Assessing RV Function: Role of strain and 3D echo

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No disclosures

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Why is RV function important

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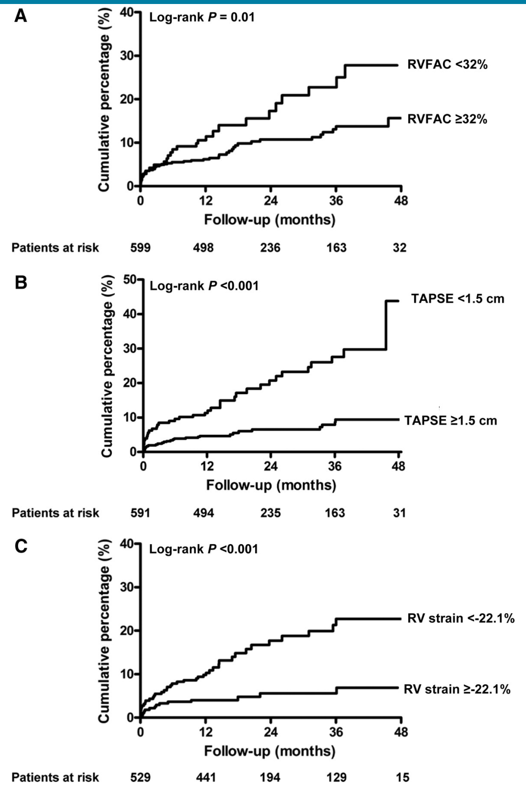
- Important for diagnosis of right heart conditions
- Prognostic value in many conditions
  - HFrEF /HFpEF
  - Post op cardiac surgery outcomes
  - CAD
  - Pulmonary hypertension
  - Mechanical circulatory support
  - CRT
- Response of RV function during treatment of various cardiac conditions assoc w prognosis



Outcomes post 1º PCI in AMI
Antoni et al Circ Img 2010;3:264-271

CMR is the gold standard for RV size and function but cost and availability pose limitations so let's look at echo options

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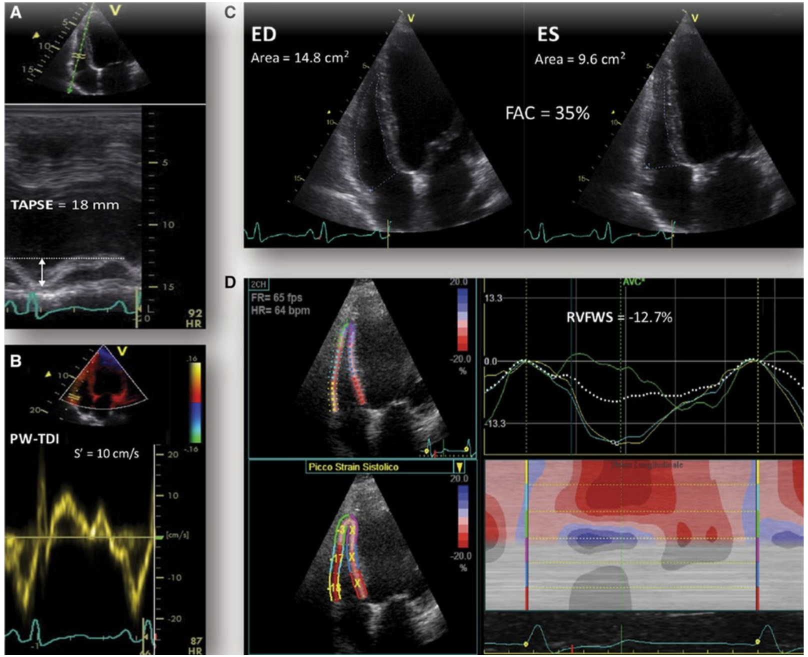
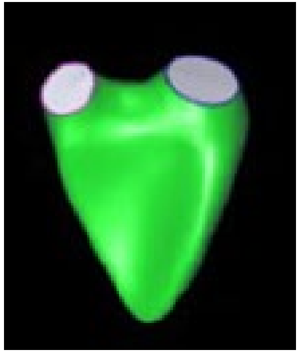


Carluccio et al Circ CV Img 2018;doi.org/10.116/Circimaging.117.006894



Muraru et al Eur Hrt J CV Img 2020;21:10-21

Why is it difficult to assess RV function with 2D echo ?

