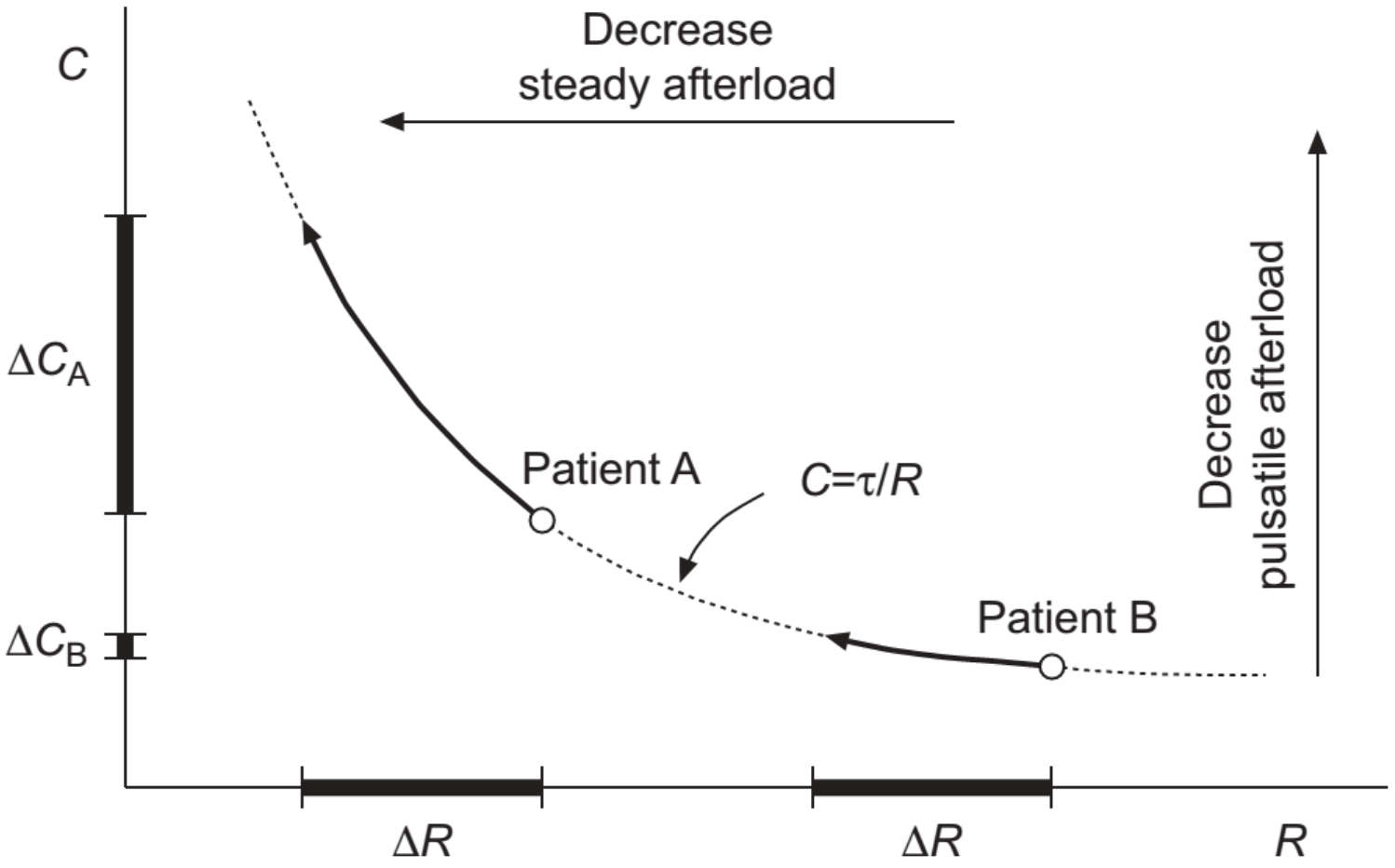
- **Resistance**
  - small arteries
  - arterioles
- **Compliance**
  - entire pulmonary circulation

Windkessel model

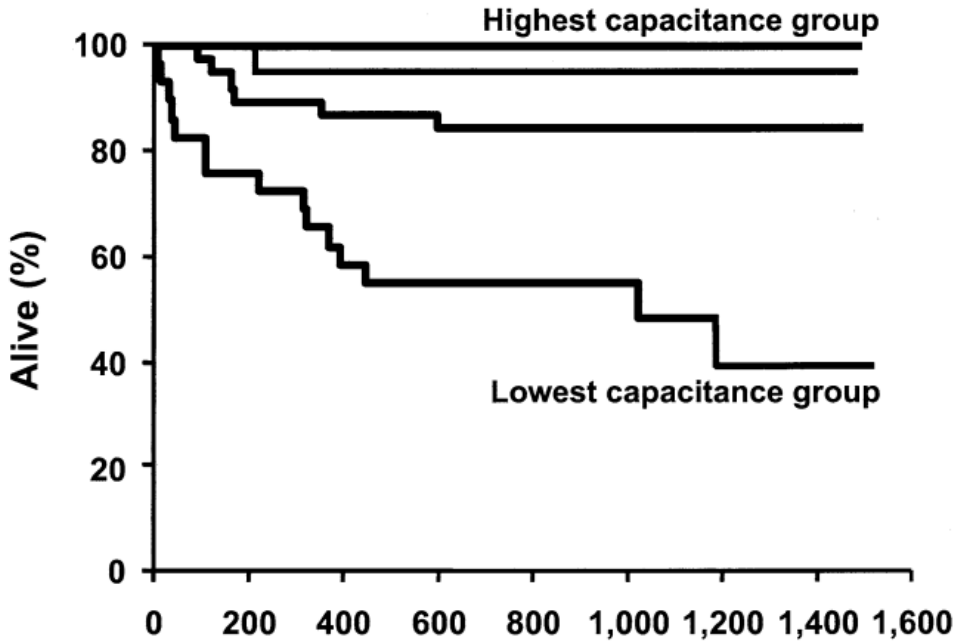




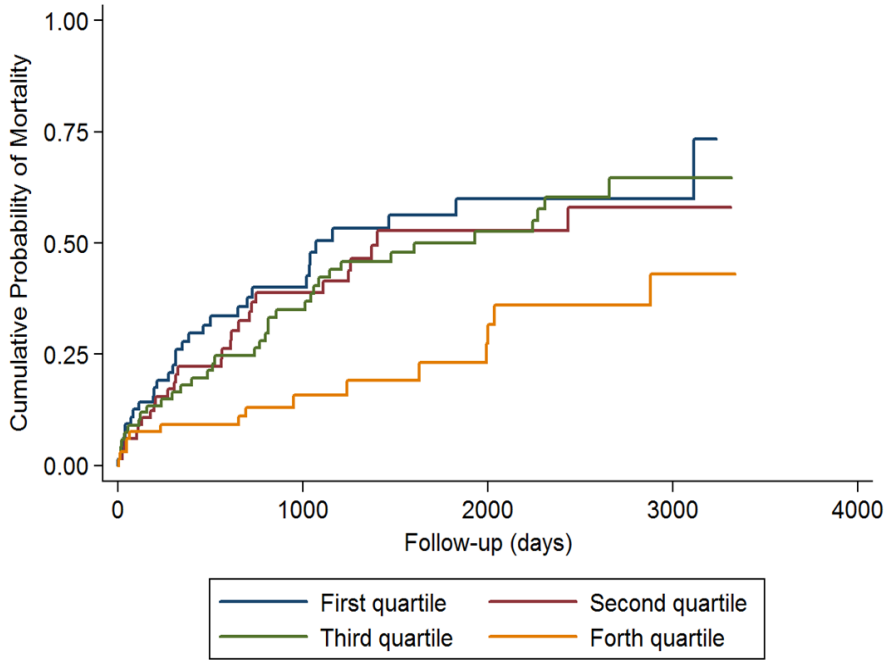
RC constant


C
Decrease
steady afterload
ΔC_A
ΔC_B
Patient A
C=τ/R
Patient B
Decrease
pulsatile afterload
ΔR
ΔR
R

