Assessing the Right Ventricle: Strain, 3D, Contrast

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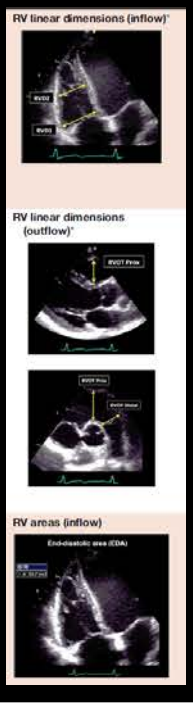

RV Size may be underestimated due to crescent shape
Dependent upon probe rotation

Regional measure, not representative

Limited normative Data Available

RV size could be underestimated if foreshortened

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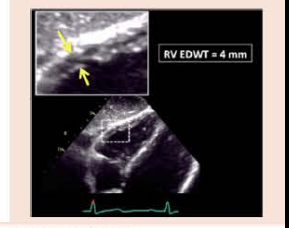
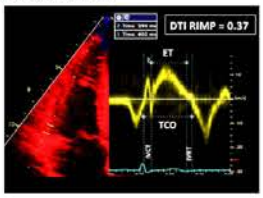
RV wall thickness



Single site measurement
Challenging if pericardium is thickened
How to define a thin RV?

Tissue Doppler RIMP



Unreliable when RA pressure is elevated

RV global systolic function
FAC

Neglects RV outflow contribution to function

Only fair IOV

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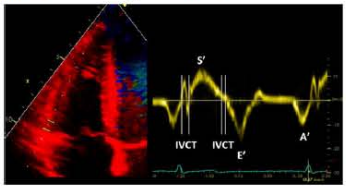
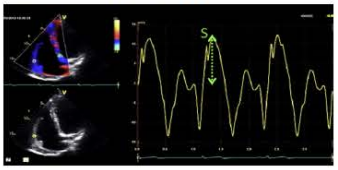
Pulsed tissue Doppler S wave



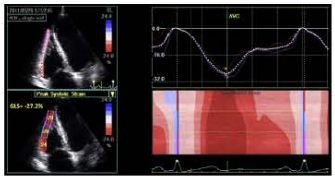
Not fully reflective of global function

Color tissue Doppler S wave



Not fully reflective of global function

GLS



Vendor Dependent

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Table 10 Normal values for parameters of RV function

Parameter	Mean ± SD	Abnormality threshold
TAPSE (mm)	24 ± 3.5	<17
Pulsed Doppler S wave (cm/sec)	14.1 ± 2.3	<9.5
Color Doppler S wave (cm/sec)	9.7 ± 1.85	<6.0
RV fractional area change (%)	49 ± 7	<35
RV free wall 2D strain* (%)	−29 ± 4.5	>−20 (<20 in magnitude with the negative sign)
RV 3D EF (%)	58 ± 6.5	<45
Pulsed Doppler MPI	0.26 ± 0.085	>0.43
Tissue Doppler MPI	0.38 ± 0.08	>0.54
E wave deceleration time (msec)	180 ± 31	<119 or >242
E/A	1.4 ± 0.3	<0.8 or >2.0
e′/a′	1.18 ± 0.33	<0.52
e′	14.0 ± 3.1	<7.8
E/e′	4.0 ± 1.0	>6.0

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RV in Pulmonary Hypertension

Routine	Common not always	Experienced
PASP	PAPd	RV 3D EF
RAP	PAPm	RV 2D strain
	RA Area	RV 3D Strain
RV size and function	PAAT	
RA qualitative description	RV FAC	
	Tei index	
RV TAPSE or S’	PVR	
LA volume		
LV diastolic function	Contrast (TR or RV)	
Presence or absence of pericardial effusion		

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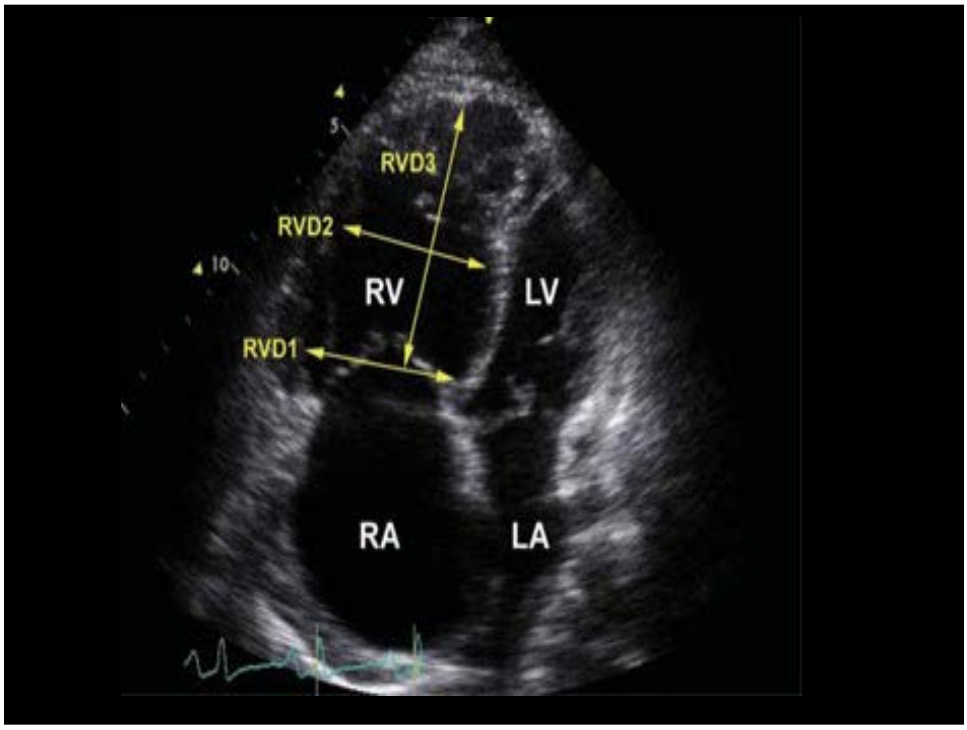

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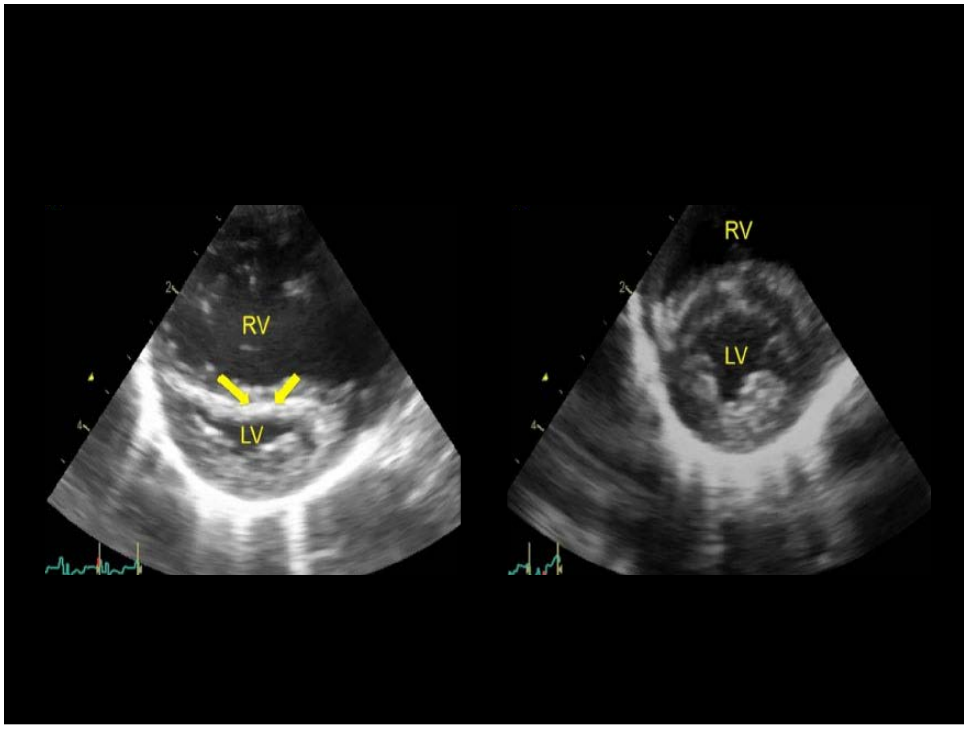

