Multi-modality Imaging in Pulmonary Arterial Hypertension : Focusing the role of CMR

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Echocardiography
Pivotal Roles in PAH

- Not confirm, but screen the presence of PH in suspected subjects
- R/O 2ndary etiologies
- FU and monitoring the treatments

Accuracy of Doppler Echocardiography in Hemodynamic Assessment of Pulmonary Hypertension

modified Bernoulli Equation

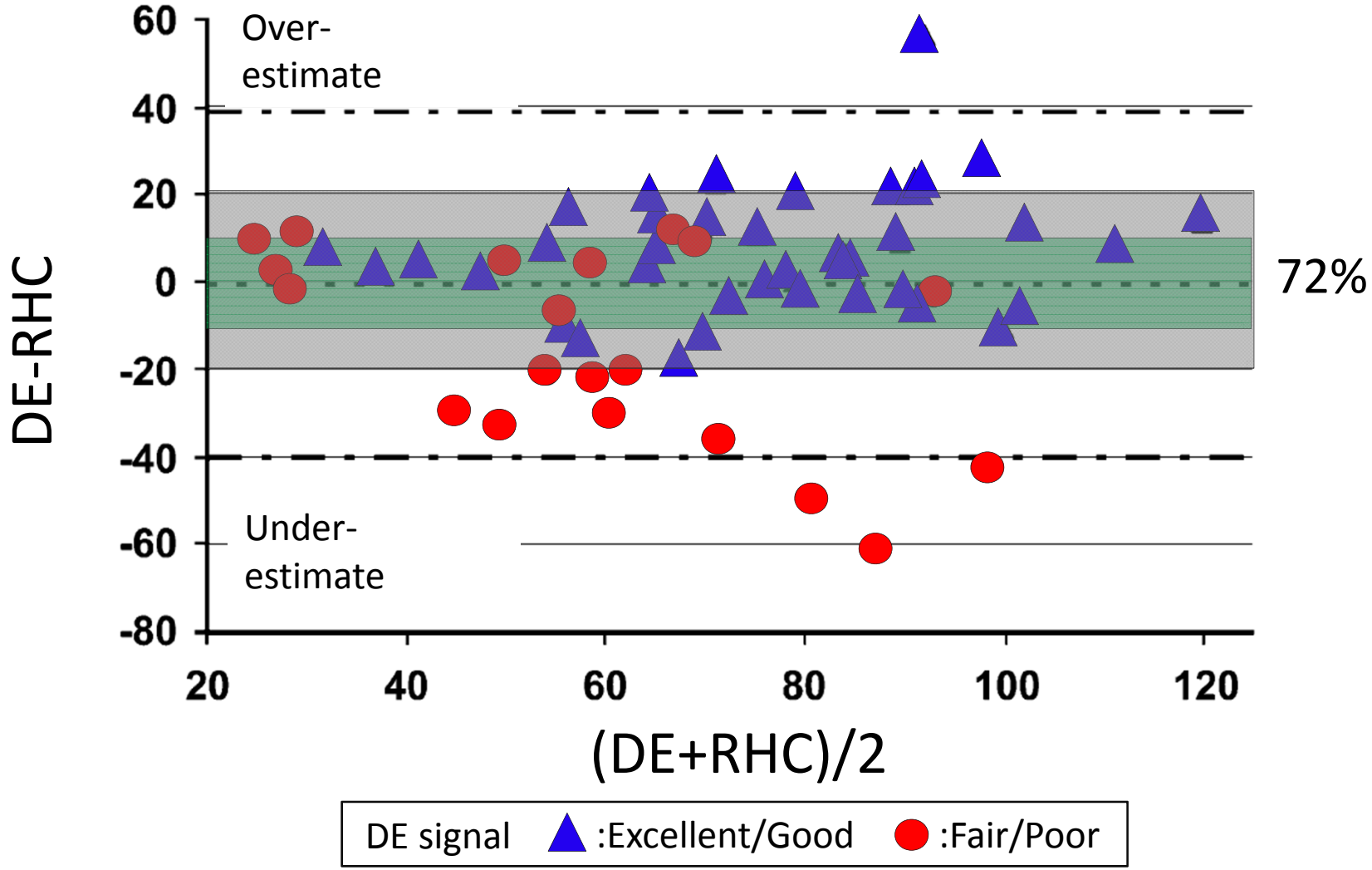
$$\textbf{PASP} = 4\,(\text{TR velocity})^2 + \text{RAP}$$

J Am Coll Cardiol 1985

establishing good correlation dose not imply that one test is an accurate substitute for another…

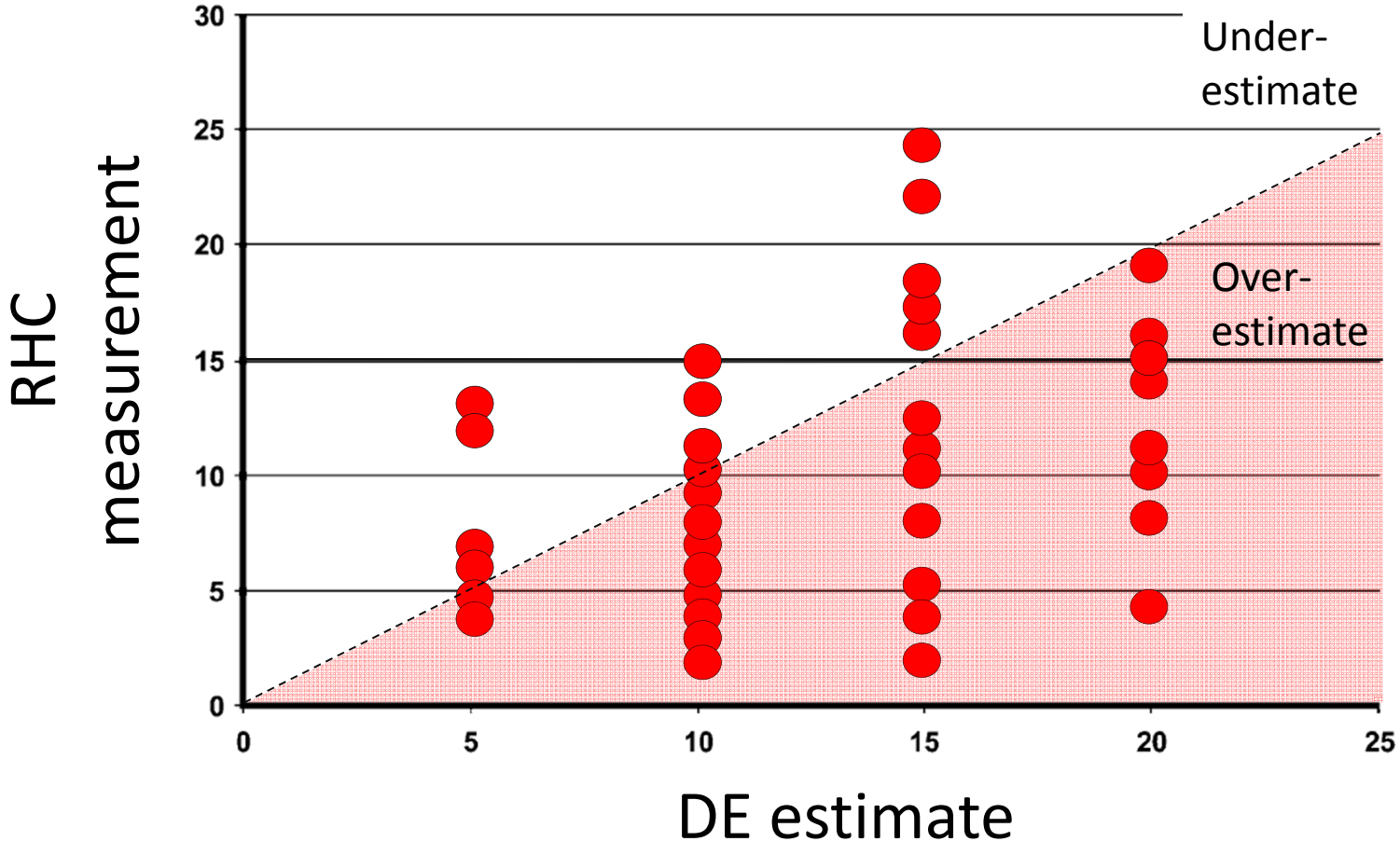
PASP (Am J Respir Crit Care Med 2009)