Capacitance and outcome

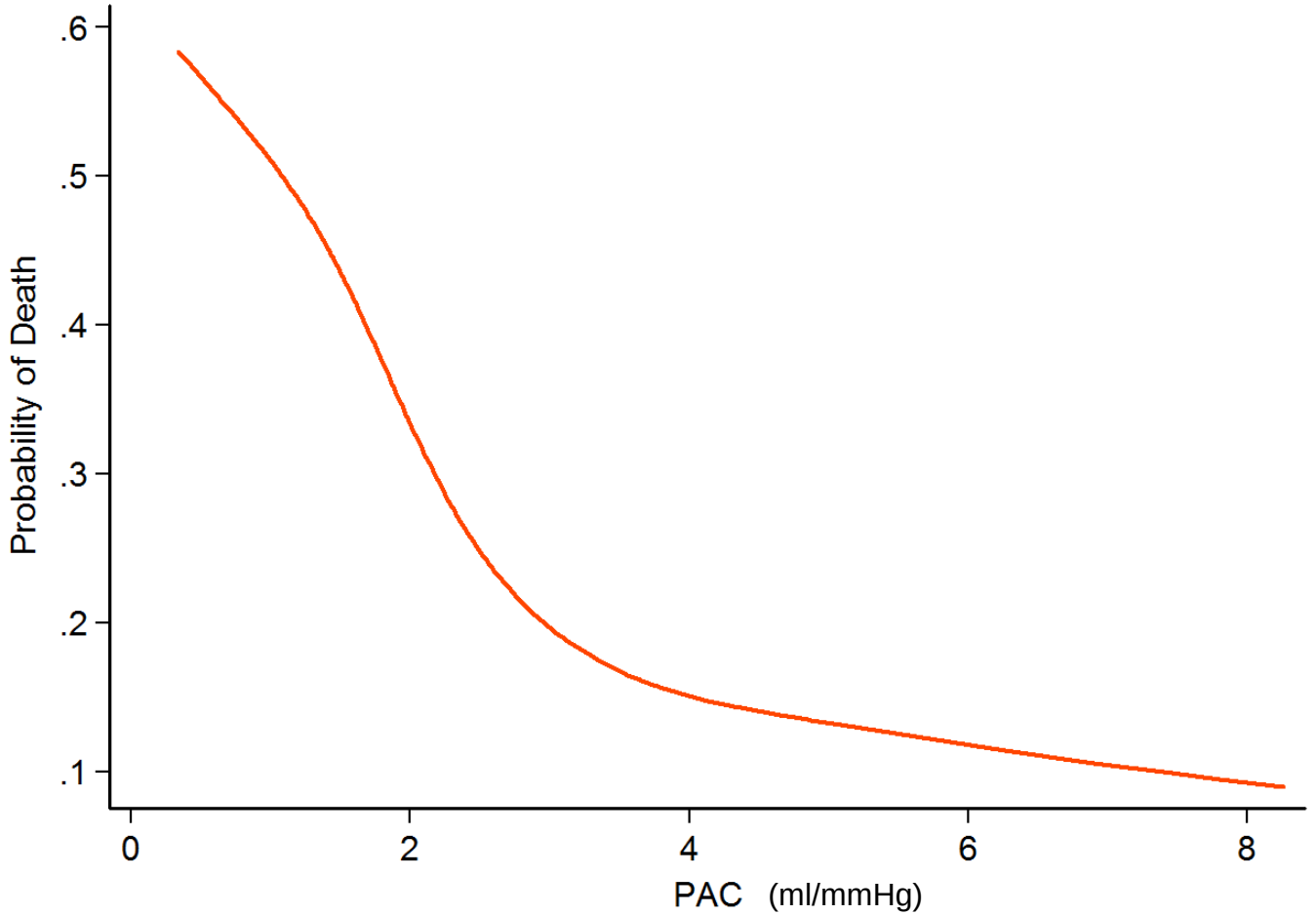


Mahapatra *et al. JACC 2006;47, 799-806*



Dragu *et al. IHS Congress 2013*

Capacitance and outcome



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Assessment of RV function in PH

- Mechanisms of RV failure in PH
- Prognostic implications
- Effect of PH-specific tx on RV

Parameters that reflect RV function

Echocardiography

- RA area[1]
- RV Area[1]
- TAPSE[1,2]
- Tei index[3]
- RV fractional area change[2]
- Degree of tricuspid regurgitation[2]
- Pericardial effusion[4]
- Inferior vena cava collapsibility[2]
- Superior vena cava flow velocity pattern[2]
- LV eccentricity index[2]
- RV filling pressure[5]

MRI

- RV EF% and SV[6]
- Mass index[7] and geometry[8]

RHC

- Right atrial pressure[9]
- Cardiac index[10]

Biomarkers

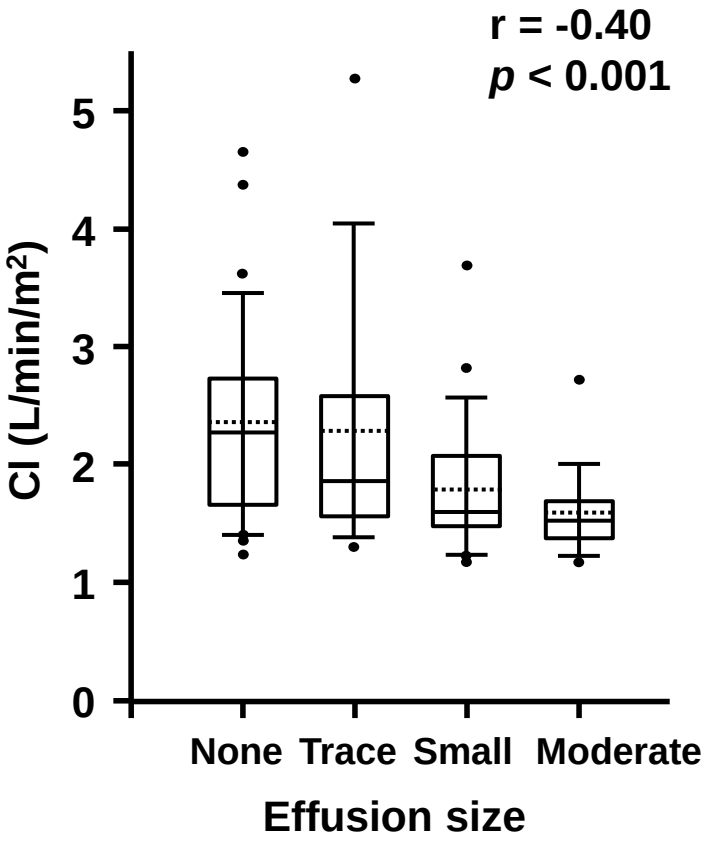
- NT-proBNP[11]
- Troponin T[12]

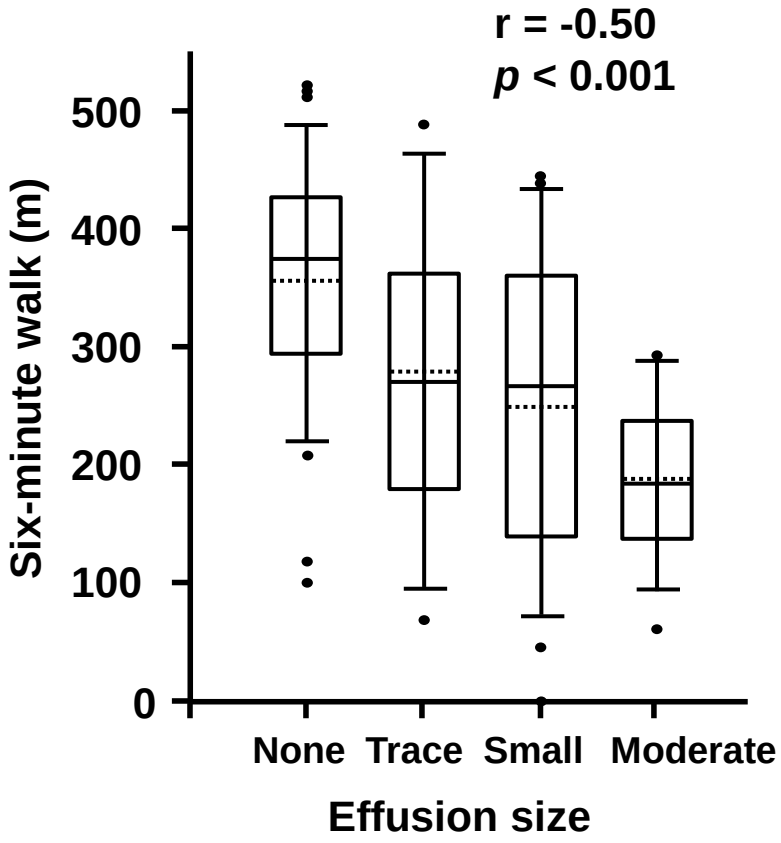
1. Grünig, *et al. DMW* 2010. 2. Ghio S, *et al. Int J Cardiol* 2010.
3. Tei C, *et al. J Am Soc Echocardiogr* 1996. 4. Raymond RJ, *et al. JACC* 2002.
5. Utsunomiya H, *et al. J Am Soc Echocardiogr* 2009. 6. van de Veerdonk M, *et al. JACC* 2011.
7. Hagger, *et al. Rheumatology* 2009. 8. Mauritz, *et al. Chest* 2012.
9. McLaughlin VV, *et al. Circulation* 2002. 10. D'Alonzo GE, *et al. Ann Intern Med* 1991.
11. Nagaya N, *et al. JACC* 1998. 12. Torbicki A, *et al. Circulation* 2003.