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- Complex shape
  - RV inflow, apex and outflow cannot be obtained in 1 image
- Retrosternal position
  - RV myocardium is thin and difficult to visualize thickening
    - Lower reproducibility of FAC
- RV motion can be deceiving
  - Apical 4 chamber
    - Often looking at epicardial motion rather than myocardial thickening
    - Limited ability to examine short axis radial and circumferential motions
  - Annular motion (TAPSE, S') can be normal yet other portions of RV abnormal (and vice versa)

2D echo for RV size and function perform reasonably well for screening

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- RV size
  - RV basal diameter, diastolic septal flattening, RV long axis length, RV area
- RV function
  - RV FAC, TAPSE, TV annular s'
- Limitations
  - Reproducibility
  - Fair correlations with CMR
  - Asymmetric changes not captured at the base of the apical 4 chamber view

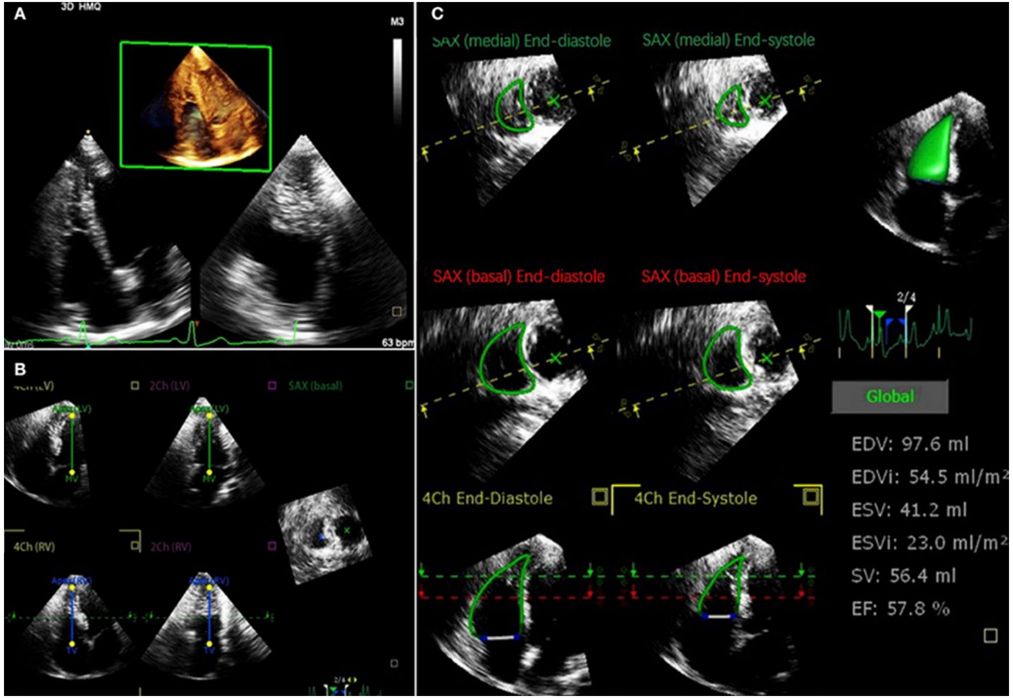
Solutions: 3D echo and RV strain

- 3D
  - Enables assessment of the entire RV volume so that EF calculation is more accurate
  - Good to excellent correlations with CMR
    - Underestimated volumes but EF not influenced
- 2D strain
  - Longitudinal motion of the entire RV myocardium not just annulus
  - Less time consuming than FAC or MPI
  - More reproducible than TAPSE, S', FAC
  - Less angle dependent than other longitudinal parameters
  - No ethnic differences

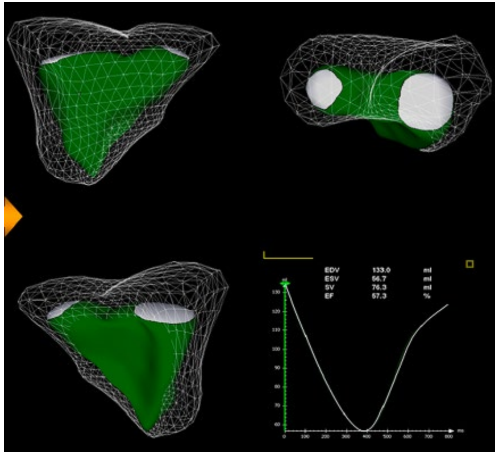
Tips for a good RV 3D echo for quantitation of RVEF

- Similar approach as 3D of the LV
  - Find best window to image the RV usually focused RV (ap 4)
    - RV in center of the sector
    - Endocardial border must be good on the 2D
      - detection from multiple views will be required
    - The entire RV free wall needs to be in the sector
      - If cut off it will also not be on the 3D
      - Avoid foreshortening of the RV
        - » Avoid an apical 5 chamber view
    - Include some LV
    - Frame rate > 10 MHz
    - Multibeat acquisition with breath hold or high volume rate 1 beat acquisition

On cart or off-line 3D reconstruction, surface rendering, display and analysis



Zhang et al, Front CV Med 2021 DOI 10.3389/fcvm.2021.641088



Tamborini et al JASE 2010;23:109-15

3D RV normal values

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- Maffesant et al Circ CV Img 2013;6:700-710