Doppler echocardiography was inaccurate in 28% of cases.
(Difference grater than ± 20mm Hg)



PASP = 4 (TR velocity)^2 + **RAP**

RAP (Am J Respir Crit Care Med 2009)



(Diameter 20mm + Compressibility 50% Criteria)

Pts with Emphysema

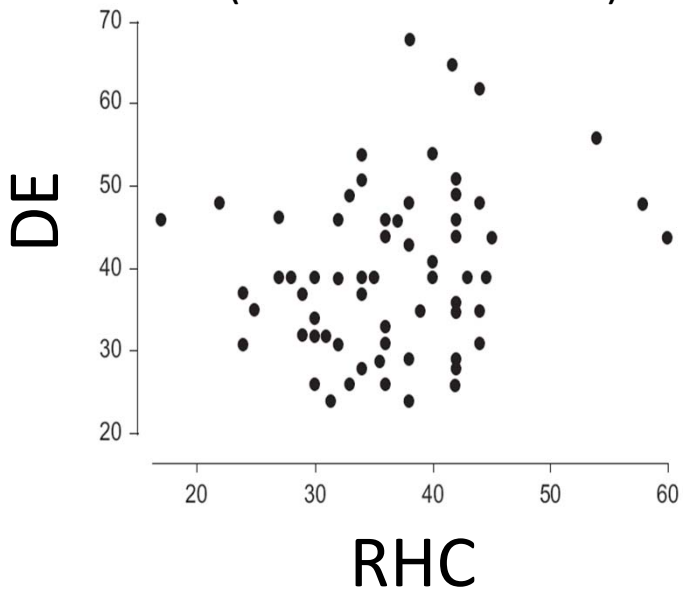
DE was inaccurate in about 1/3 of cases.
(Difference grater than ± 10mm Hg)

Pts with Advanced Lung Disease

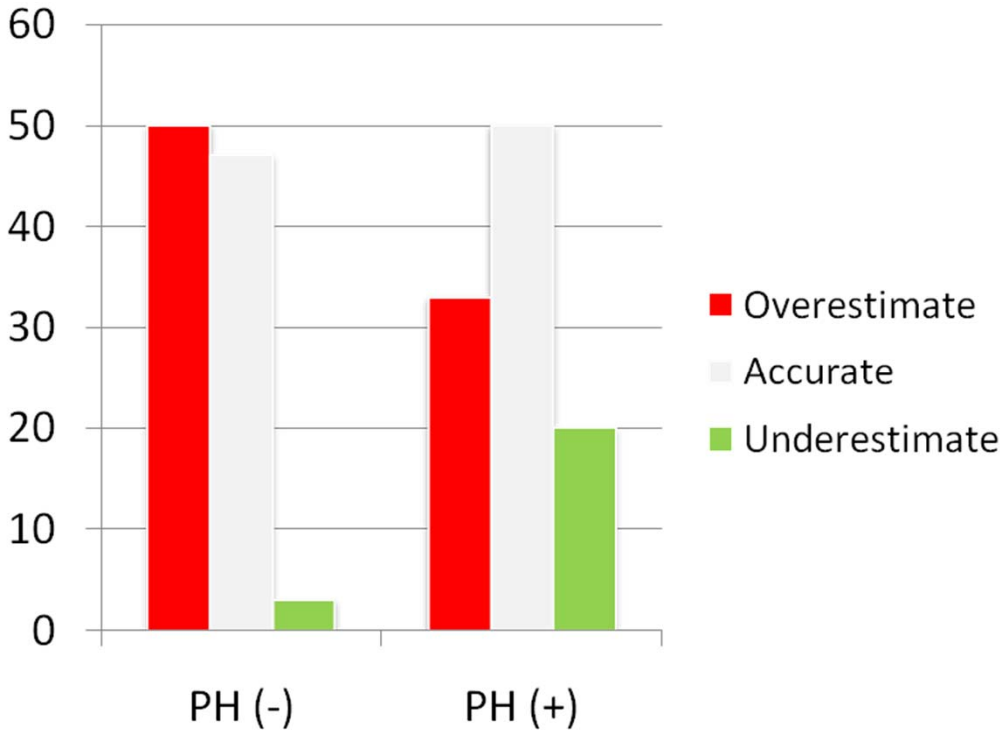
DE was inaccurate in 48% of cases.
(Difference grater than ± 10mm Hg)

PASP

Pearson correlation = 0.23
(95% CI: 0.001-0.44)



(Eur Respir J 2007)



(Am J Respir Crit Care Med 2007)

Contents

- **Emerging role of CMR in PAH: Merit of CMR**
- **Importance and Measurement of RV function in PAH: Role of CMR**
- **Severance PAH clinic Data**

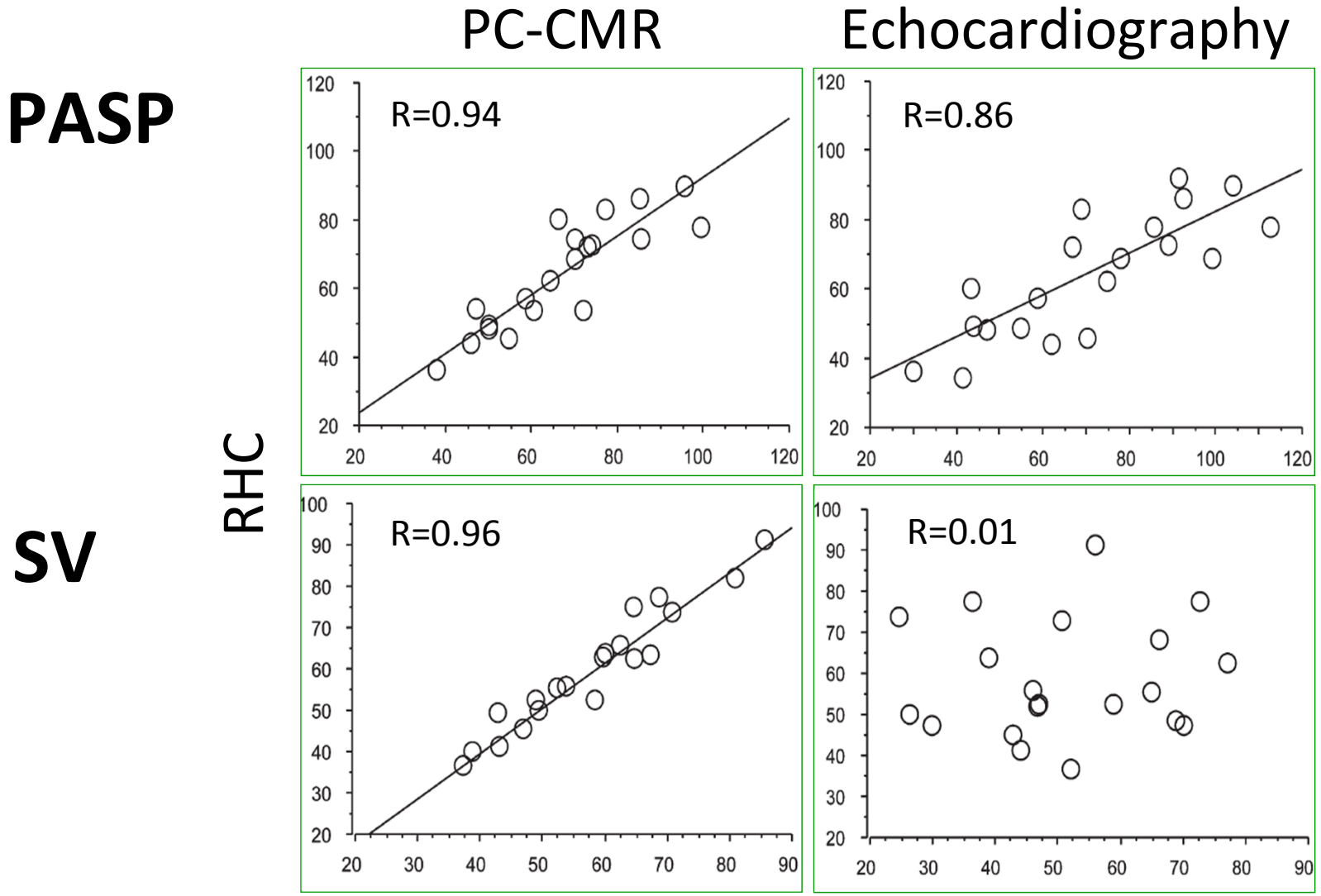
Merit of CMR
#1. Omni-plane

Clinical indications for CMR : ESC Consensus Report

Although CMR is analogue to echocardiography, major advantage is that it can be conducted in any orientation or plane.