Echo

- **Variables in good correlation with:**
  - Hemodynamics
  - Anatomy
- **Limited visualisation of RV:**
  - Complex geometry
  - Extensive trabeculations
  - Retrosternal position

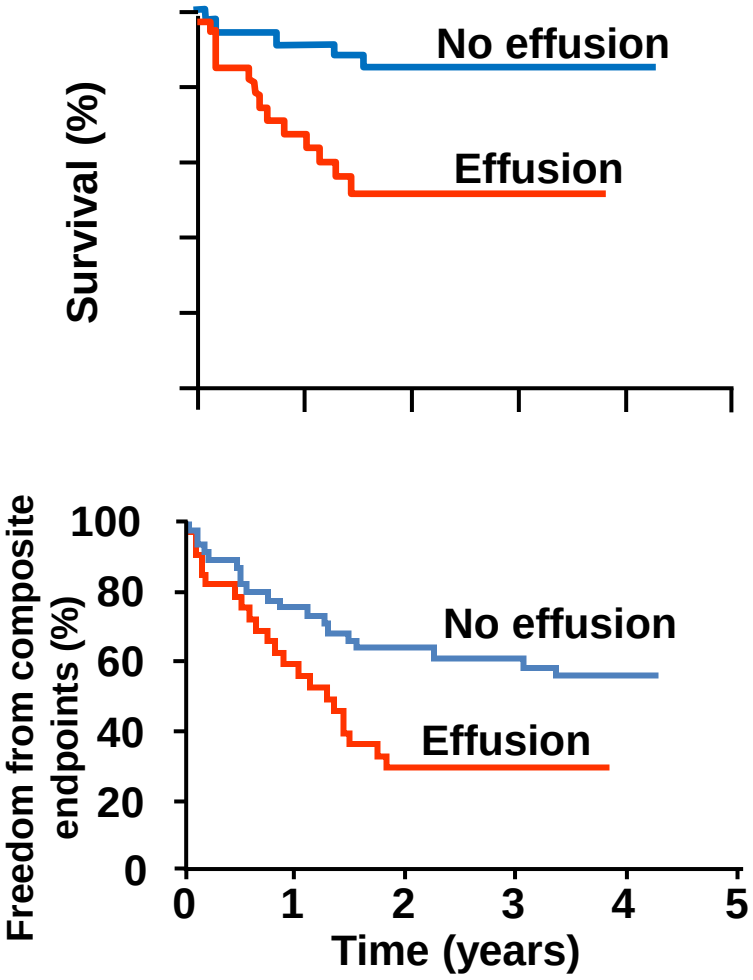
Echo - Pericardial effusion



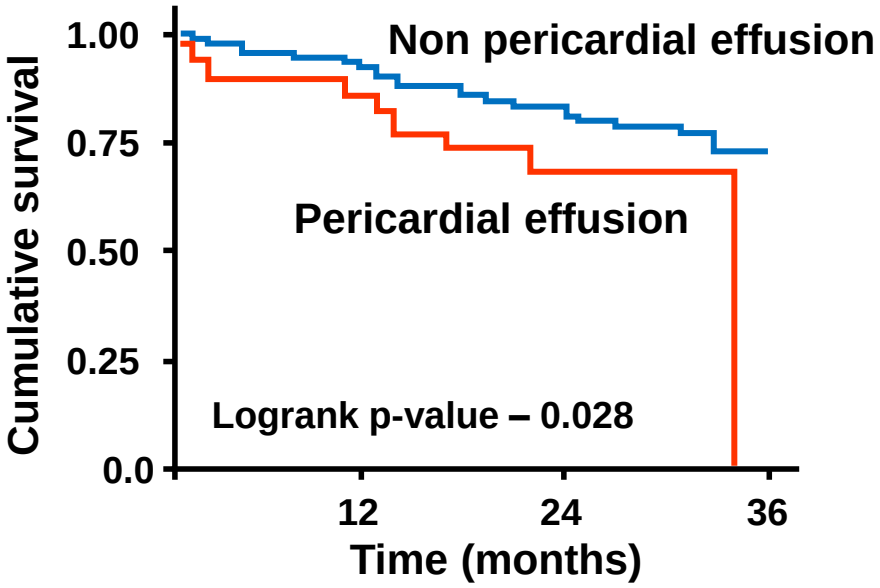


Hinderliter, *et al. AJC* 1999; 84:481-4.

Echo - Pericardial effusion

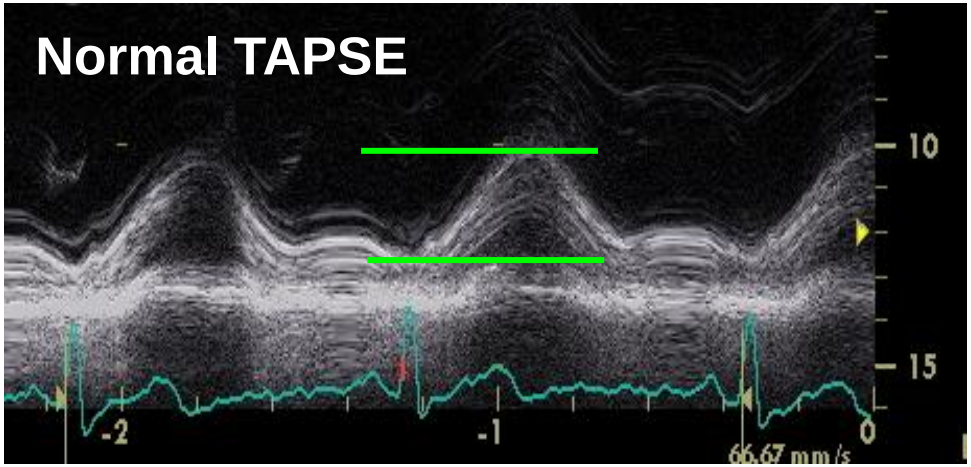


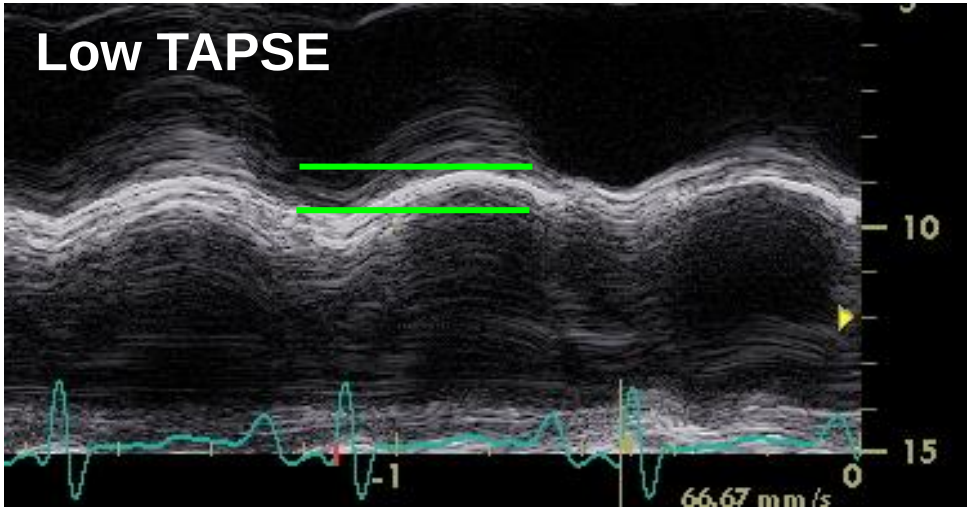
Raymond RJ, *et al. JACC* 2002; 39:1214-9.



Zhang, *et al. Chest* 2011; 140:301-9.