Age, y	n (Women, Men)	RV EDV, ml			RV ESV, ml		
		All	Women	Men	All	Women	Men
<30	114 (46, 68)	105 (69, 183)	88 (66, 136)	122 (80, 189)	46 (18, 88)	35 (14, 71)	51 (30, 94)
30–39	98 (50, 48)	92 (64, 147)	85 (63, 117)	114 (72, 153)	36 (18, 67)	31 (17, 52)	45 (25, 66)
40–49	98 (53, 45)	90 (63, 132)	82 (64, 106)	101 (75, 137)	35 (16, 54)	30 (15, 44)	40 (23, 62)
50–59	91 (49, 42)	90 (62, 138)	79 (62, 117)	101 (72, 138)	33 (18, 62)	29 (18, 46)	37 (22, 63)
60–69	69 (39, 30)	85 (47, 139)	79 (43, 100)	98 (76, 149)	32 (14, 61)	30 (13, 40)	37 (20, 68)
≥70	37 (23, 14)	77 (50, 125)	70 (51, 86)	98 (64, 129)	23 (11, 53)	20 (12, 32)	34 (18, 54)
All	507 (260, 247)	91 (61, 150)	81 (58, 120)	107 (74, 163)	35 (16, 72)	30 (15, 52)	44 (22, 80)

Age, y	n (Women, Men)	RV SV, ml			RV EF, %		
		All	Women	Men	All	Women	Men
<30	114 (46, 68)	63 (41, 95)	56 (42, 77)	69 (41, 101)	58 (42, 75)	60 (45, 80)	56 (42, 68)
30–39	98 (50, 48)	60 (36, 93)	56 (38, 72)	68 (37, 97)	61 (48, 76)	63 (52, 77)	60 (48, 72)
40–49	98 (53, 45)	56 (37, 82)	51 (39, 71)	63 (39, 86)	63 (51, 79)	65 (50, 79)	61 (51, 75)
50–59	91 (49, 42)	56 (35, 78)	50 (35, 68)	63 (44, 84)	62 (46, 75)	62 (47, 76)	62 (45, 73), *P*=0.51
60–69	69 (39, 30)	52 (28, 85)	49 (25, 61)	64 (48, 88)	61 (50, 79)	61 (53, 75)	63 (50, 78), *P*=0.75
≥70	37 (23, 14)	54 (31, 77)	49 (31, 64)	61 (45, 79)	68 (56, 81)	71 (60, 81)	65 (56, 75)
All	507 (260, 247)	57 (36, 87)	52 (35, 72)	66 (40, 91)	62 (47, 77)	63 (49, 79)	60 (45, 75)

Tamborini et al, JASE 2010;23:109-15

Age decile (y)	RVEDV (mL)			RVESV (mL)			RVEF (%)		
	All	Men	Women	All	Men	Women	All	Men	Women
<30	92 ± 23	107 ± 22	78 ± 12	33 ± 13	41 ± 12	24 ± 8	66 ± 8	62 ± 6	69 ± 9
30-39	88 ± 20	99 ± 22	79 ± 11	30 ± 10	35 ± 10	25 ± 7	66 ± 8	64 ± 8	69 ± 7
40-49	86 ± 19	96 ± 20	76 ± 13	28 ± 10	34 ± 10	22 ± 7	68 ± 8	64 ± 8	71 ± 7
50-59	87 ± 20	99 ± 21	74 ± 8	30 ± 11	36 ± 11	24 ± 6	66 ± 7	65 ± 6	67 ± 8
60-69	82 ± 22	96 ± 13	68 ± 19	27 ± 10	31 ± 10	23 ± 10	67 ± 9	68 ± 9	67 ± 10
>70	80 ± 22	94 ± 23	70 ± 15	26 ± 11	33 ± 12	21 ± 7	68 ± 7	65 ± 6	71 ± 7
All	86 ± 21	99 ± 14	74 ± 14	29 ± 11	35 ± 7	23 ± 7	67 ± 8	64 ± 8	69 ± 8