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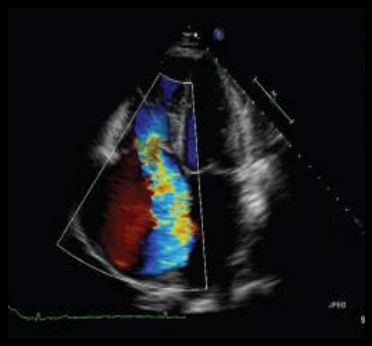

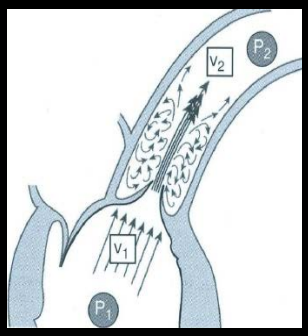

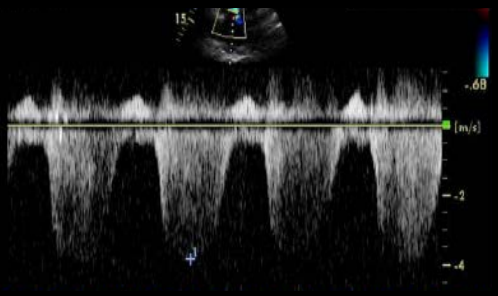

Pressure gradient = $4V^2$

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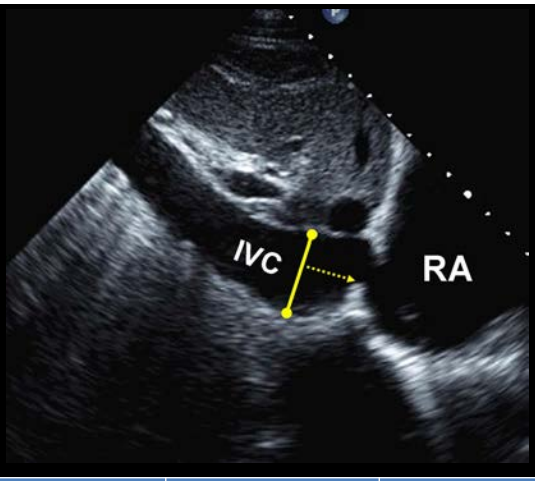

IVC diameter cm	% collapse with sniff	Estimated RAP mmHg
<2.1	>50%	3
<2.1	<50%	8
>2.1	>50%	8
>2.1	<50%	15

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You have a PASP – now what?

- PASP is high- PH is confirmed
  - There may be supportive anatomic evidence of PH
  - Consider cause of PH
  - Emphasize in conclusions
  - Look for change from previous
- PASP is not high or could not be measured
  - Is there anatomic evidence?
  - Not enough TR – give contrast? Try another formula
  - IS THIS INTEROBSERVER VARIABILITY OR A REAL CHANGE?

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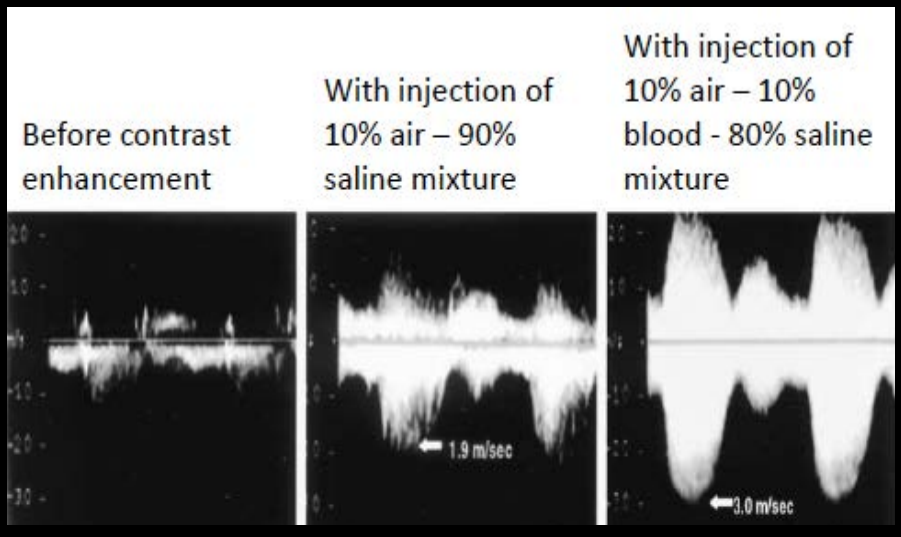

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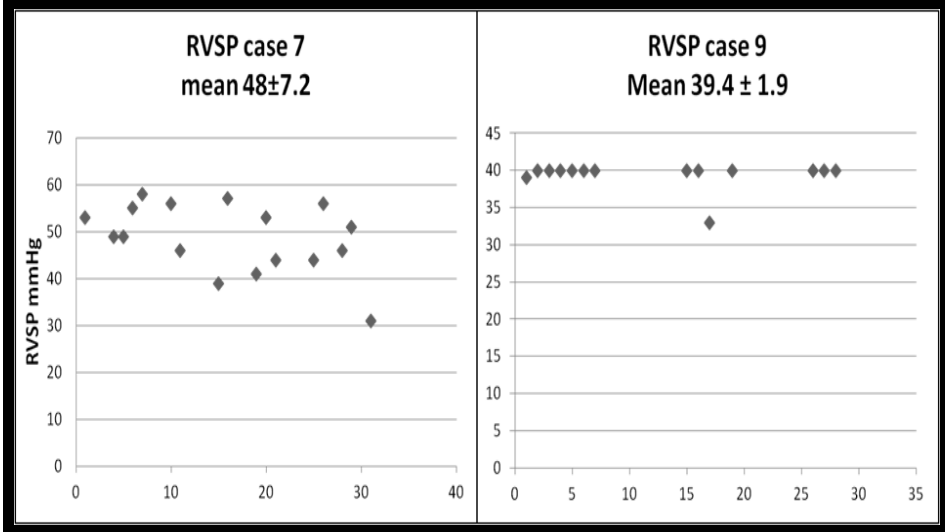

Patton DM et al, Echocardiography Jan 34:12

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Phase 1: Pre-Intervention

18 participants of varying experience level shown 8 echo cases and anonymously asked to assess the RVSP

Phase 2: Teaching Intervention

1. Review of ASE Right Heart Guidelines
2. Group discussion of factors contributing to IOV in first 8 cases
3. Development of a group consensus document for RVSP interpretation
4. Presentation by PH expert

Phase 3: Post-Intervention

15 participants of varying experience level shown 8 additional echo cases and anonymously asked to assess the RVSP