Echo - TAPSE

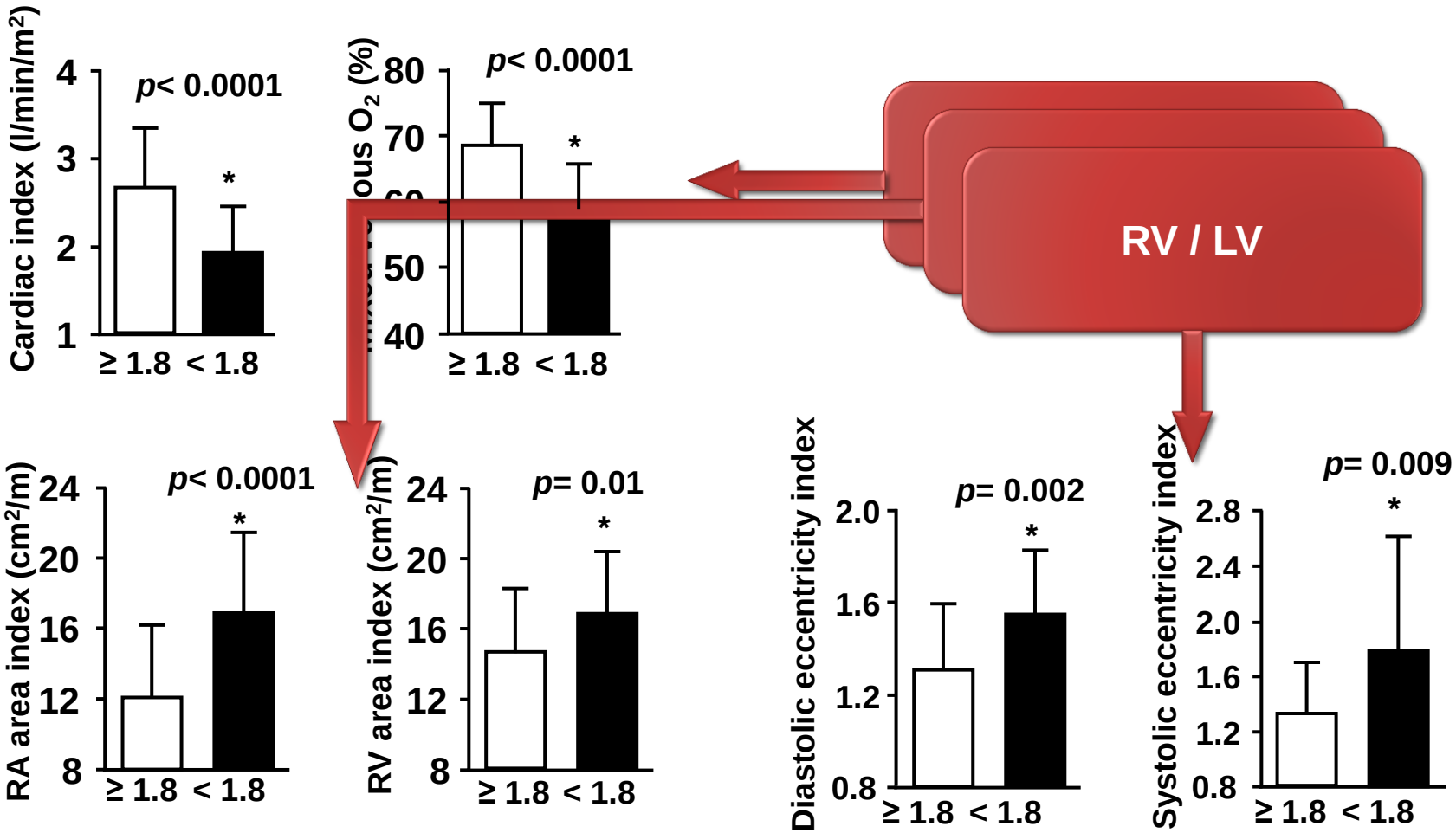




- Longitudinal movement of lateral tricuspid annulus towards apex at peak systole
- Abundant longitudinal fibres
- Correlates with RV systolic function

Rudski LG, *et al*. *J Am Soc Echocardiogr* 2010; 23:685-713.

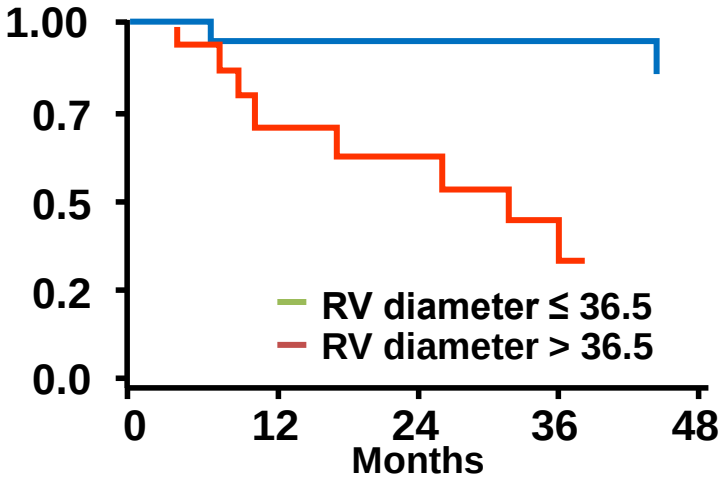
Echo - TAPSE



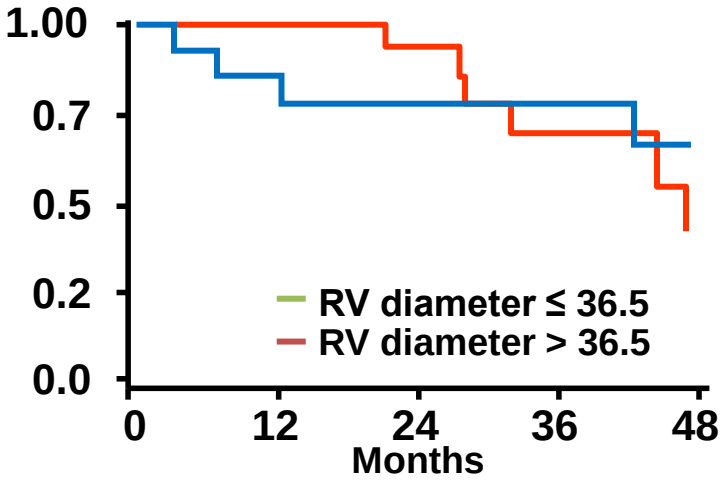
Forfia, *et al. Am J Respir Crit Care Med* 2006; 174:1034-41.

Echo - RV morphology

Survival curves in patients with RV wall thickness ≤ 6.6 mm



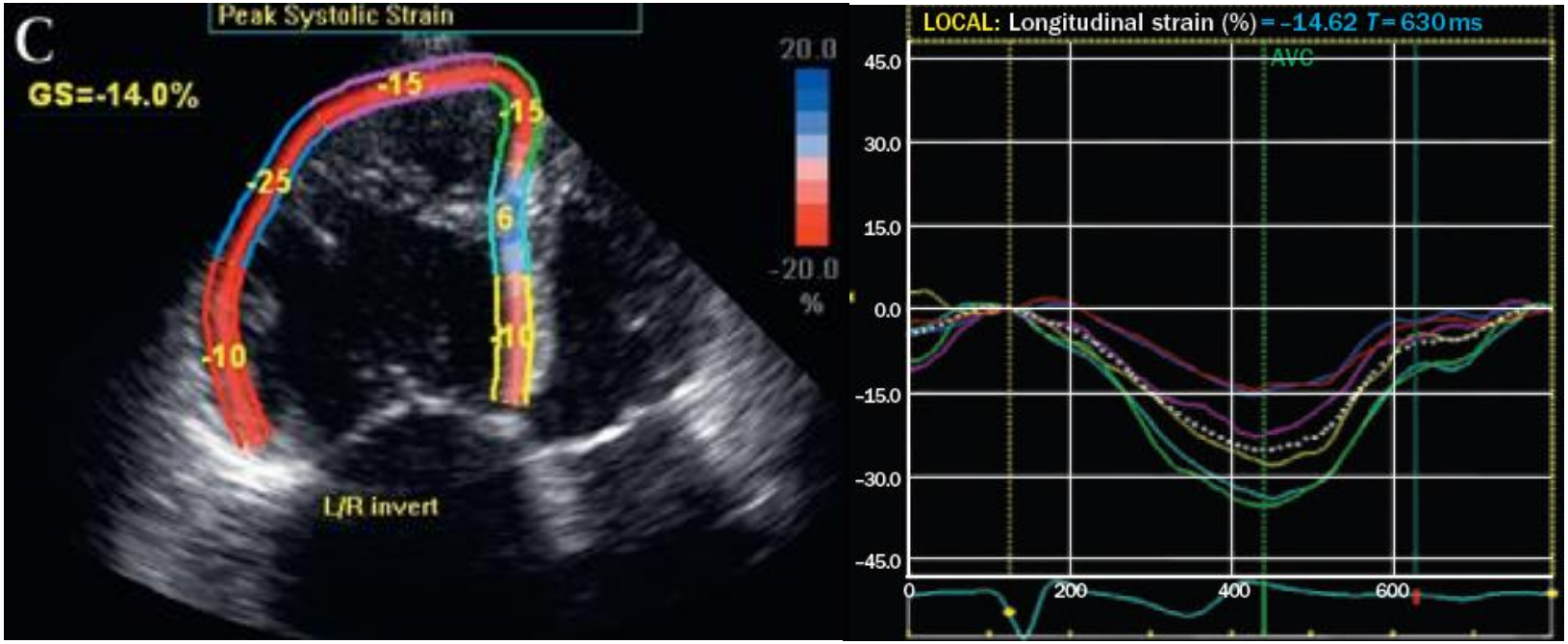
Survival curves in patients with RV wall thickness > 6.6 mm