Pennell et al. Eur Hear J 2004

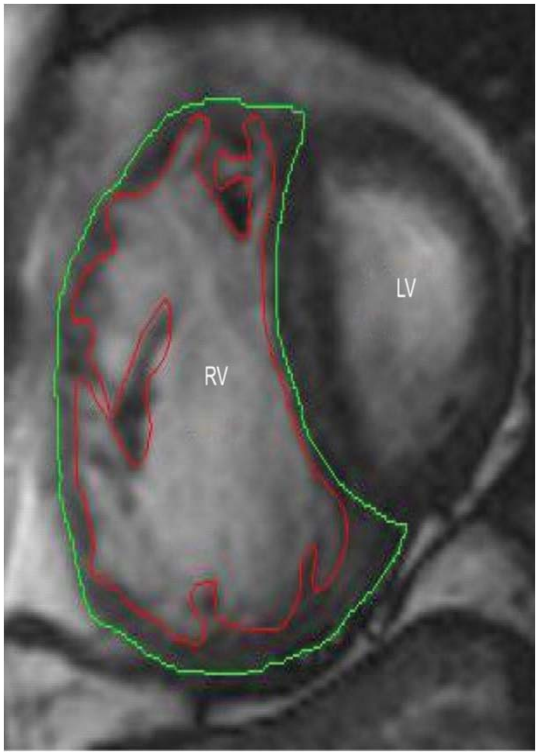
Hemodynamic Assessment in PAH



Nogami et al. J Magn Resonance Imaging 2009

#2. Excellent tissue-contrast

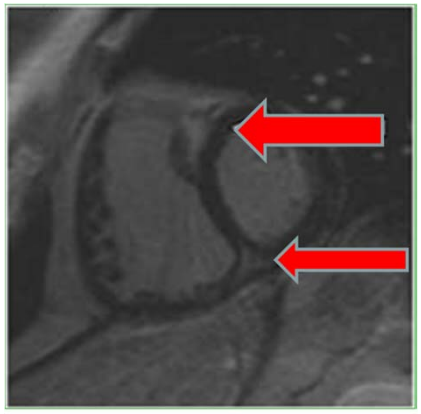
CMR Inter-study variability: RV



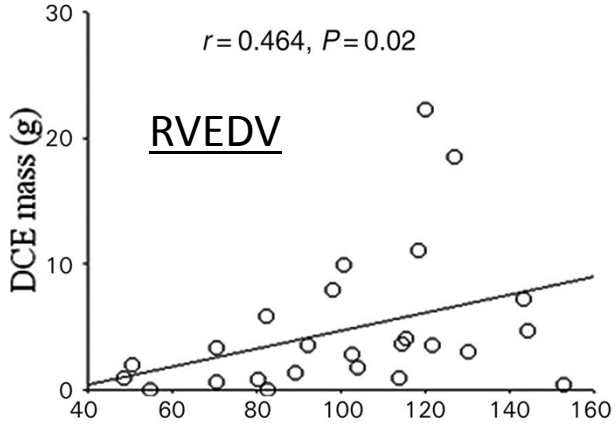
CV (%)	Normal	CHF	LVH
EDV	4.2 (2.9/5.5)	7.8 (3.1)	6.2 (4.9)
ESV	8.1 (6.5/17.5)	14.5 (4.4)	18.1 (9.2)
SVI	4.3 (3.9/10.7)	7.5 (5.7)	10.8 (5.6)
EF	4.3 (2.4/8.6)	10.4 (7.3)	10.0 (3.7)
RVMI	7.8 (2.8/11.6)	9.0 (4.8)	9.4 (3.9)

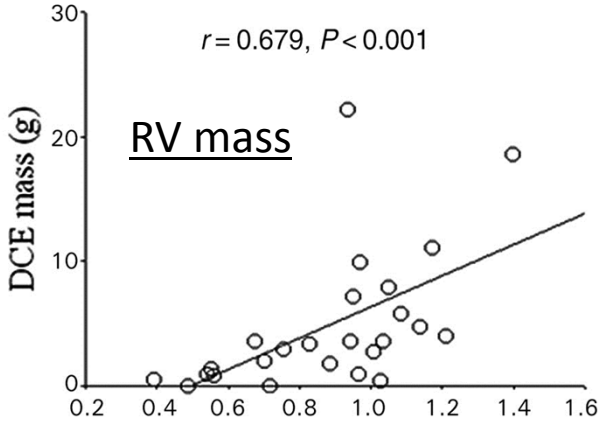
Grothues, et al. Am Heart J 2004 (2002)