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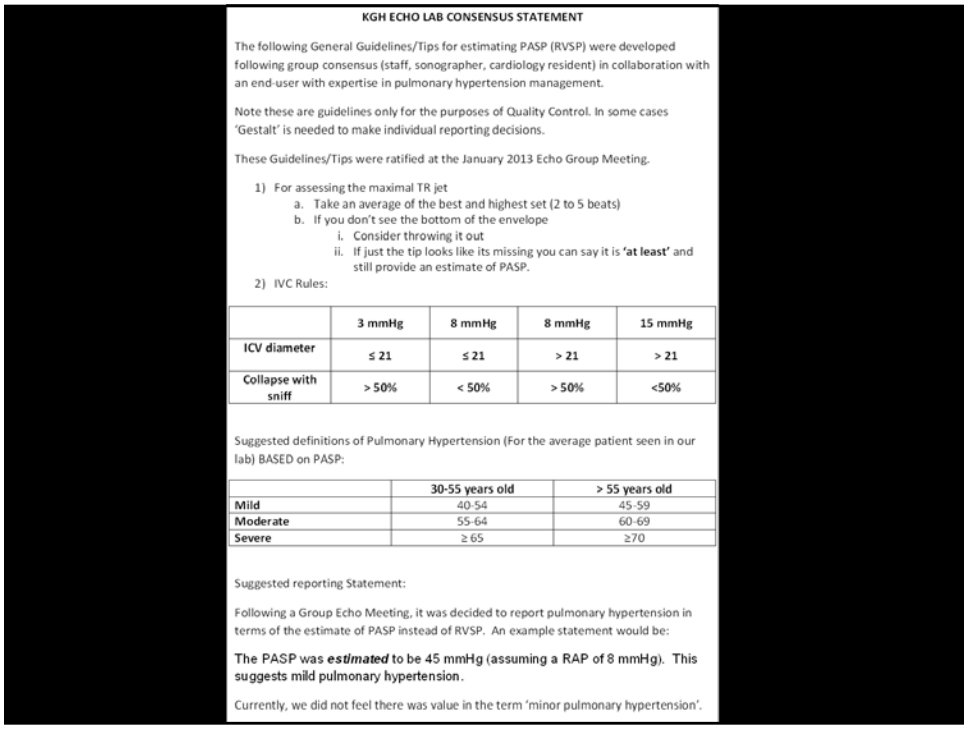

KGH ECHO LAB CONSENSUS STATEMENT

The following General Guidelines/Tips for estimating PASP (RVSP) were developed following group consensus (staff, sonographer, cardiology resident) in collaboration with an end-user with expertise in pulmonary hypertension management.

Note these are guidelines only for the purposes of Quality Control. In some cases 'Gestalt' is needed to make individual reporting decisions.

These Guidelines/Tips were ratified at the January 2013 Echo Group Meeting.

1) For assessing the maximal TR jet
   a. Take an average of the best and highest set (2 to 5 beats)
   b. If you don't see the bottom of the envelope
      i. Consider throwing it out
      ii. If just the tip looks like its missing you can say it is **'at least'** and still provide an estimate of PASP.
2) IVC Rules:

	3 mmHg	8 mmHg	8 mmHg	15 mmHg
ICV diameter	≤ 21	≤ 21	> 21	> 21
Collapse with sniff	> 50%	< 50%	> 50%	<50%

Suggested definitions of Pulmonary Hypertension (For the average patient seen in our lab) BASED on PASP:

	30-55 years old	> 55 years old
Mild	40-54	45-59
Moderate	55-64	60-69
Severe	≥ 65	≥70

Suggested reporting Statement:

Following a Group Echo Meeting, it was decided to report pulmonary hypertension in terms of the estimate of PASP instead of RVSP. An example statement would be:

The PASP was ***estimated*** to be 45 mmHg (assuming a RAP of 8 mmHg). This suggests mild pulmonary hypertension.

Currently, we did not feel there was value in the term 'minor pulmonary hypertension'.

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What about Assessment of RV in Pulmonary Hypertension?

Commonly Conducted	Occasionally Conducted	Experienced/Advanced
PASP RAP RV size and function RA qualitative description RV TAPSE or S' LA volume LV diastolic function Presence or absence of pericardial effusion	PAPd PAPm RA Area PAAT RV FAC Tei index PVR Contrast (TR or RV)	RV 3D EF RV 2D strain RV 3D Strain

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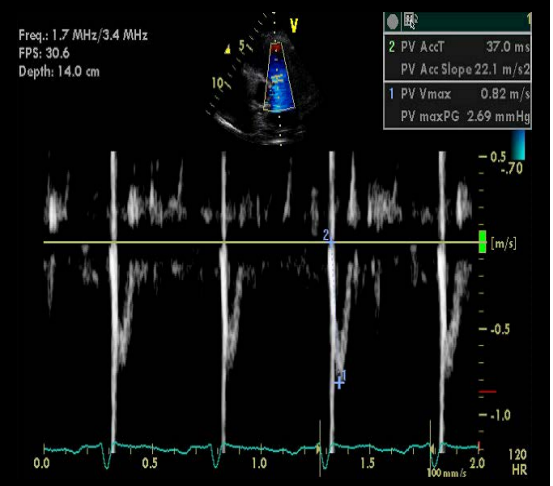
Estimating Mean PAP

- PAPm = 79 - 0.45 X RVOT AT
  PW in systole
- PAPm = 60 - 0.33 X PAAT
  if AT <120
- 90 – (0.62 x AT)
- 4 x (early PR velocity)^2 + RAP



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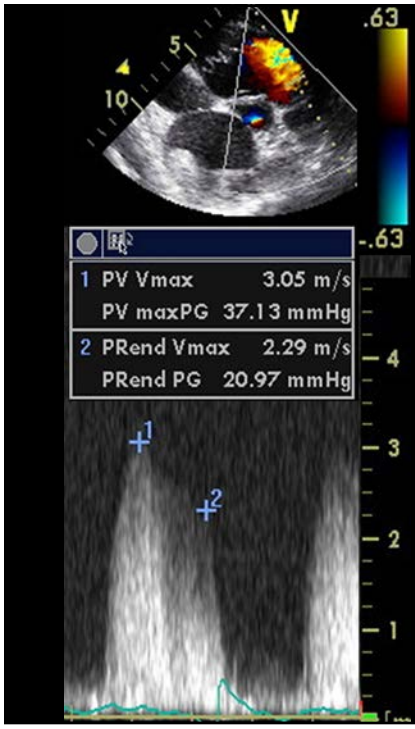

mPAP=

4 × (early PI velocity)^2 + estimated RAP=

37 mm Hg + RAP.

Point 2 marks the PI velocity at end-diastole.

PADP=
4 × (end PI velocity)^2 + estimated RAP.

21 mm Hg + RAP.

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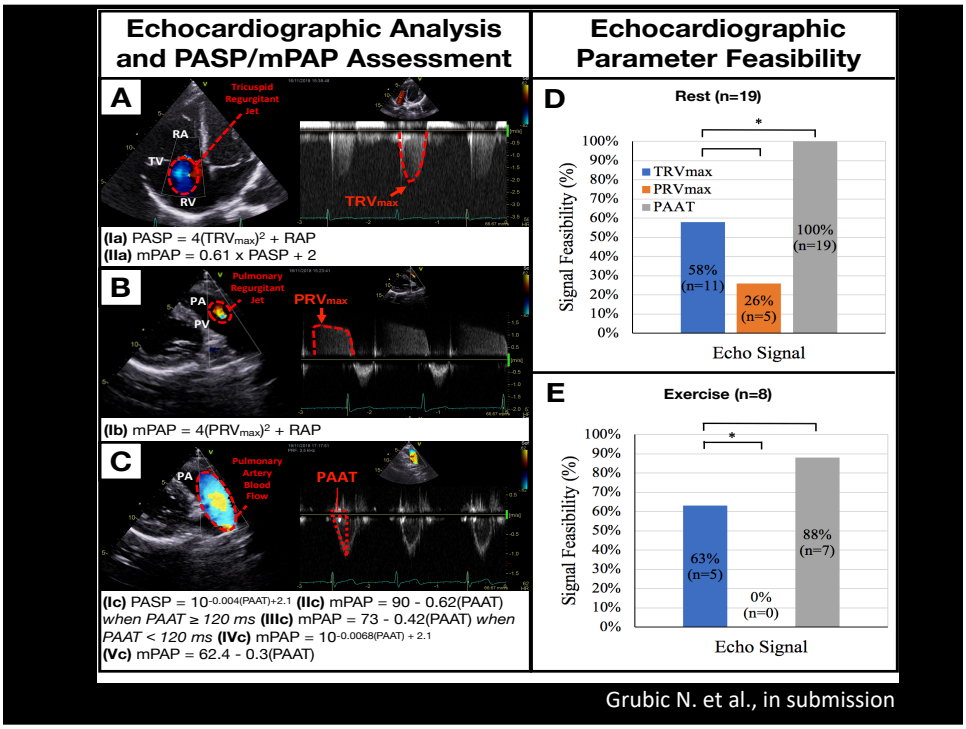