- Death rate per 100 patient-year:
- RV diameter < 36.5 mm
  - 6.6 (95%CI 3.3-13.2)
- RV diameter > 36.5 mm
  - 15.9 (95%CI 9.4-26.8)

Ghio, *et al. AJC* 2011; 107:628-32.

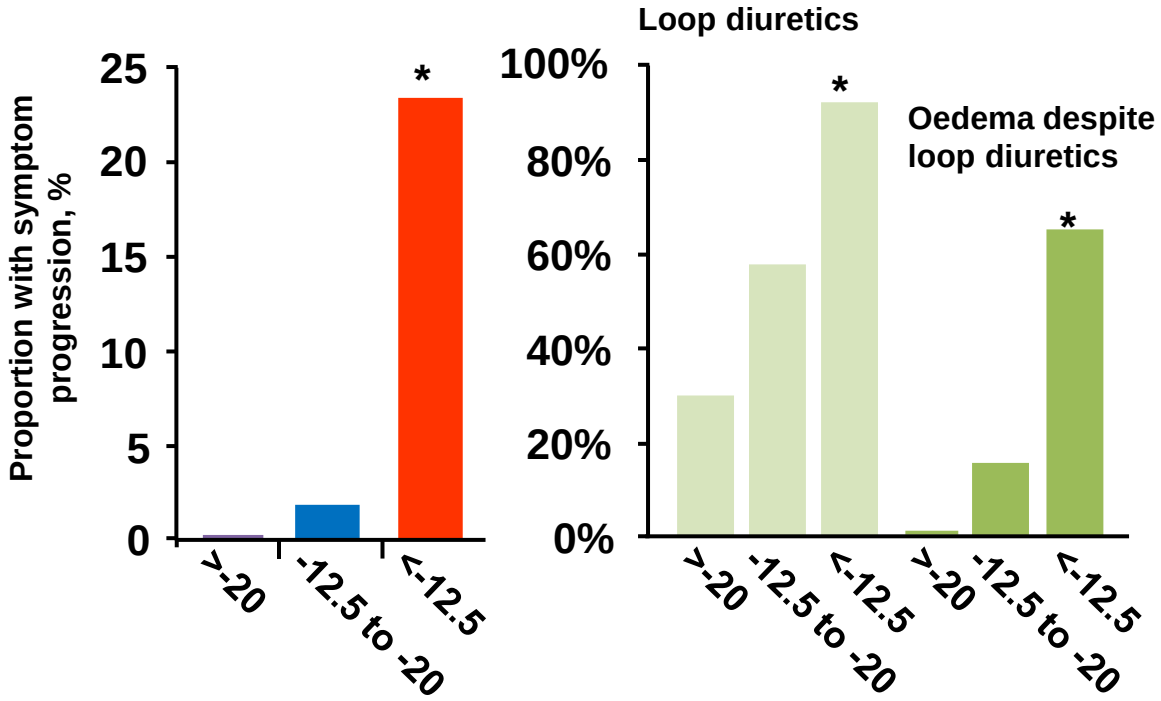
Echo - 2D longitudinal strain

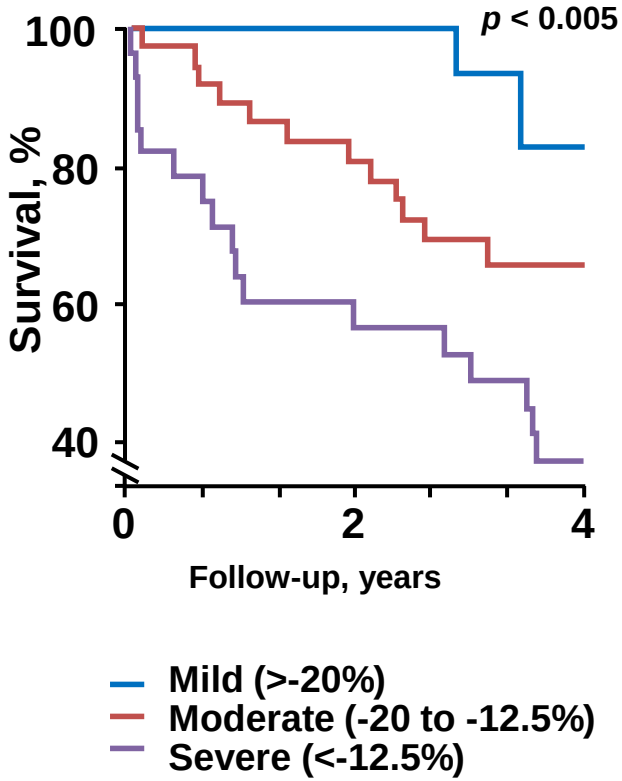


- Percentage change in myocardial deformation
- Doppler or speckles
- More negative = better contractility
- Unlike TAPSE it takes whole RV into account
- Load dependent

Freed, *et al. Cur Cardiol Rep* 2012; online early pub.

Echo - 2D longitudinal strain

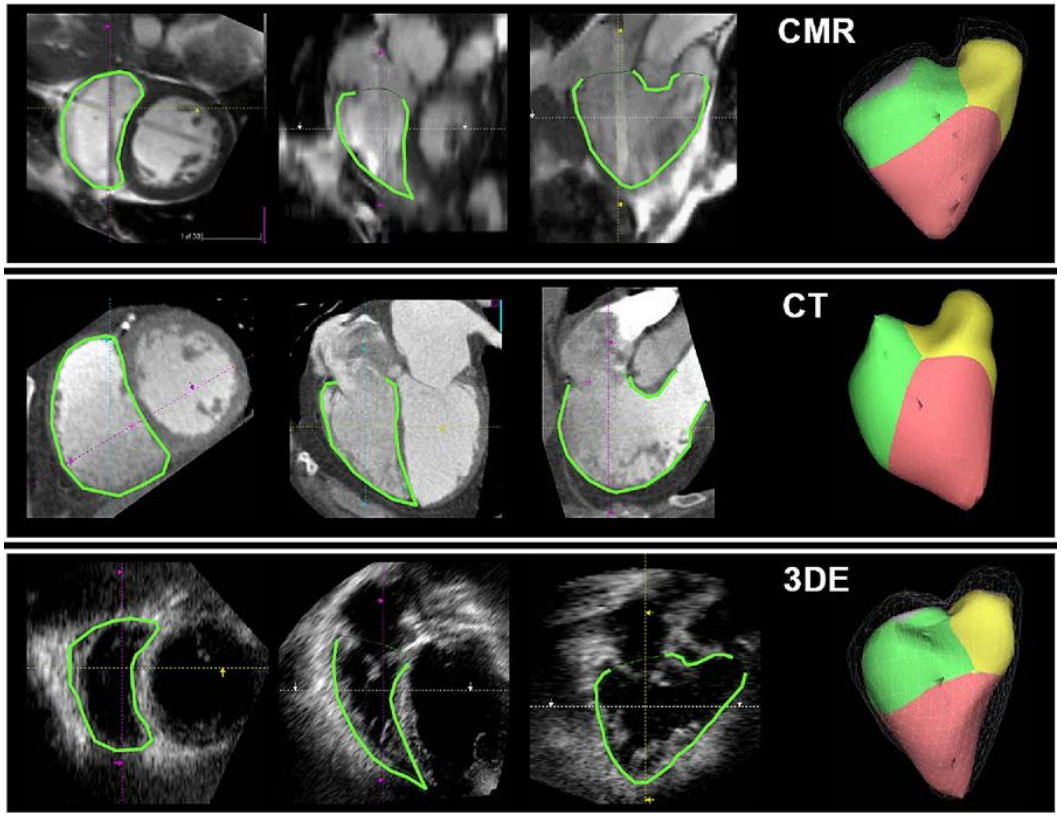




Sachdev, *et al. Chest* 2011; 139:1299-1309.