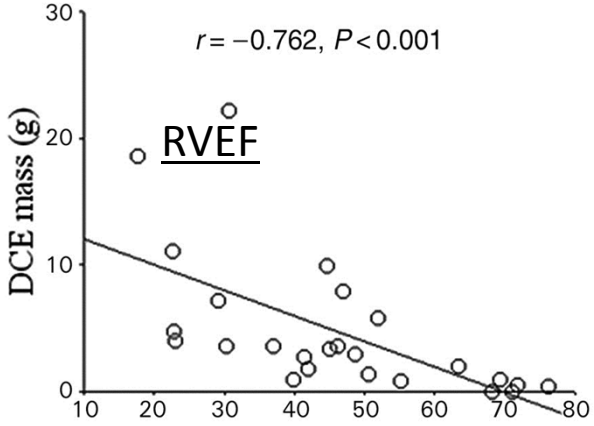
#3. Delayed hyperenhancement

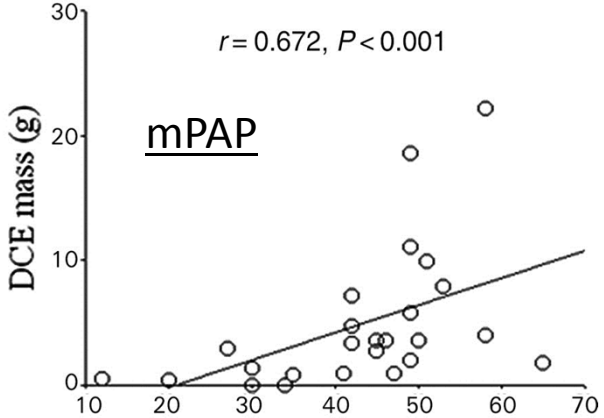


delay contrast enhancement



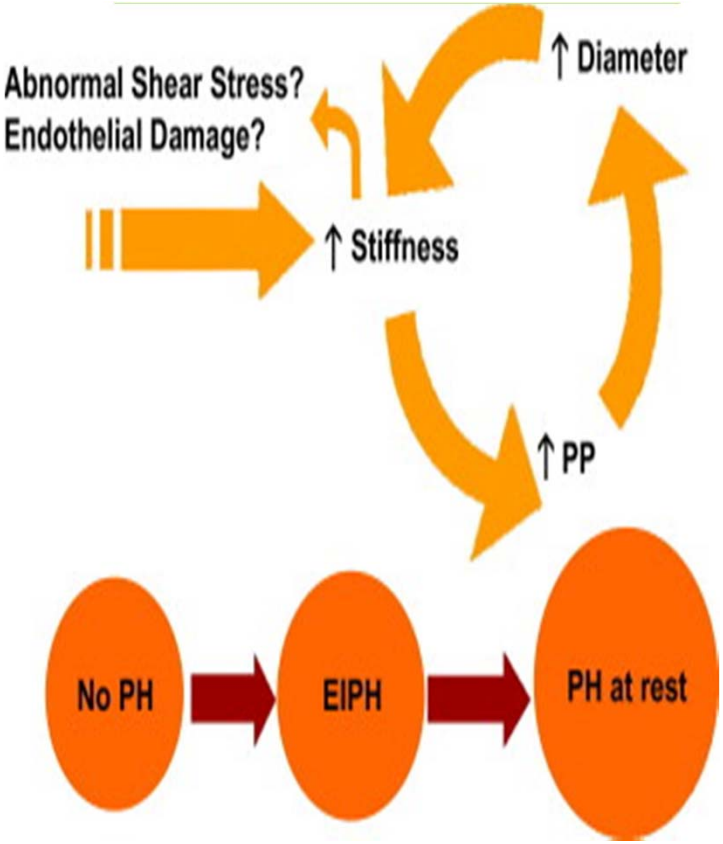






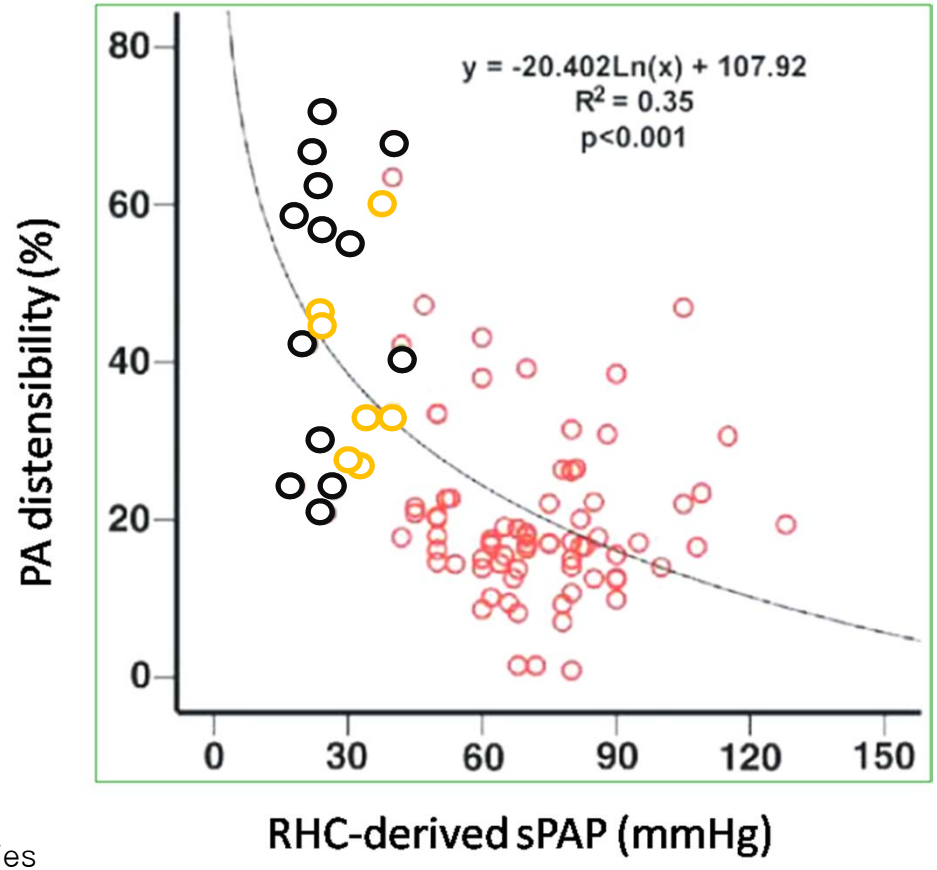
Blyth et al. Eur Heart J 2005

#4. PA distensibility



causing further stiffening and shear stress abnormalities
and establishing a positive feedback cycle of disease progression.