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	Tei index	
RV TAPSE or S'	PVR	
	Contrast (TR or RV)	
LA volume		
LV diastolic function		
Presence or absence of pericardial effusion		

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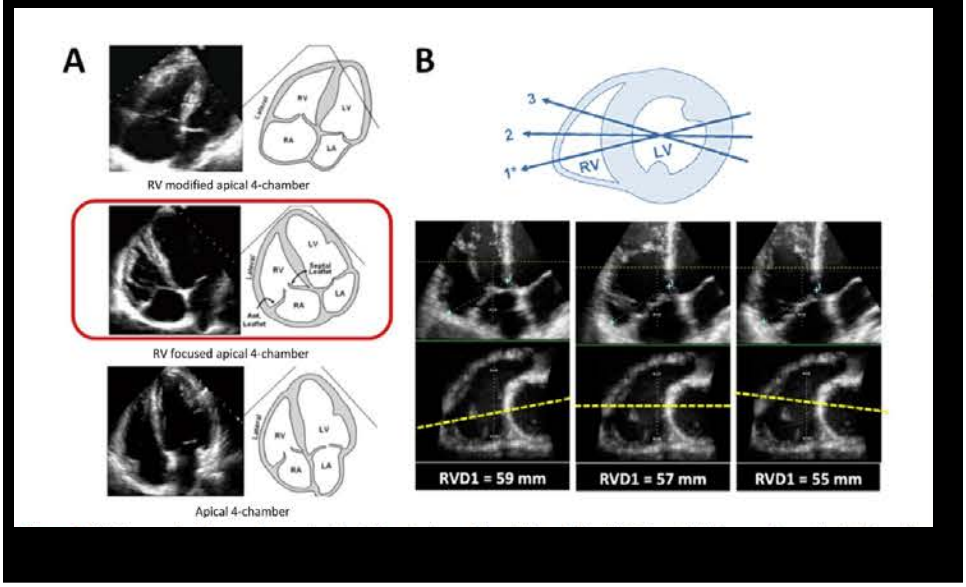
Advantage of 3D imaging of the RV
- Chamber size



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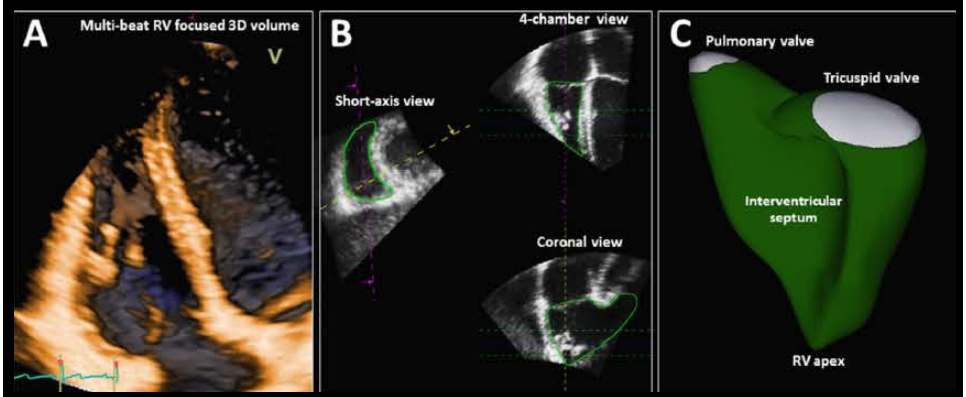
Advantage of 3D Imaging
- EF can now include RVOT contribution



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RIGHT VENTRICULAR SIZE AND FUNCTION

Quantification of Right Ventricular Size and Function from Contrast-Enhanced Three-Dimensional Echocardiographic Images

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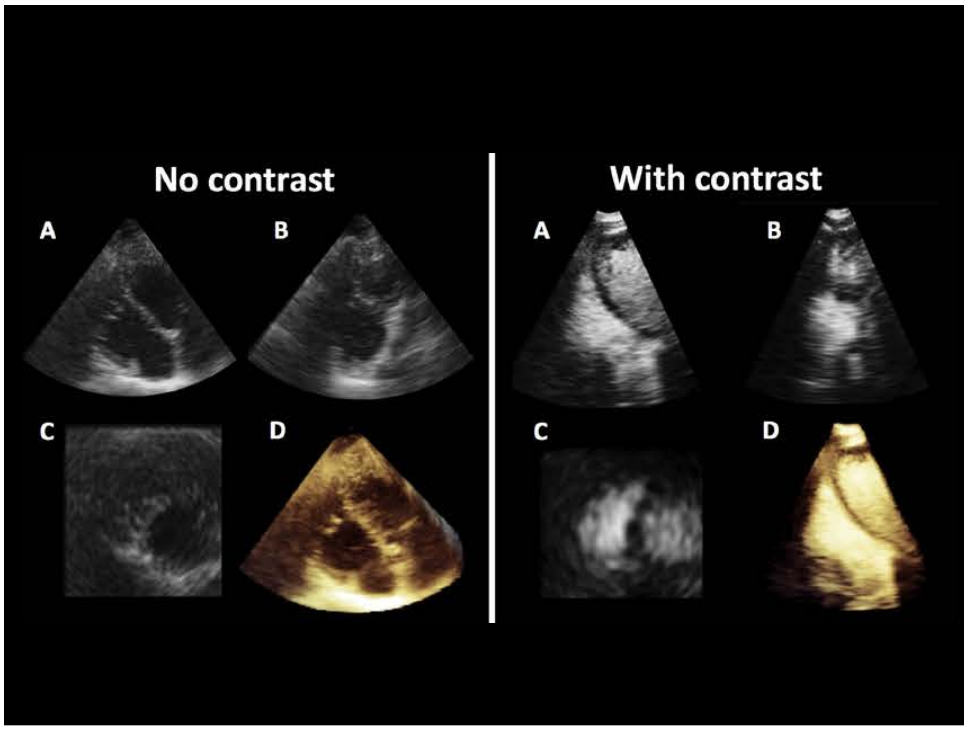