Echo - 3D

- Rapid acquisition of full volume 3D data
- Accurate & reproducible measures of RV

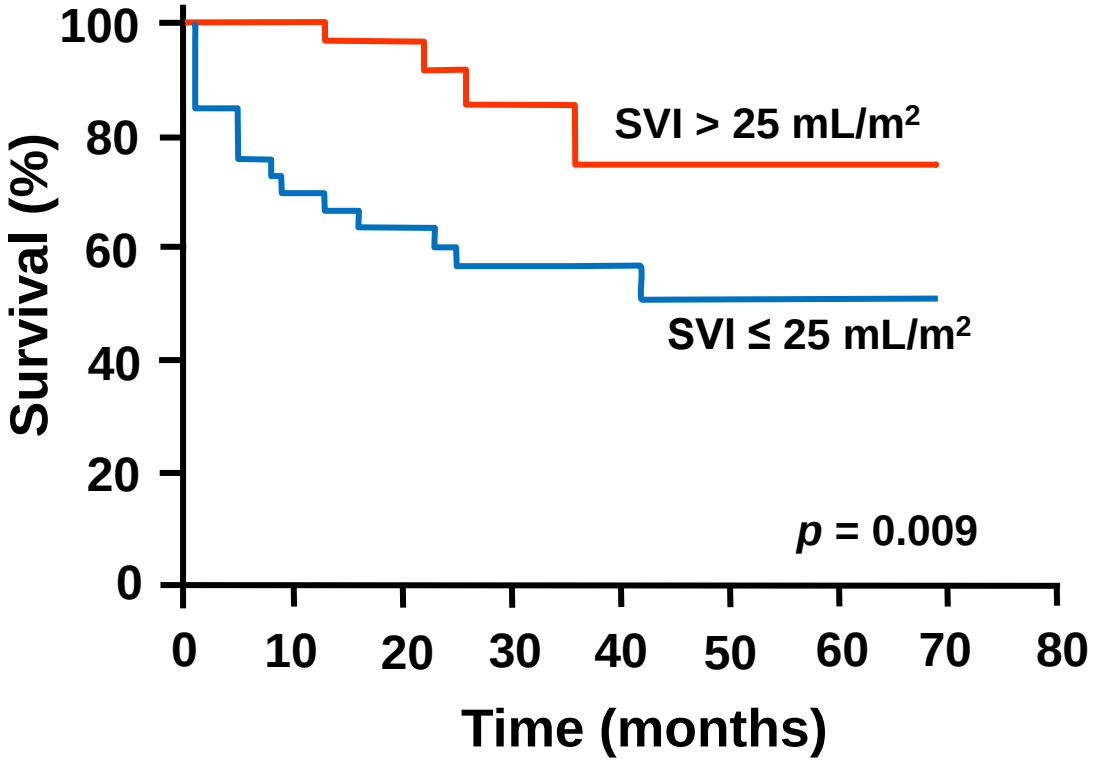


ESV (ml)	EDV (ml)	EF (%)
Correlation		
0.89	0.87	0.87
(-9ml)	(-14ml)	(-2%)

Sugeng, *et al. JACC Imag* 2010; 3:10-8.

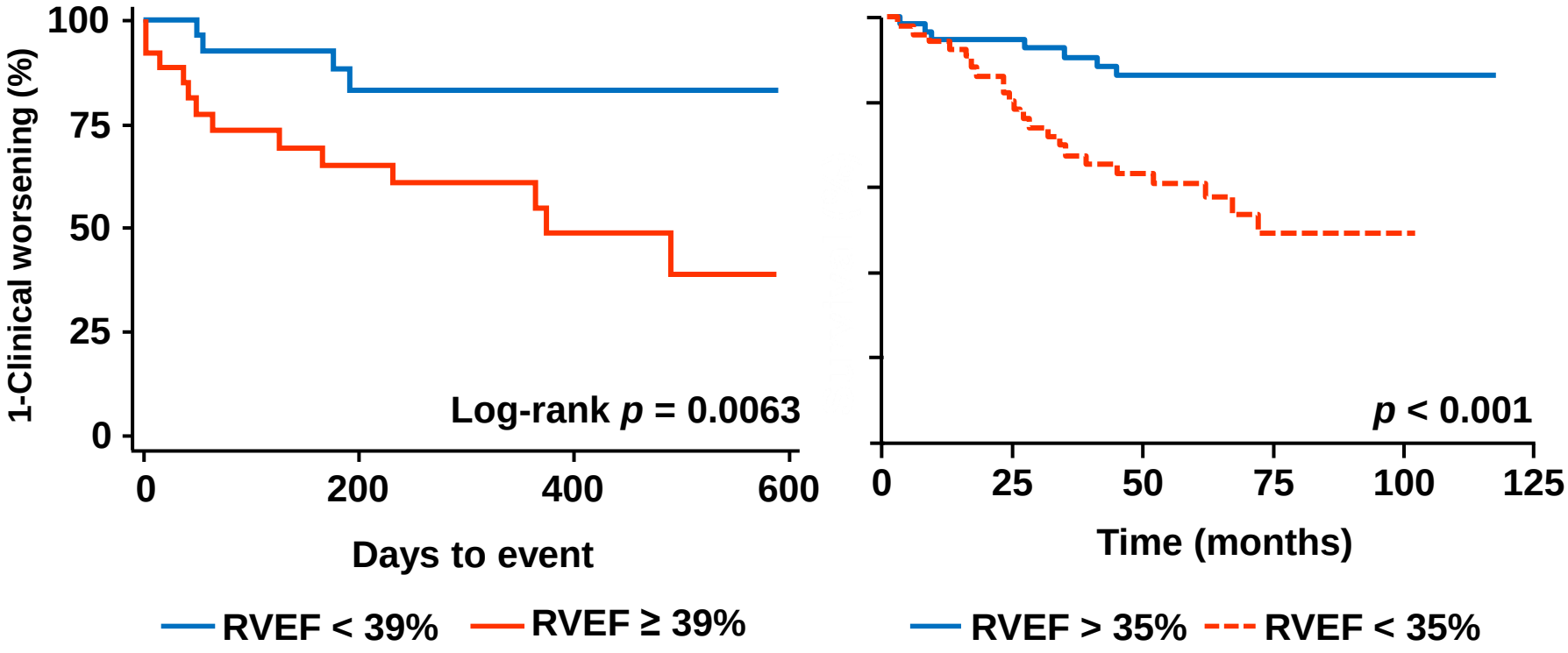
CMRI - Stroke volume

- 64 IPAH prevalent patients
- Measured at baseline by MRI
- Mean follow-up: 32 months



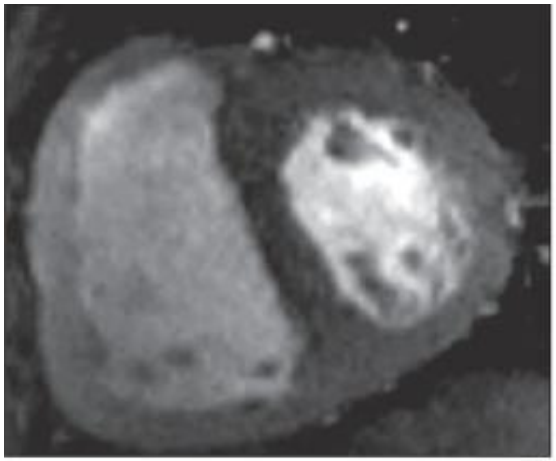
Van Wolferen SA, *et al. Eur Heart J* 2007; 28:1250-7.