Jardim et al. Eur Respr J 2007

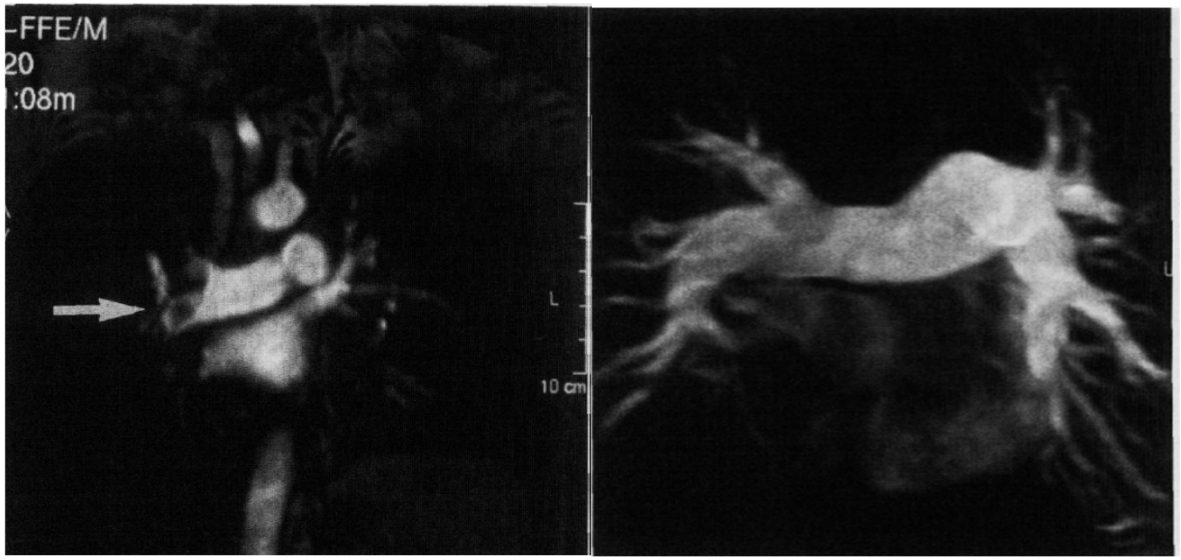


Sanz et al. JACC CV imaging 2009

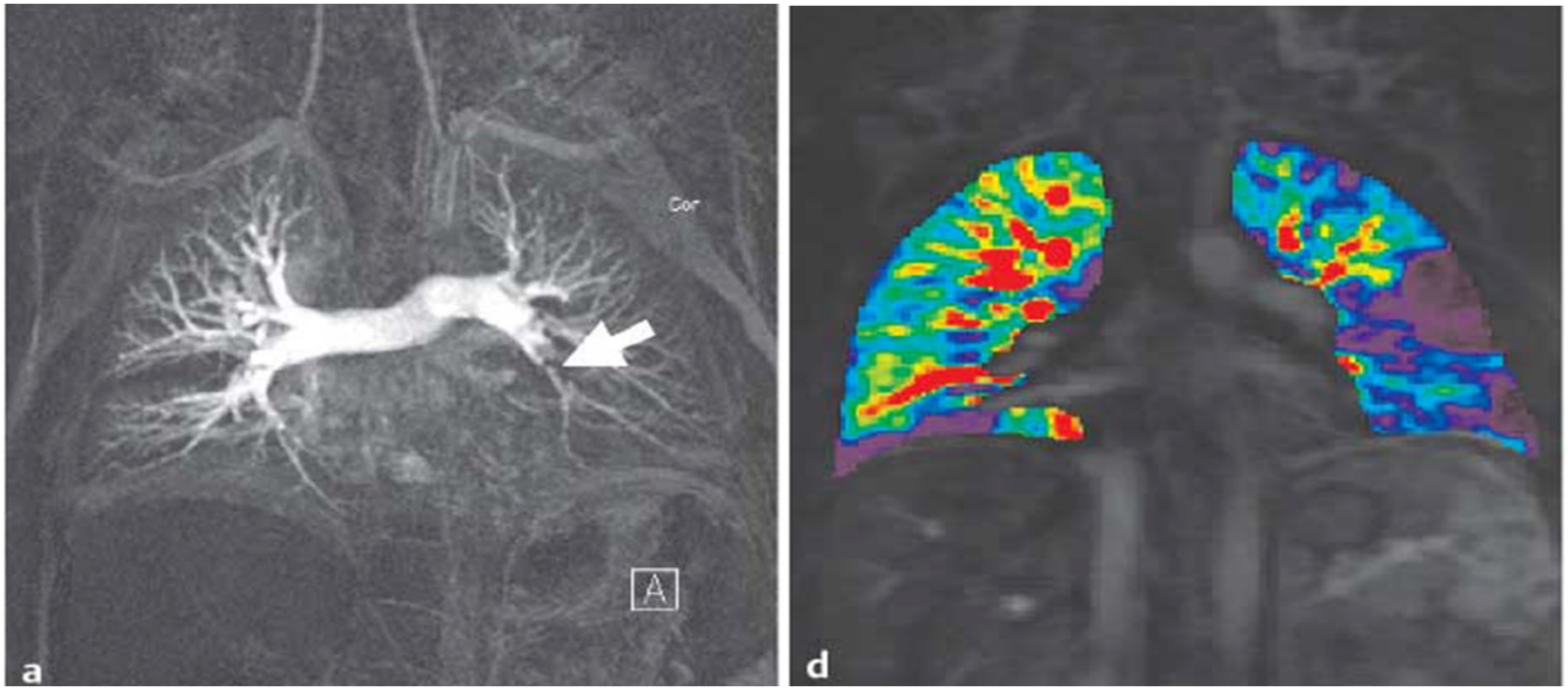
#5. PAH & embolism with MRA

(CHEST 2001; 120:1556–1561)

Methods: **Fifty patients (21 women; mean [± SD] age, 52 ± 16 years) were examined with gadolinium-enhanced PMRA for the evaluation of pulmonary artery (PA) disease. The diagnosis of PAH (*ie*, systolic PA pressure of > 35 mm Hg) was determined by Doppler echocardiography. The criteria for the diagnosis of chronic PAH by PMRA were dilated central PAs (diameter > 28 mm) and abnormal proximal-to-distal tapering of the PAs. The diagnostic criterion for acute and chronic PE was the presence of an intravascular filling defect.**



Lung Perfusion MRI: PTE



Fink et al. Fortschr Roentgenstr2004

ACCF/ACR/AHA/NASCI/SCMR 2010 Expert Consensus on CMR

No guidelines or appropriate use criteria highlighting the utility of CMR for assessment of pulmonary artery diseases exclusive of congenital heart disease.

Hundley et al. Circulation 2010

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Predictors of Survival

-PPH (N=178), NYHA III/IV-

Variables	HR (95% CI)	P-value
Age		NS
Gender		NS
Hx. of Syncope		NS
Hx. of RHF	2.19 (1.31-3.64)	0.003
NYHA IV vs. III	2.24 (1.34-3.73)	0.002
6MWD (<250m)	2.20 (1.31-3.69)	0.003
mRAP (>12mmHg)	2.74 (1.58-4.75)	0.0003
mPAP (<65mmHg)	1.72 (1.04-2.86)	0.036
Cardiac Index		NS
TPR		NS
SvO2 (<55%)		NS

Stibon et al. JACC 2002

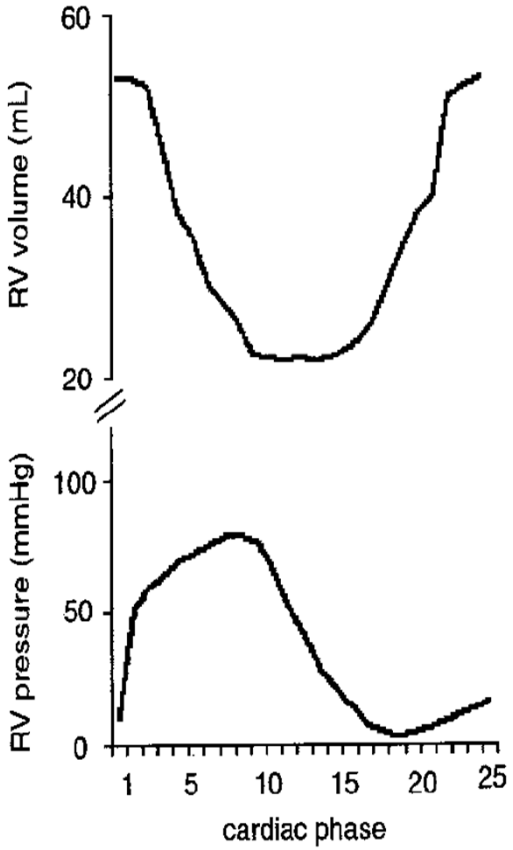
Parameters in evaluation of RV function

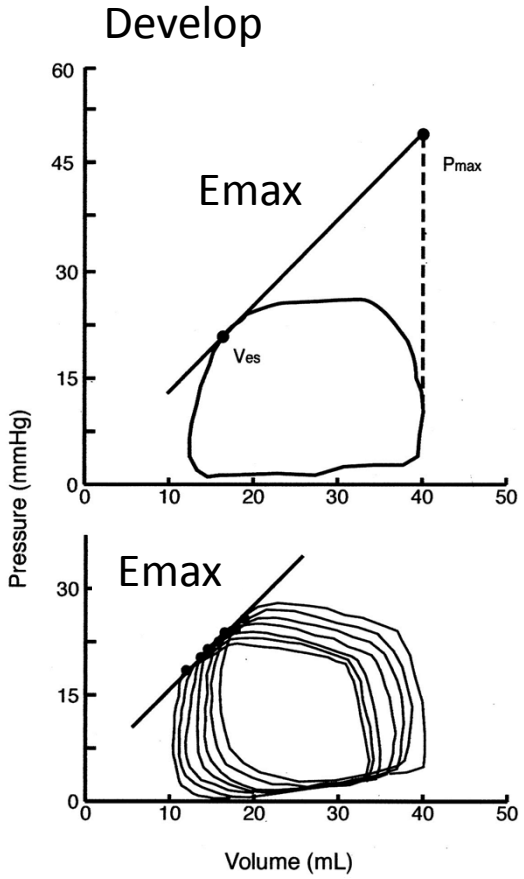
Functional Parameters	Clinical Utility	Load Dependence*
RVEF, %	Clinical validation, wide acceptance Prognostic value in cardiopulmonary disorders[9]	+ + +
RVFAC, %	Good correlation with RVEF Prognostic value in MI and bypass surgery[48]	+ + +
TAPSE, mm	Simple measure not limited by endocardial border recognition: Good correlation with RVEF	+ + +
Sm annular, cm/s	Good sensitivity and specificity for RVEF <50%[63]	+ + +
Strain	Correlates with stroke volume[69,70]	+ + +
Strain rate, s^{-1}	Correlates with contractility[69,70]	+ +
Maximal RV elastance, mm Hg/mL	Most reliable index of contractility[9]	+