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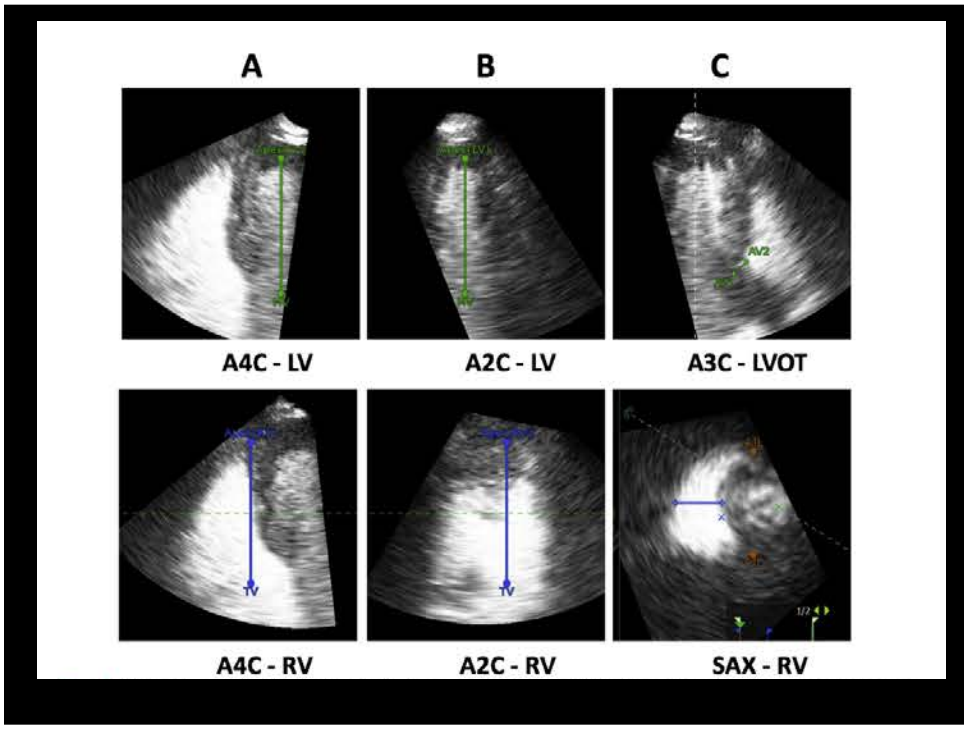

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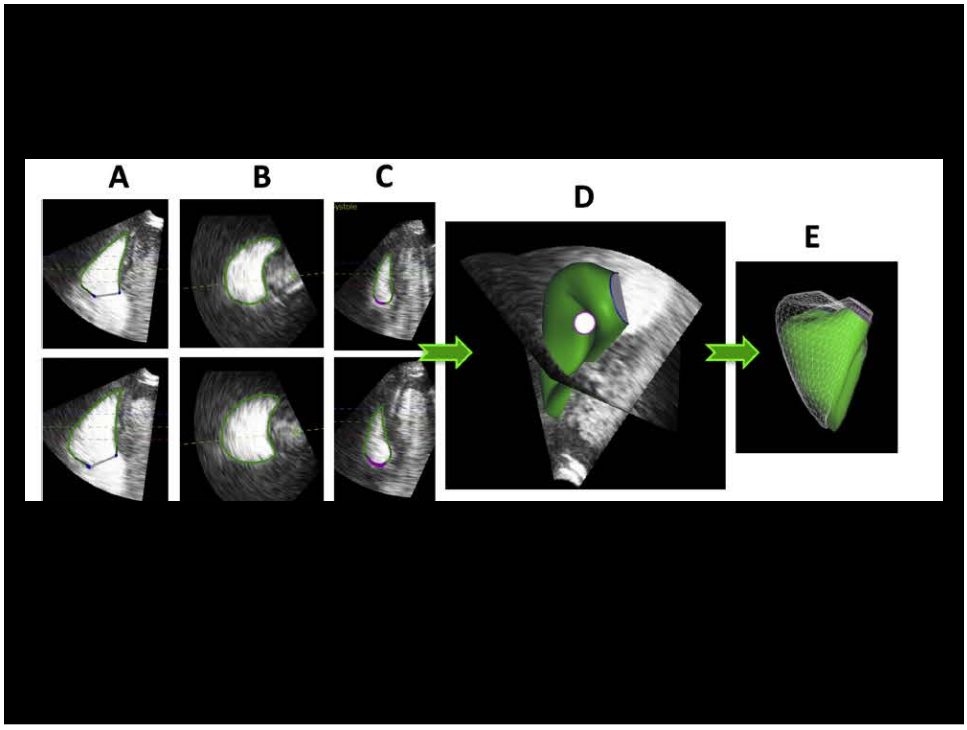

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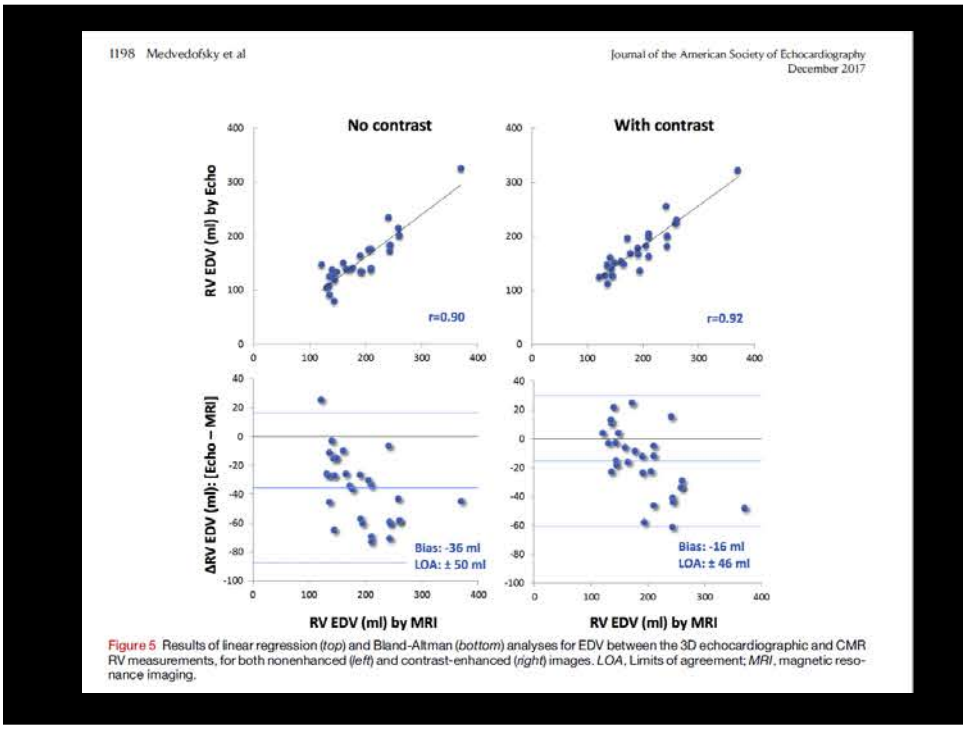

Figure 5 Results of linear regression (*top*) and Bland-Altman (*bottom*) analyses for EDV between the 3D echocardiographic and CMR RV measurements, for both nonenhanced (*left*) and contrast-enhanced (*right*) images. *LOA*, Limits of agreement; *MRI*, magnetic resonance imaging.