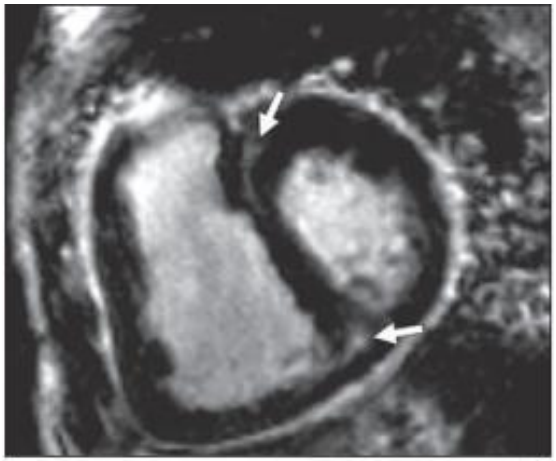
CMRI - RV ejection fraction

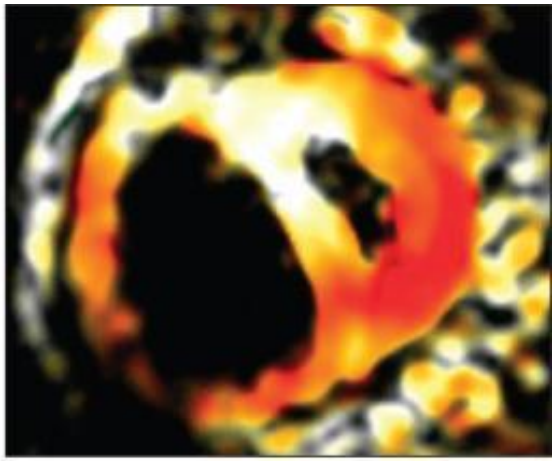


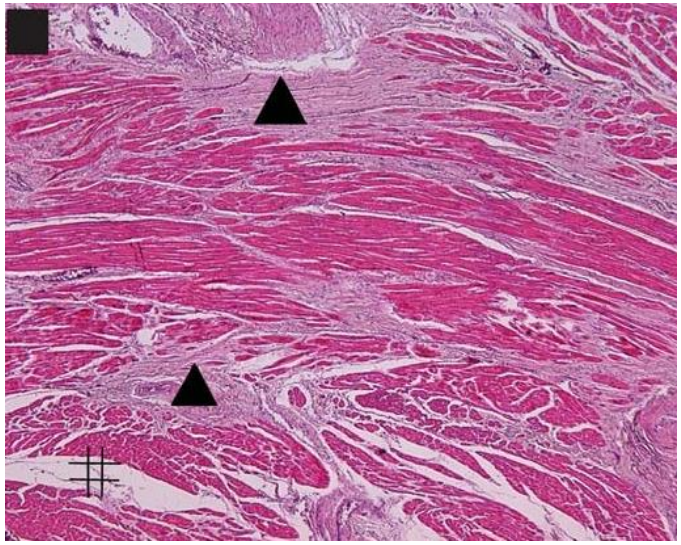
Freed *et al*. *JCMR* 2012; 14:11.
van de Veerdonk *et al*. *JACC* 2011; 58:2511-9.