Haddad et al Circulation 2008

RV performance:
MRI analysis of RV Pressure-Volume loop

Balloon-
tipped
catheter in R V

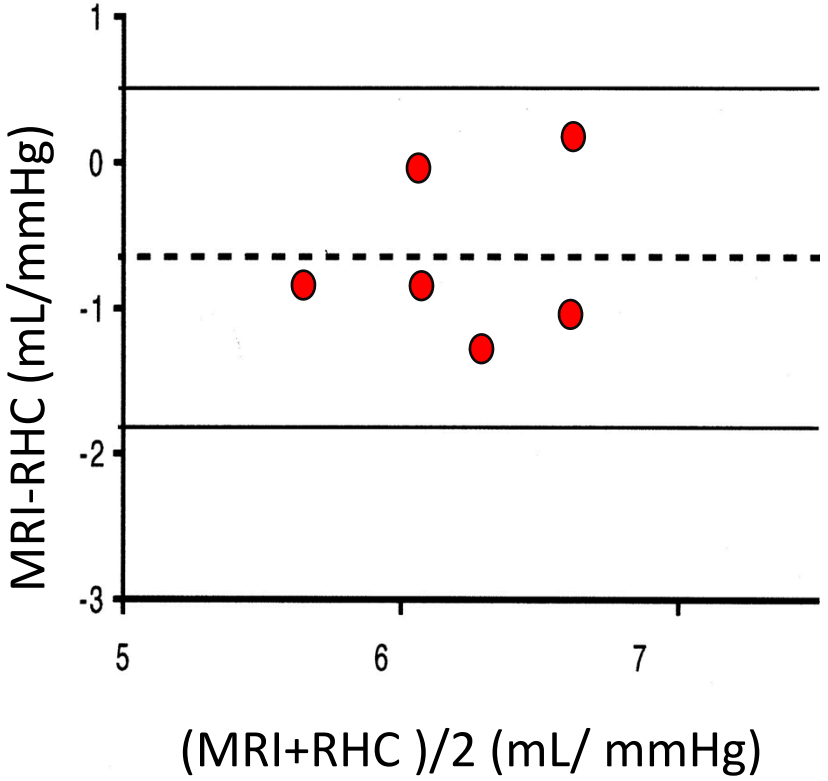




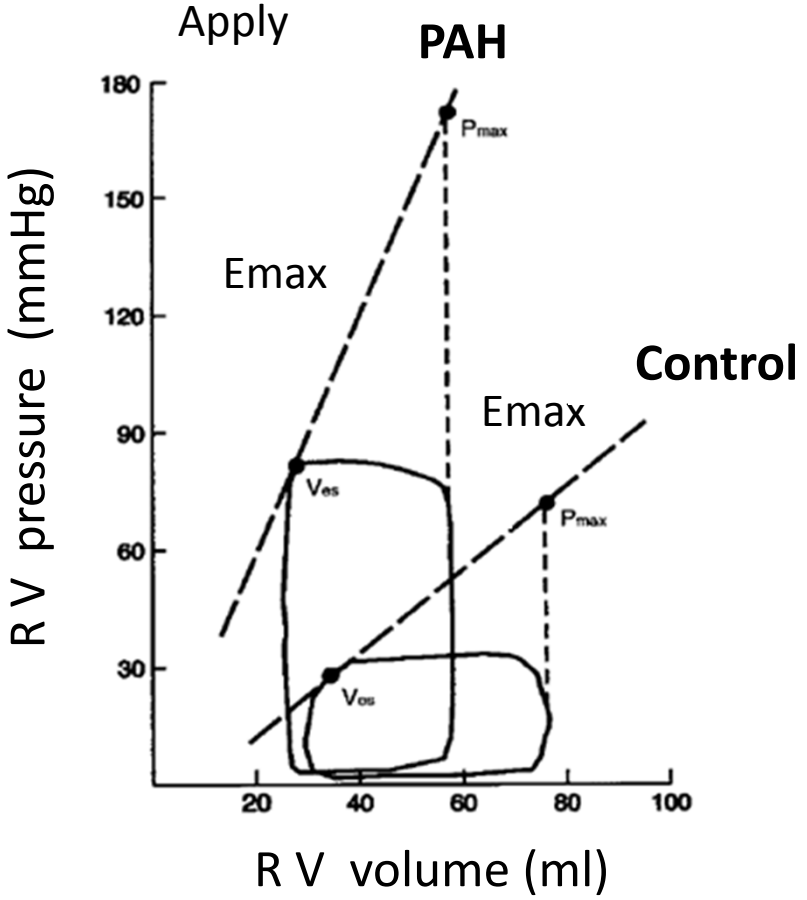
Kuehne et al. Circulation 2004

RV performance:
MRI analysis of RV Pressure-Volume loop

Validate



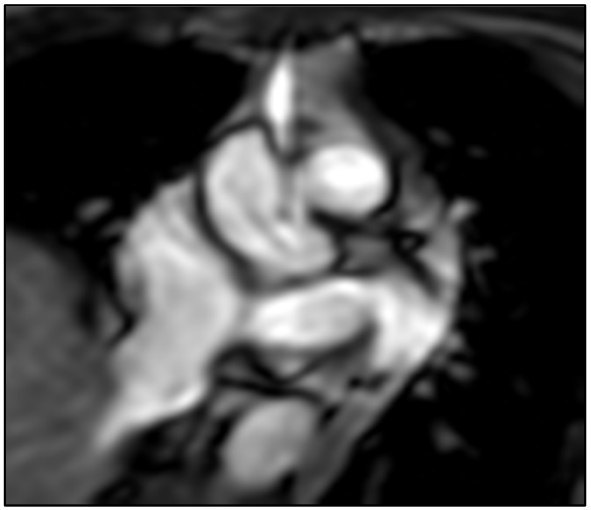
Apply

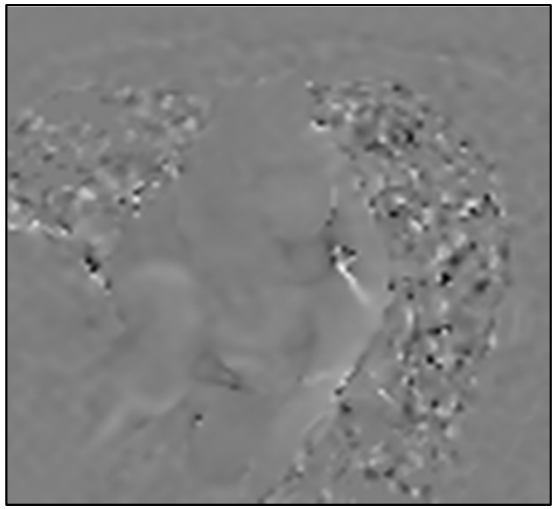


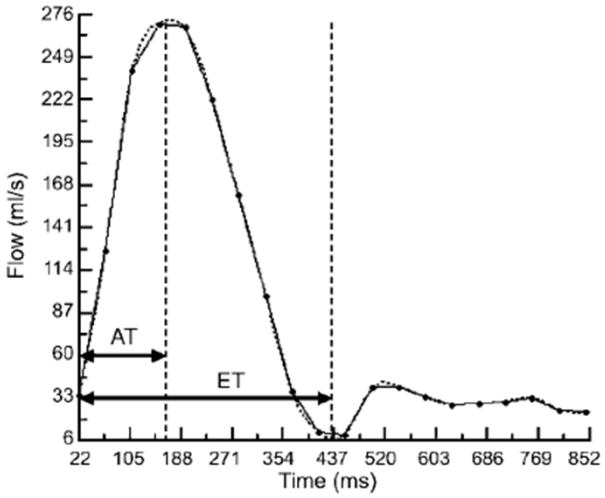
Kuehne et al. Circulation 2004

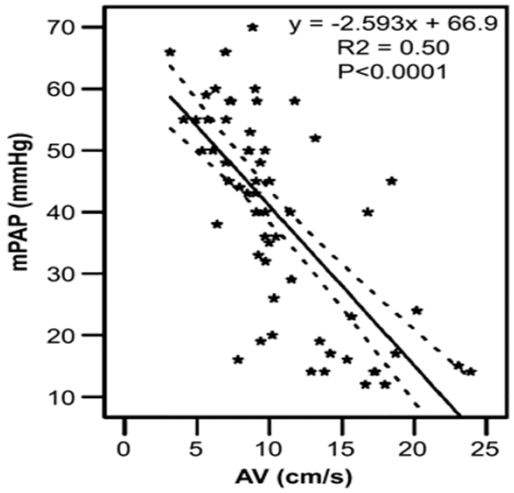
Other application of PC-CMR in PAH

: AT, ET and AV









Sanz et al Radiology 2007

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Study Aims