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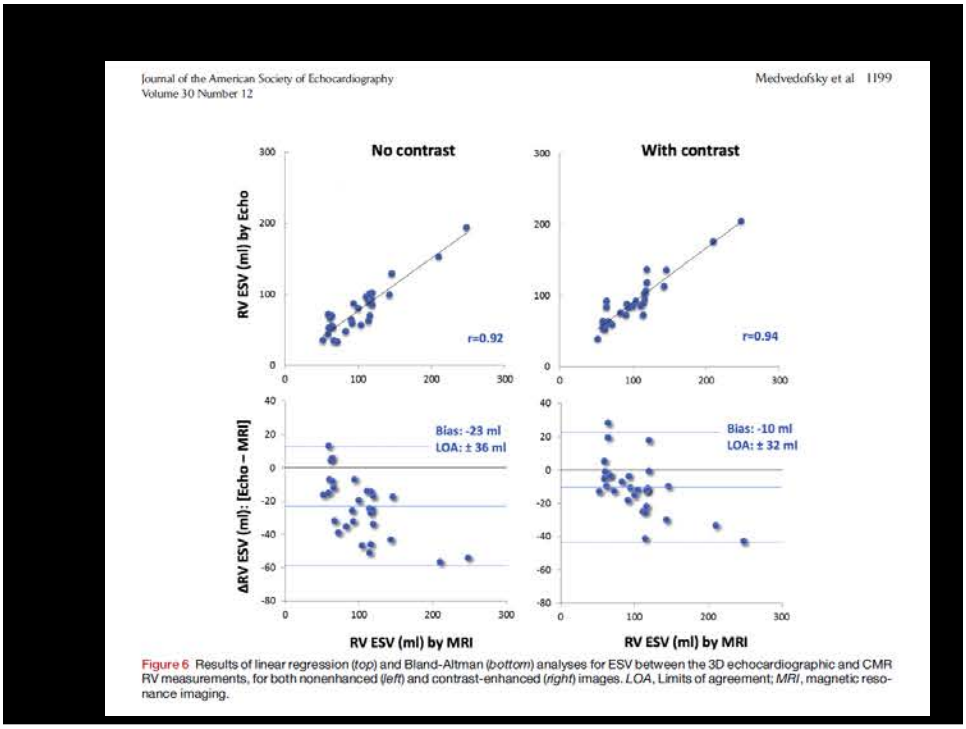

Figure 6 Results of linear regression (*top*) and Bland-Altman (*bottom*) analyses for ESV between the 3D echocardiographic and CMR RV measurements, for both nonenhanced (*left*) and contrast-enhanced (*right*) images. *LOA*, Limits of agreement; *MRI*, magnetic resonance imaging.

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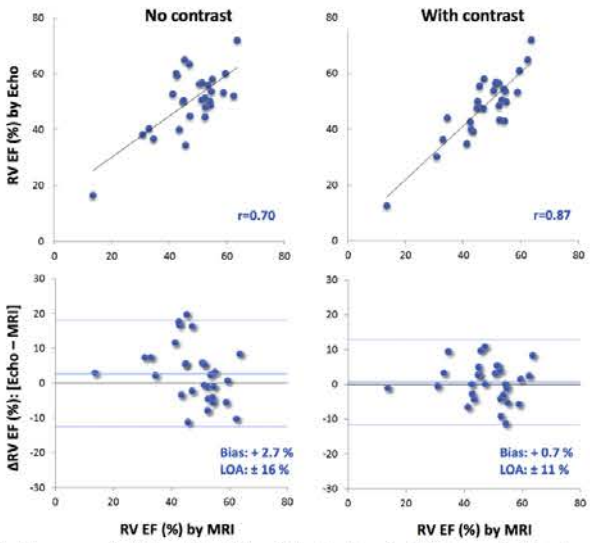

Figure 7 Results of linear regression (*top*) and Bland-Altman (*bottom*) analyses for RVEF between the 3D echocardiographic and CMR RV measurements, for both nonenhanced (*left*) and contrast-enhanced (*right*) images. *LOA*, Limits of agreement; *MRI*, magnetic resonance imaging.

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- 3D underestimates EDV and ESV
- RVEF compares well, less underestimation
- Better correlation to CMR following contrast injection for volumes
- Offline analysis still required, learning curve but feasible

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Three-Dimensional Speckle Tracking of the Right Ventricle

Toward Optimal Quantification of Right Ventricular Dysfunction in Pulmonary Hypertension

Benjamin C. F. Smith, MSc,*† Gary Dobson, MDCM, MSc,†‡ David Dawson, MSc,* Athanasios Charalampopoulos, MD,§ Julia Grapsa, MD, PhD,*§ Petros Nihoyannopoulos, MD*†

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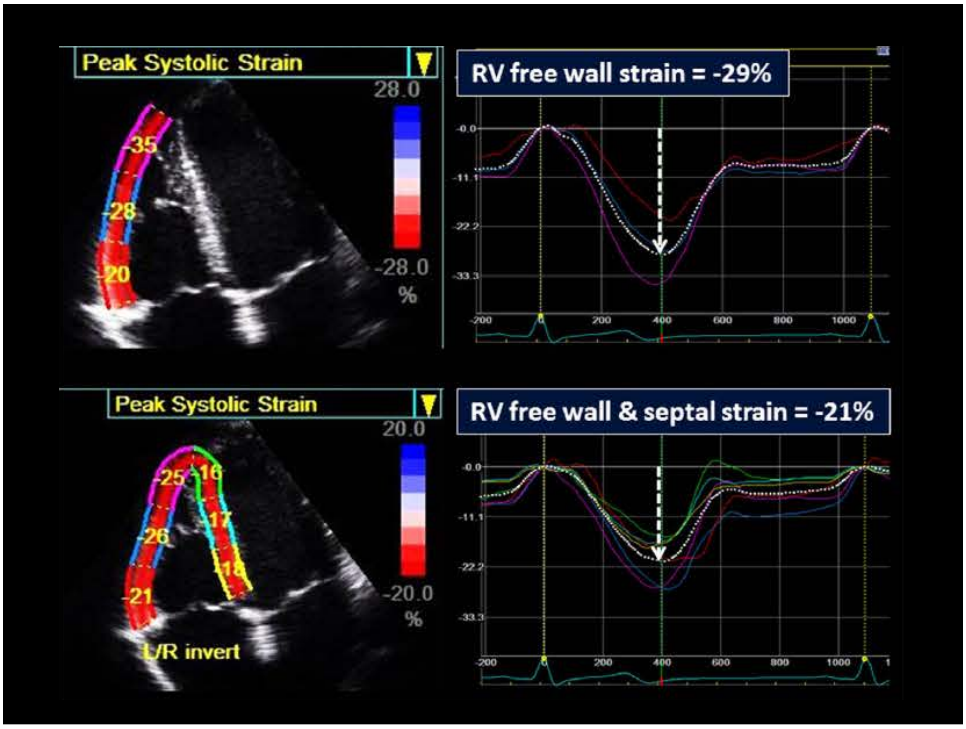