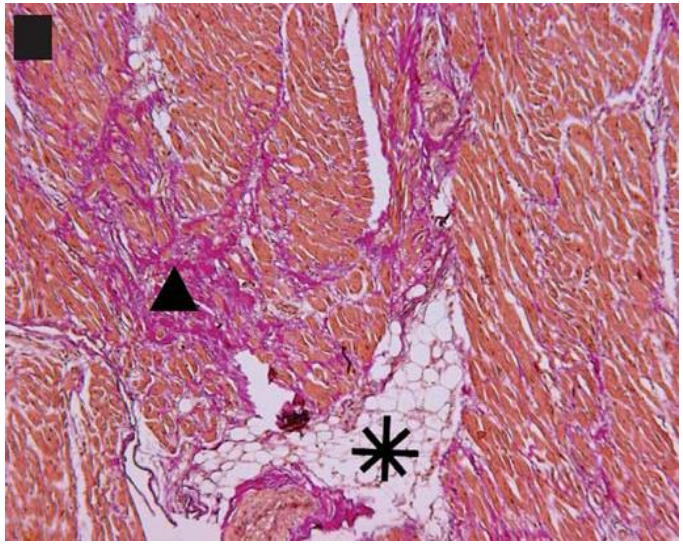
CMRI - Myocardial delayed enhancement



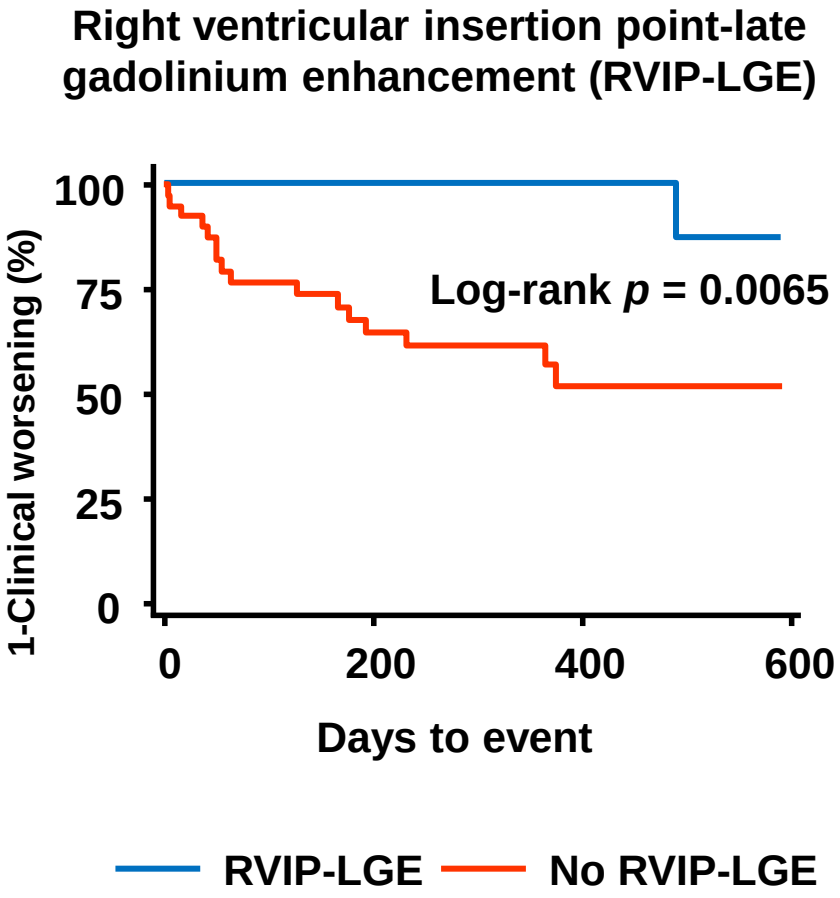


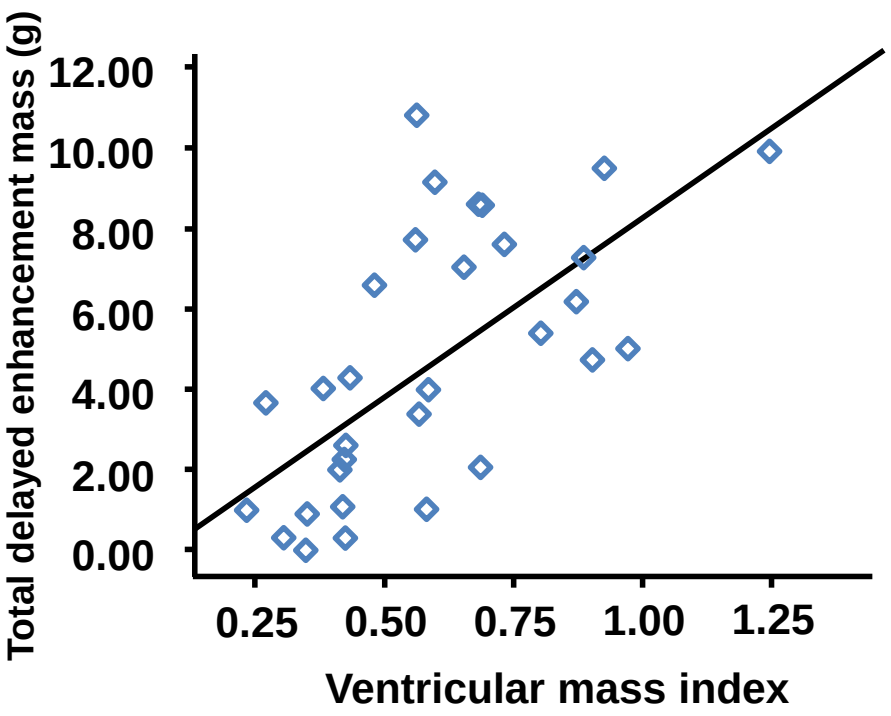






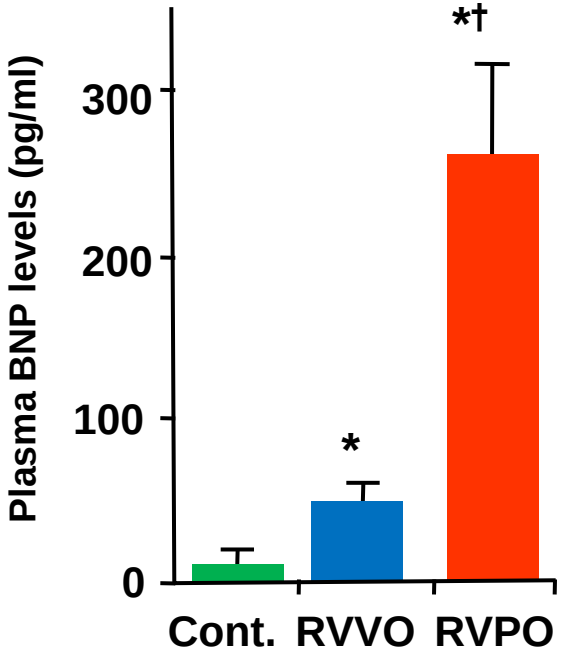
CMRI - Myocardial delayed enhancement



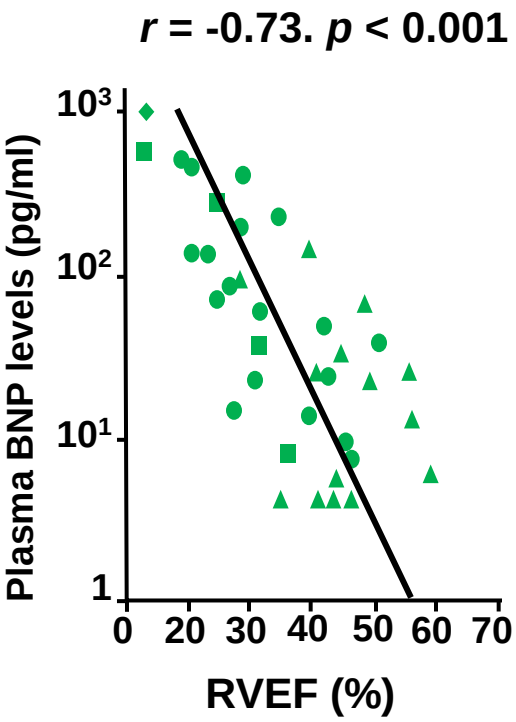


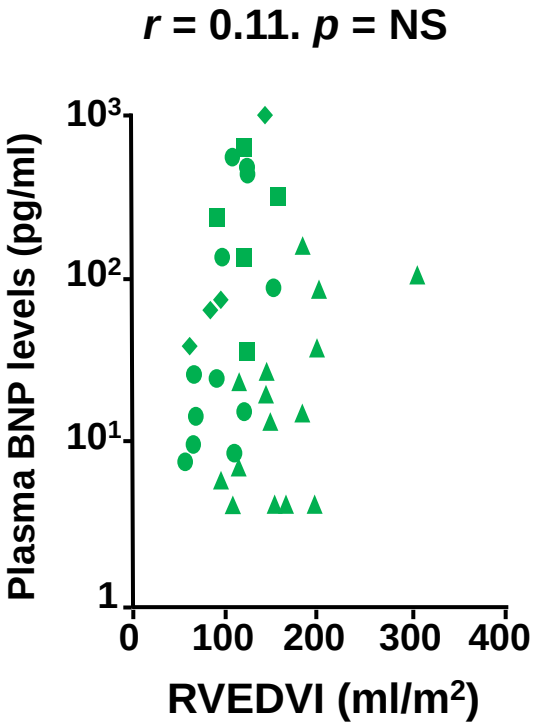
Freed, *et al*. *JCMR* 2012; 14:11.
Shehata, *et al*. *AJR* 2011; 196:87-94.

BNP as surrogate of RV function



*$p < 0.05$ vs control
†$p < 0.05$ vs RVVO

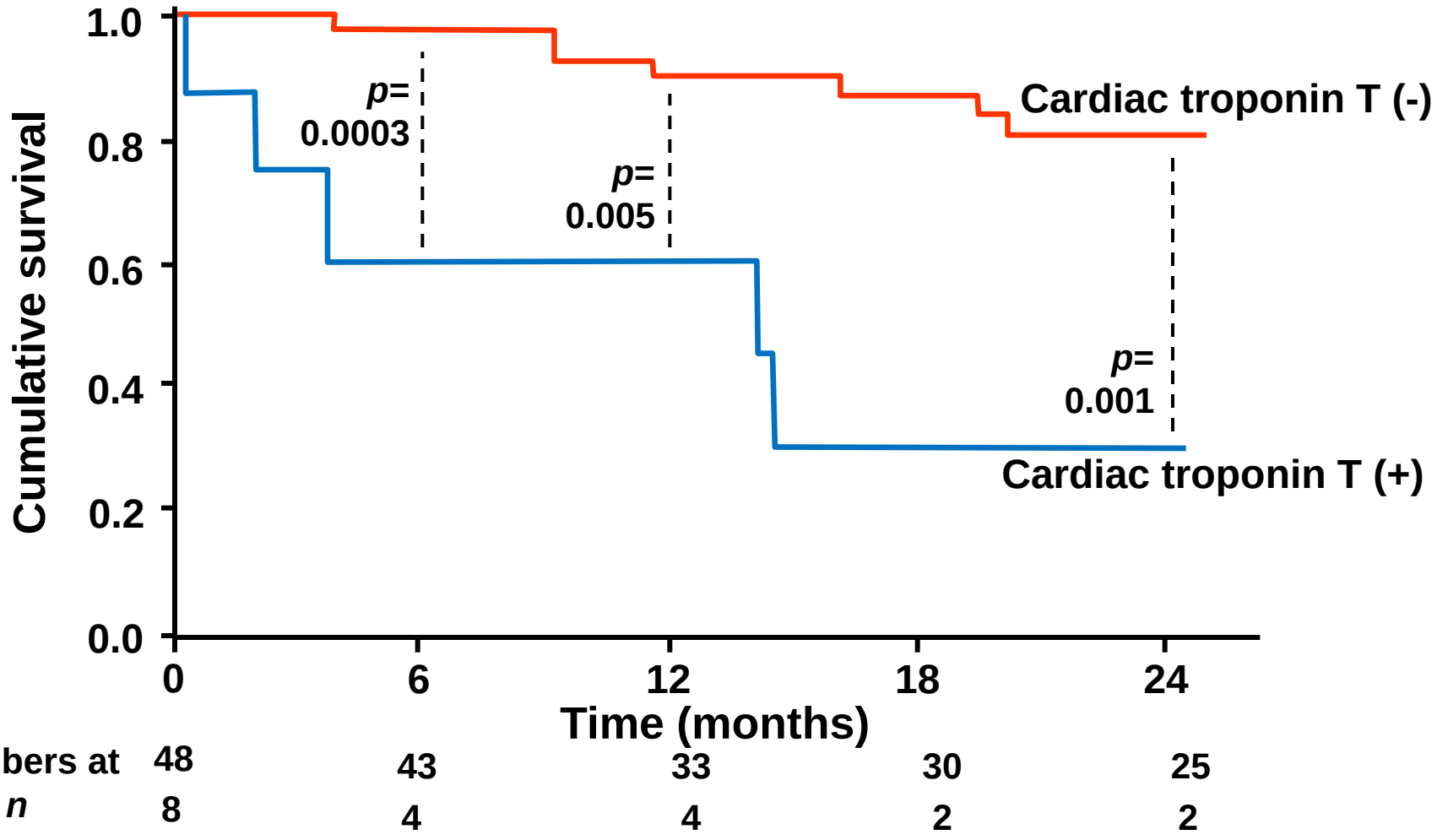




44 patients
18 - ASD (RVVO)
16 - CTEPH (RVPO)

Nagaya N, *et al*. *J Am Coll Cardiol* 1998; 31:202-8.

Prognostic value of cardiac troponin T in PAH and CTEPH patients



Torbicki A, *et al. Circulation* 2003; 108:844-8.

Conclusion

- Sir William Harvey 1616 – “De Motu Cardis”

  “Thus the right ventricle may be said to be made for the sake of transmitting blood through the lungs, not for nourishing them.”

- Paucity of knowledge regarding RV

- Understanding of RV adaptation to PH crucial for Tx.