- To validate the correlation of CMR-derived index with RV hemodynamics in PAH

- To compare it to clinical performance in patients with PAH

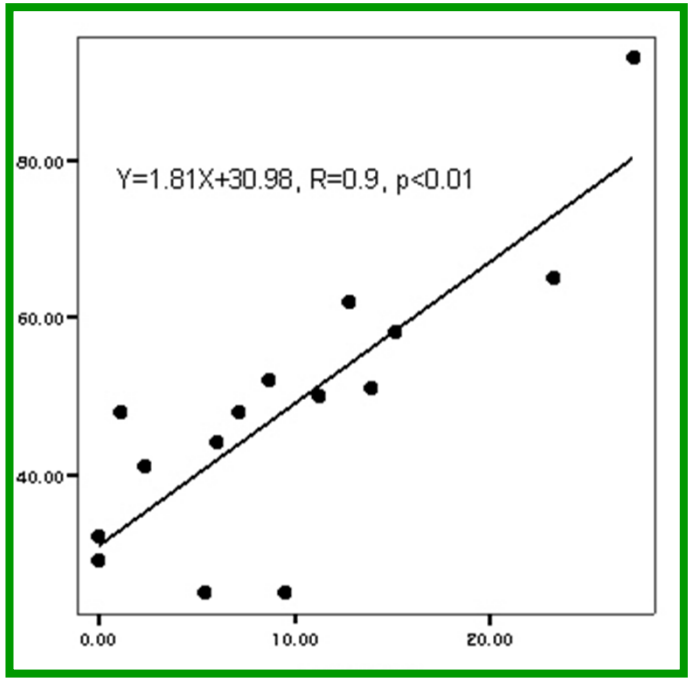
Study Design

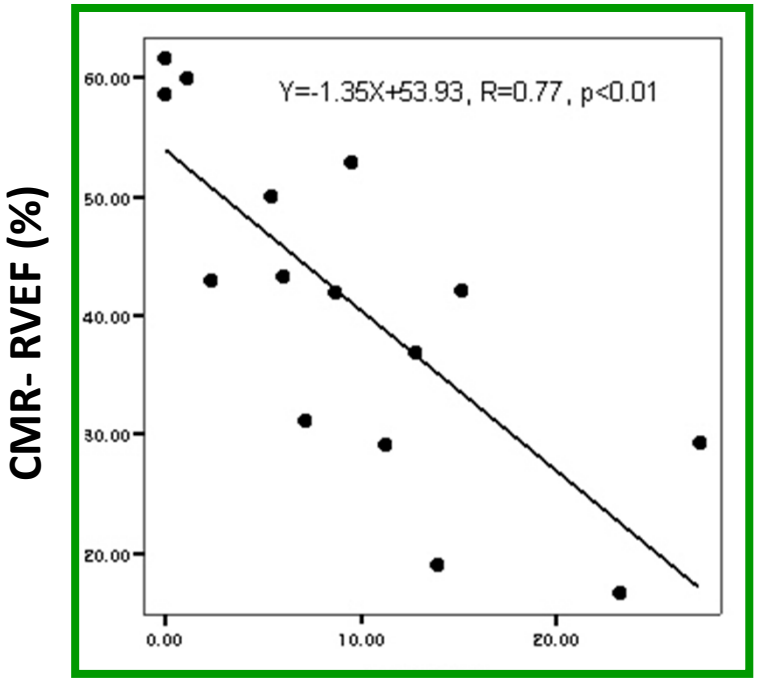
- Prospective, Mar2009-Jul 2010
- In Severance PAH Clinic
- Total 30 among 50 consecutive patients
- Work-up
  - Pre-Tx: Lab, TTE, RHC, CMR and 6MWT
  - Post-Tx: Lab, TTE and 6MWT within 3-6 months

Clinical Characteristics

	Patients (N=30)
Age	45±14
Male (%)	9 (30%)
BSA (Kg/m^2)	1.64±0.22
Idiopathic PAH (%)	15 (50%)
6MWD(m)	370±103
mRAP (mmHg)	14.33±14.62
mPAP (mmHg)	50.96± 23.1
Stroke Volume (ml)	57.96 ± 25.32
Cardiac Output (L/min)	4.44 ± 1.63
PVR (Wood Unit)	10.33 ± 6.52