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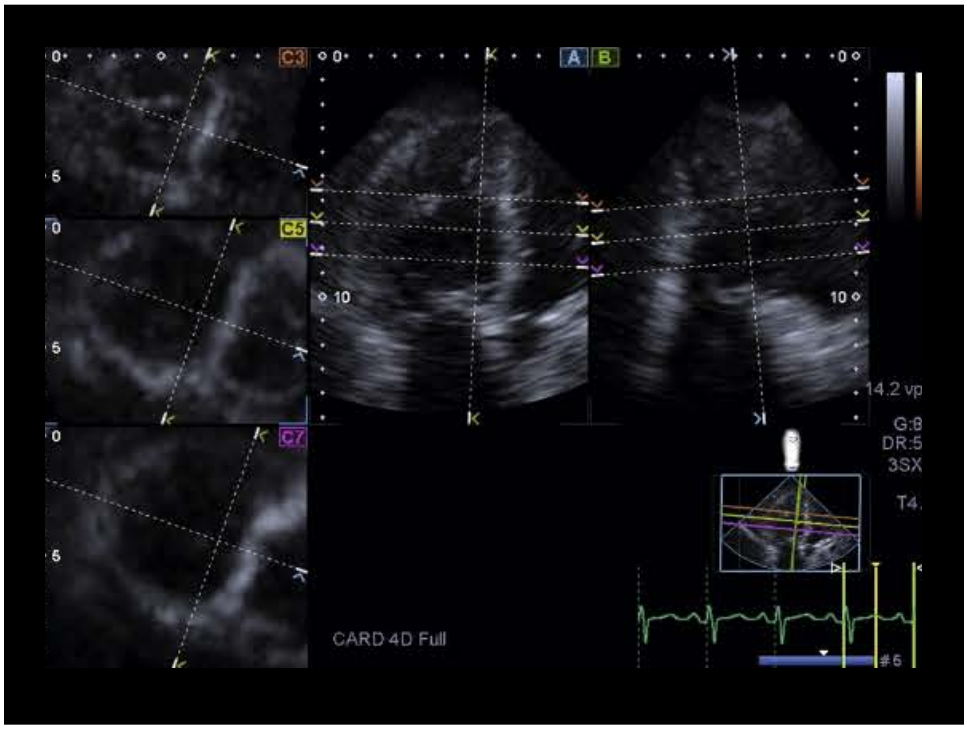
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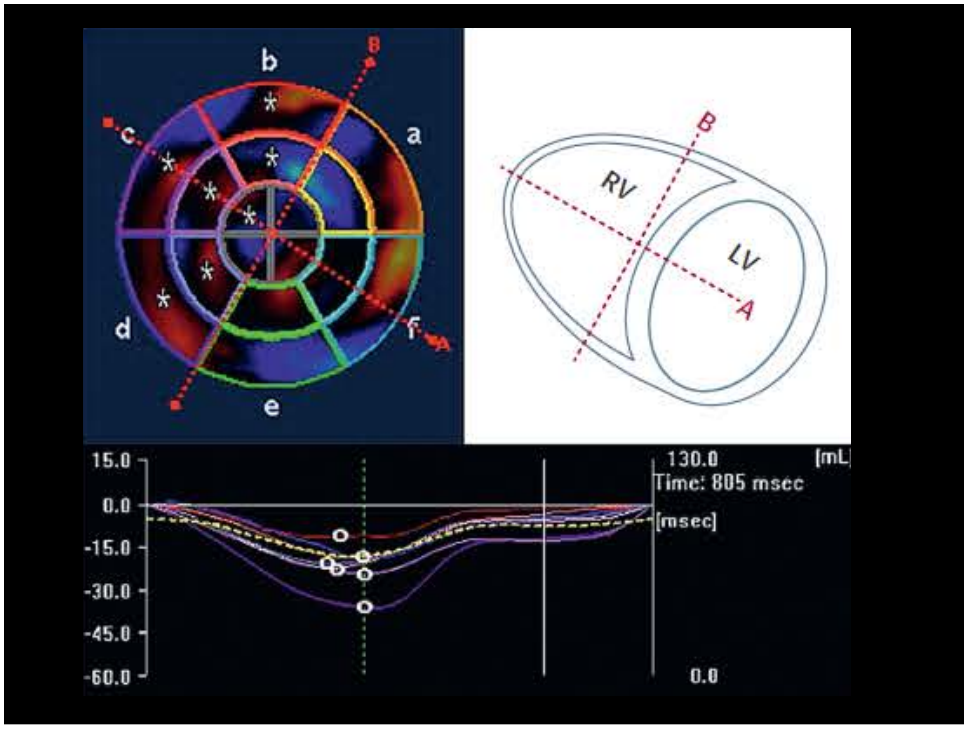
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B
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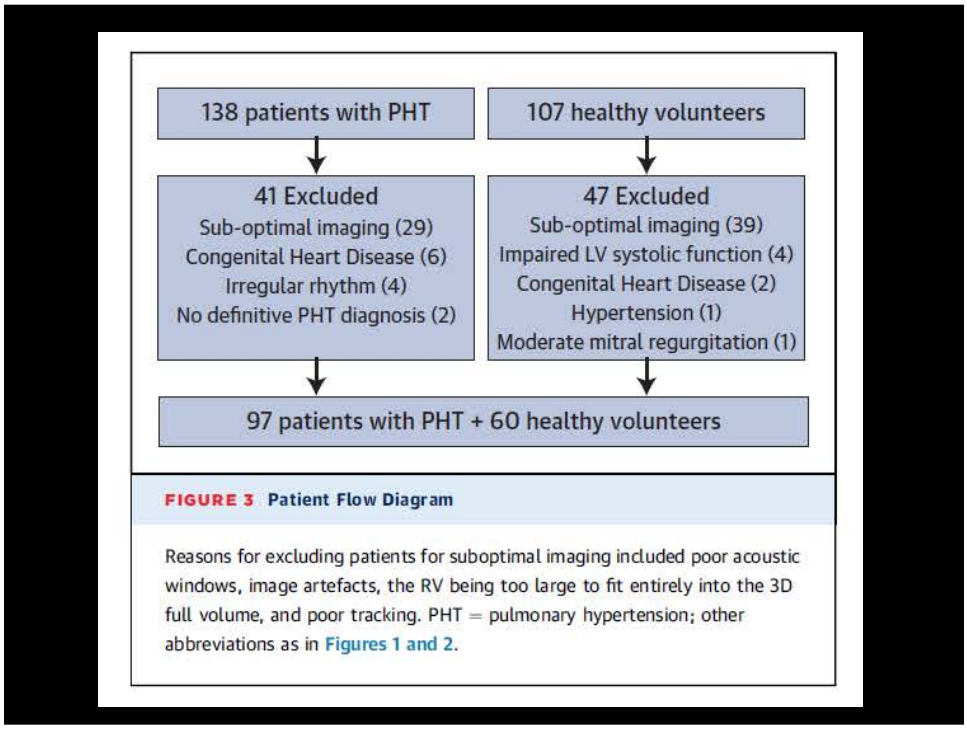

FIGURE 3 Patient Flow Diagram

Reasons for excluding patients for suboptimal imaging included poor acoustic windows, image artefacts, the RV being too large to fit entirely into the 3D full volume, and poor tracking. PHT = pulmonary hypertension; other abbreviations as in Figures 1 and 2.

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TABLE 2 Comparison of Global Strain in Patients and Healthy Volunteers

RV Free Wall Strain (%)	Patients (n = 99)	Control Patients (n = 60)	p Value
Radial	23.2 ± 14.4	34.9 ± 18.2	<0.001
Longitudinal	−15.5 ± 3.8	−17.9 ± 4.4	0.001
Circumferential	−12.2 ± 4.5	−15.7 ± 6.1	<0.001
Area	−24.3 ± 7.3	−30.8 ± 7.2	<0.001

Values are mean ± SD.
RV = right ventricular.

TABLE 3 ROC Cutoff Values Predicting Impaired RVEF

	Cutoff	Sensitivity	Specificity	AUC
AS	−28.9%	88.5%	88.6%	0.942
CS	−15.4%	91.2%	75.0%	0.885
LS	−16.8%	73.1%	76.3%	0.755
RS	39.6%	55.8%	93.0%	0.745
TAPSE	21 mm	73.3%	72.5%	0.761

AS = area strain; AUC = area under the curve; CS = circumferential strain; LS = longitudinal strain; ROC = receiver-operating characteristic; RS = radial strain; RVEF = right ventricular ejection fraction; TAPSE = tricuspid annular plane systolic excursion.