DHE to mPAP and RV function

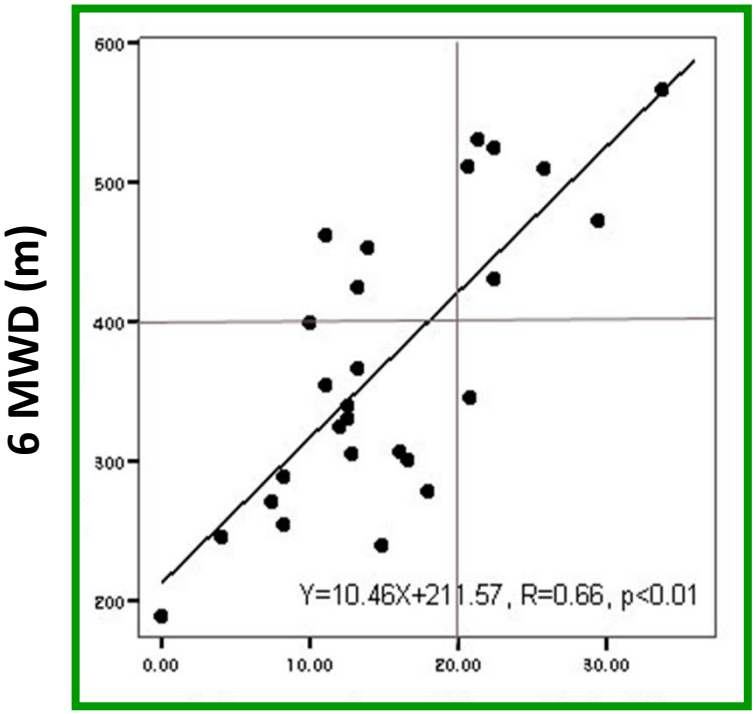


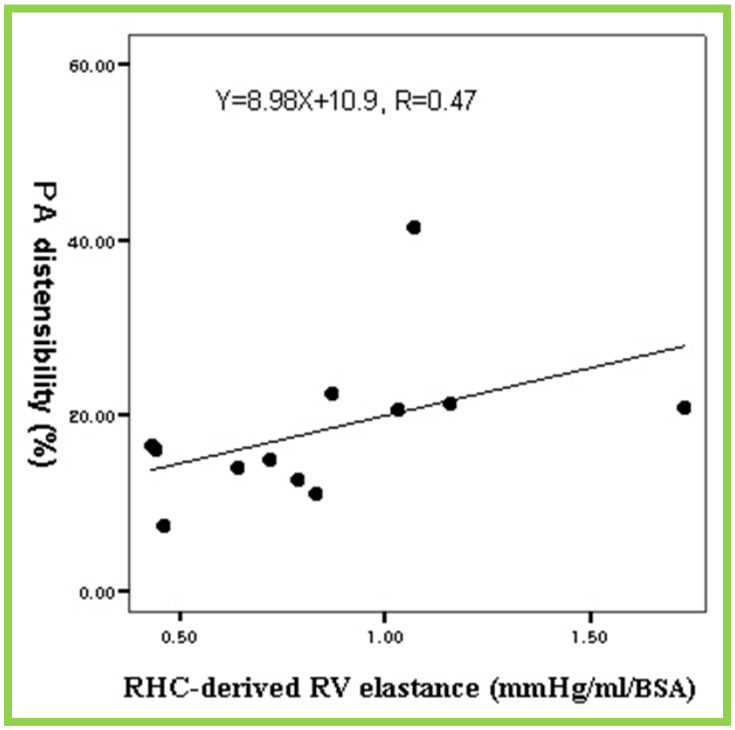


Multivariate Regression of 6MWD

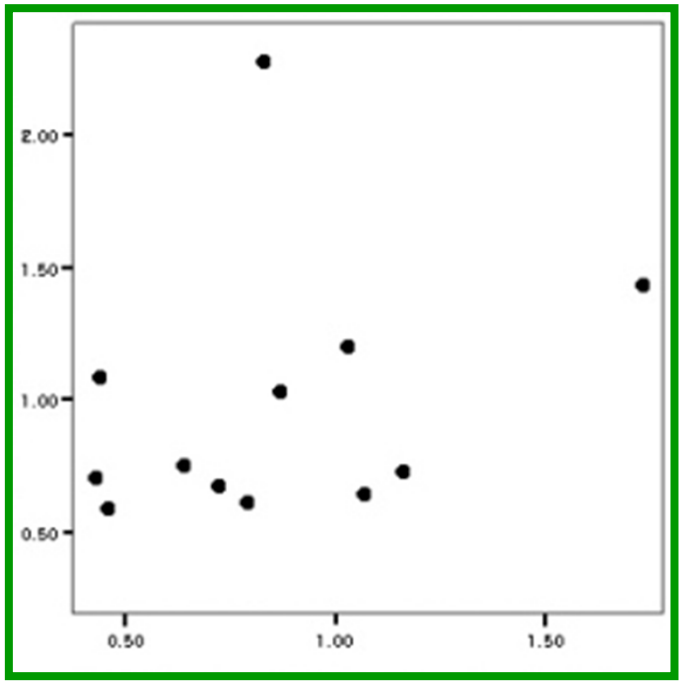
Variable	OR (95%CI)	P value
Age	0.94(0.79-1.12)	0.50
Functional Class (I-IV)	0.74(0.82-1.28)	0.88
mRAP (mmHg)	1(0.92-1.23)	0.40
mPAP (mmHg)	0.98(0.86-1.12)	0.83
PVR (wood unit)	1(0.85-1.39)	0.49
PA Distensibility (%)	1.6(1.02-2.48)	0.03*
RVEF (%)	1(0.82-1.28)	0.88

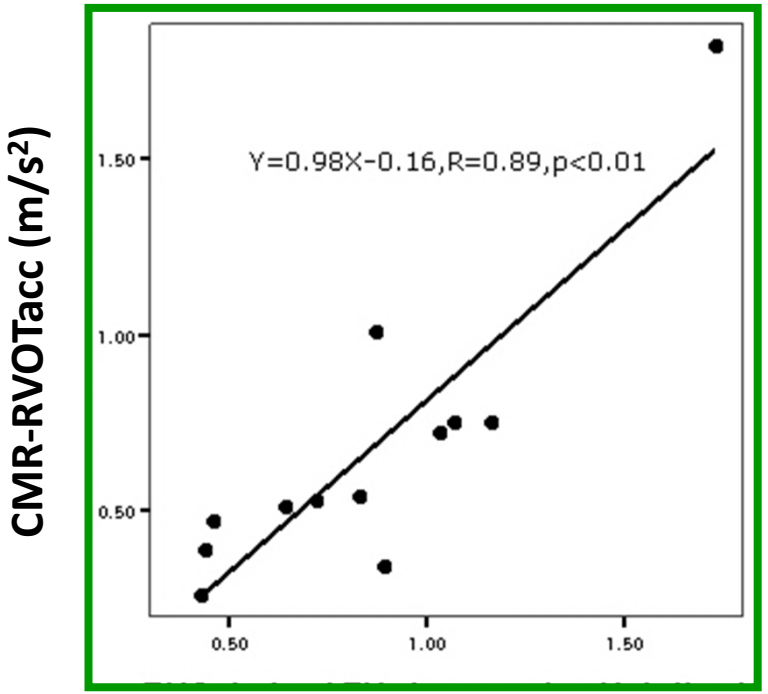
6MWD and PA distensibility





CMR-derived RVOTacc (m/s^2)





Comparison of differenct imaging modalities in PAH

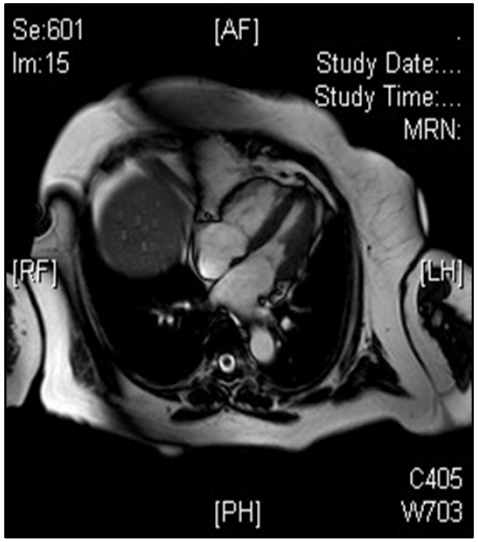
Metric	CMR	Echo-TTE	Echo-TEE	x-ray catheterisation	Nuclear
RV volumes (ml)	+++	++	+++	+	+
Ejection fraction (%)	+++	+	+	+	–
RV mass (g)	+++	+	+	–	–
RV pressure (mmHg)	+	++	++	+++	–
RV remodelling including septal curvature	+++	+	+	–	–
RA size/volume	+++	+	+	–	–
Tricuspid regurgitation	++	+++	+++	–	–
Pulmonary artery/branch (mm)	+++	+	+	+	–
Pulmonary artery compliance (mm/mmHg)	+++	+	+	+	–
Pulmonary artery flow (ml/beat)	+++	+	+	+++	–
Qp:Qs (shunt)	+++	+	+	+++	–
Pericardial effusion	+++	++	++	–	–

CMR is the most suitable to provide the information of PAH-related matrics in the most of cases.

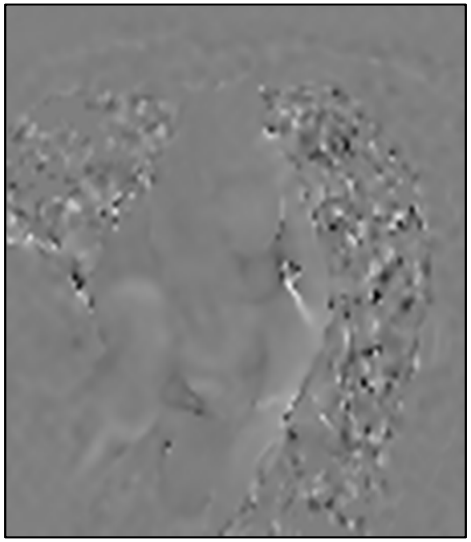
Benza, J Am Coll Cardiol 2008

MRI One-Stop Shop for the Comprehensive Assessment of PAH

Anatomy Function

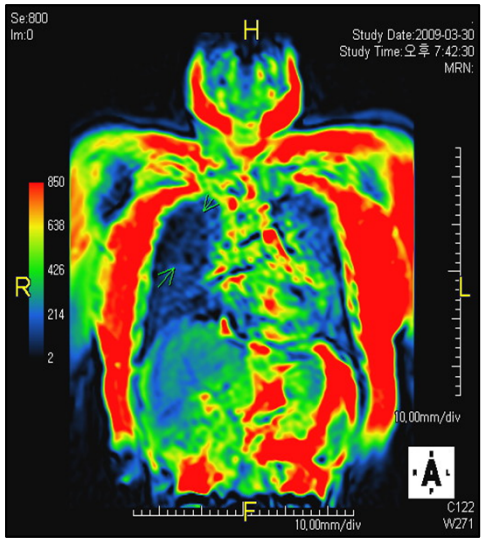


Flow



Angiogram

Perfusion



Estimated average costs of CMR and other cardiac imaging procedures

Pennell et al. Eur Hear J 2004

	Average Cost	Cost Range
Echocardiography	1	1
CT	3.13	±1.39
SPECT	3.27	±2.88
CMR	5.51	±3.51
RHC and LHC	19.96	±13.55

Overall incidence of claustrophobia leading to cancellation of postoperative MRI was 14%.

Katznelson et al. Neuropsychiatr Dis Treat 2008

Conclusions

CMR may provide more accurate and broad variety of information than echocardiography for the non-invasive evaluation of RV and PA structure and function that is integral to PH…

go a long way to replace echocardiography

but is a complementary tool as a reference standard.