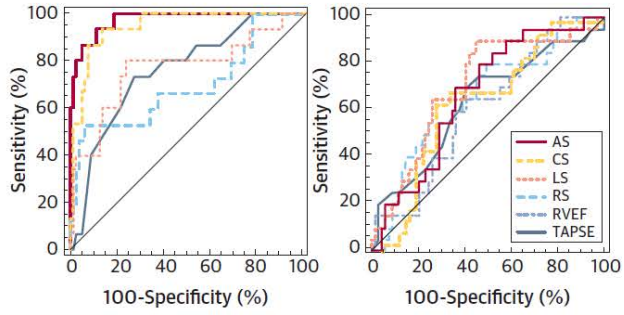

FIGURE 5 ROC Curves for Impaired RVEF and Mortality

Receiver-operating characteristic (ROC) curves are shown for impaired RVEF **(left)** and mortality **(right)**. AS **(red)**, CS **(orange)**, LS **(salmon)**, RS

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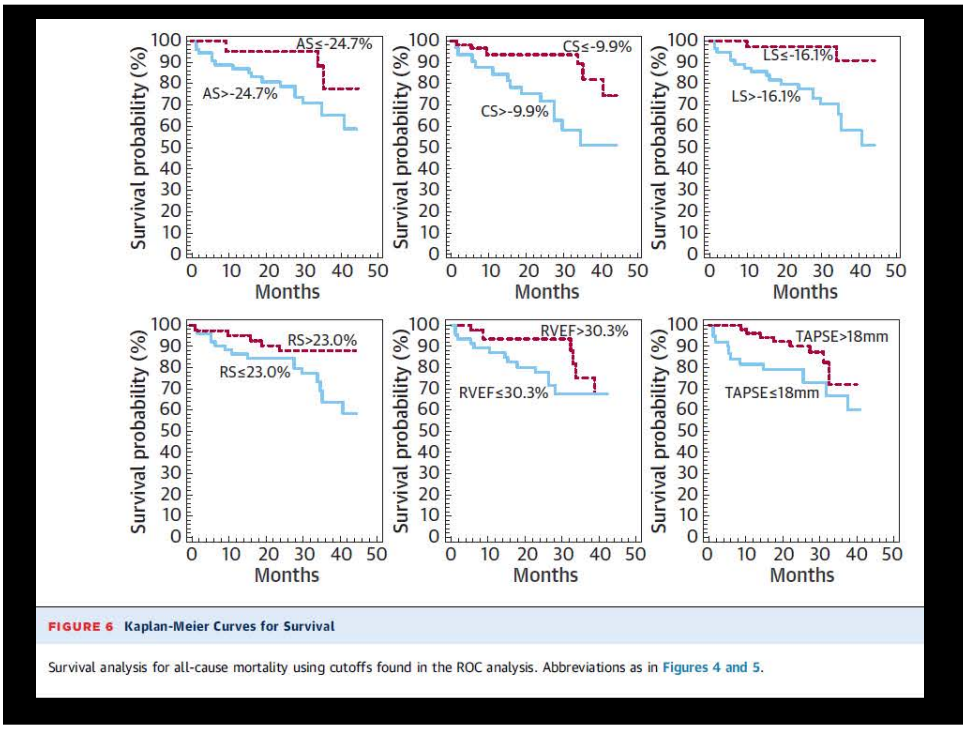

FIGURE 6 Kaplan-Meier Curves for Survival

Survival analysis for all-cause mortality using cutoffs found in the ROC analysis. Abbreviations as in Figures 4 and 5.

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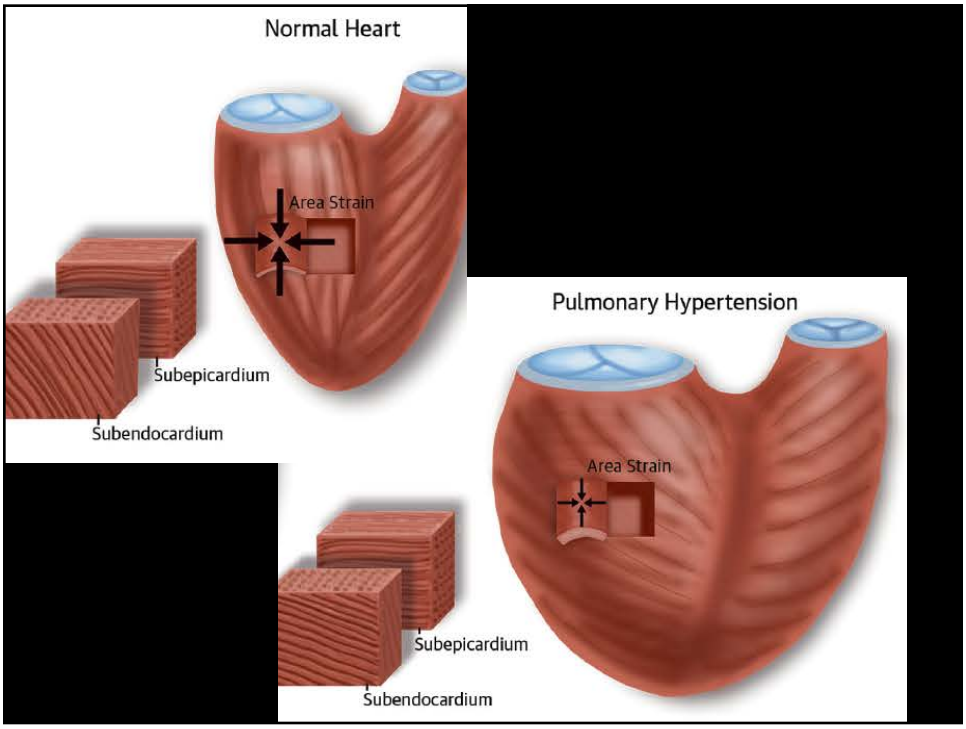

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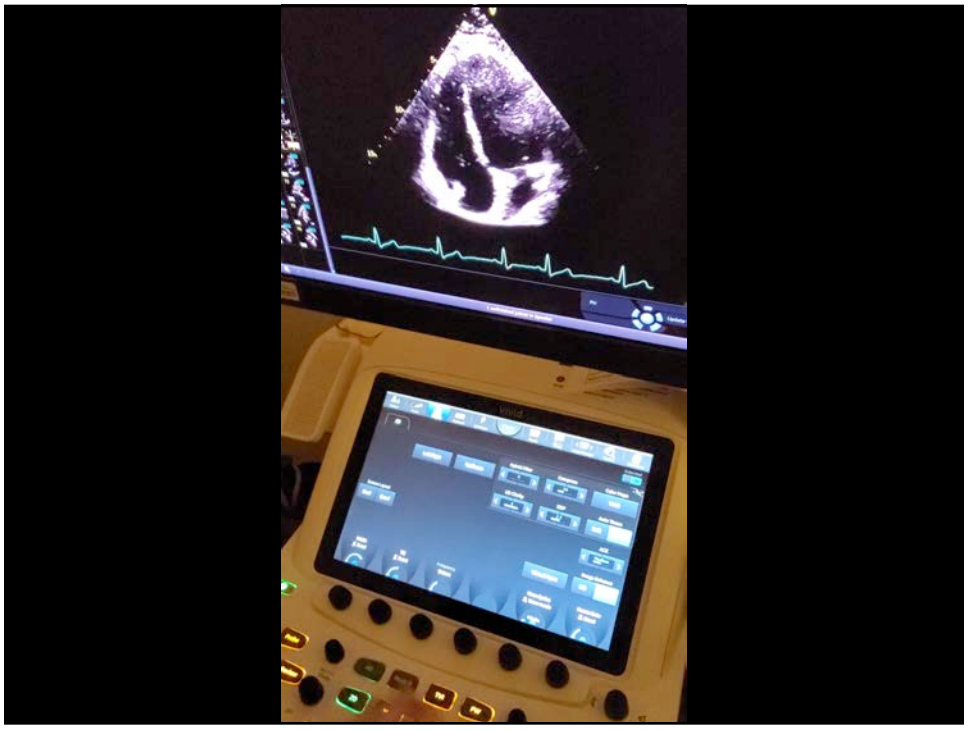

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- Basic 2D methods recommended but limited because of RV geometry and difficulty in visualization
- 3D improves RVEF compared with MRI – RVOT now improved
- 3D Contrast improves volumes but learning curve
- 2D strain (LS) is useful, but some out of plane data analysis
- 3D strain allows for AS (composite of LS and CS) better predictor of mortality
- Advanced methods are feasible and useful, but complex, propriety based and not standardized
- Currently using LV methods instead of dedicated software

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