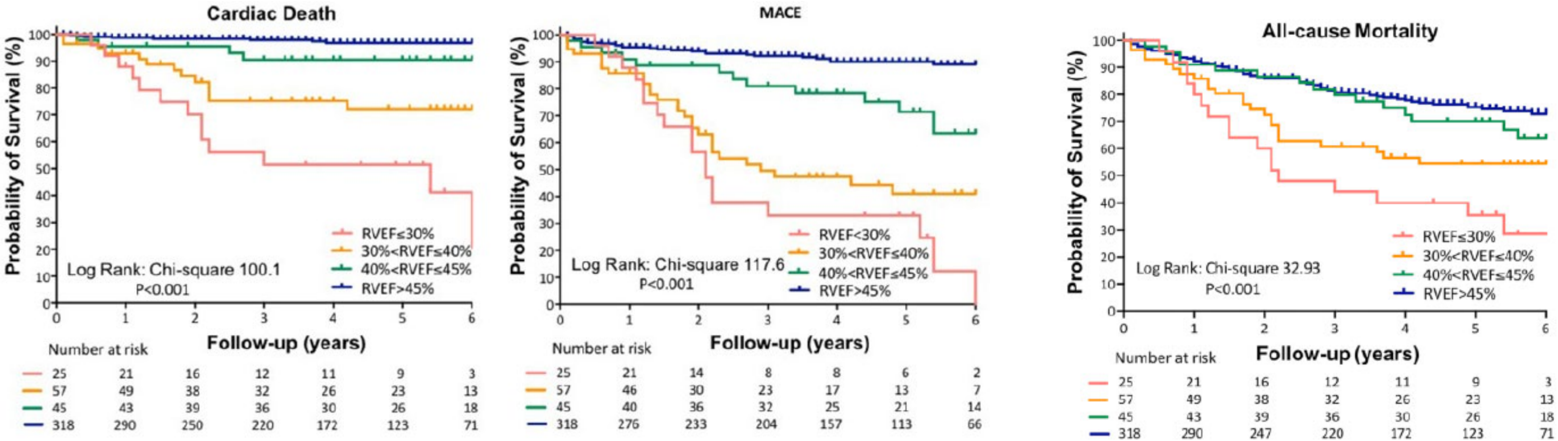
3D echo indexed RV EDV and ESV

- Tamborini et al, JASE 2010;23:109-15
- Correlate with age and sex

	RVEDV index (mL/m^2)			RVESV index (mL/m^2)		
Age decile (y)	All	Men	Women	All	Men	Women
<30	53 ± 10	57 ± 11	48 ± 6	18 ± 7	22 ± 6	15 ± 5
30-39	49 ± 8	50 ± 10	49 ± 6	16 ± 4	18 ± 5	15 ± 4
40-49	48 ± 9	50 ± 9	47 ± 8	16 ± 5	18 ± 5	14 ± 5
50-59	49 ± 9	52 ± 10	46 ± 8	17 ± 5	19 ± 5	15 ± 4
60-69	46 ± 10	50 ± 6	41 ± 10	15 ± 5	16 ± 5	13 ± 5
>70	46 ± 12	50 ± 13	43 ± 10	15 ± 6	18 ± 7	13 ± 4
All	49 ± 10	52 ± 8	46 ± 8	16 ± 6	18 ± 4	14 ± 4

3D echo

- Partition values for RVEF
  - Muraru et al Eur Hrt J CV Img 2020;21:10-21
    - Derivation and validation populations
      - Followed for 4 years to confirm prognostic value

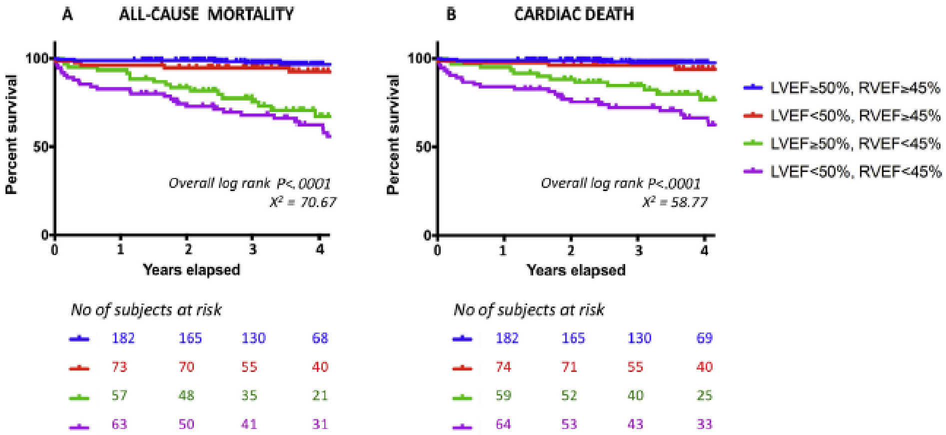


Relative prognostic value of LV and RV EF in CV Disease

Surkova et al JASE 2019;32:1407

- 394 patients with various CV diseases
  - 4 year follow up

  - All cause mortality and CV mortality in patients with normal LVEF and reduced RVEF higher than in those with reduced LVEF and normal RVEF
    - And similar to those with reduced EF in both ventricles



Automated Machine learning-based 3D quantification of RV size and function

Genovese et al, JASE 2019;3:969-77

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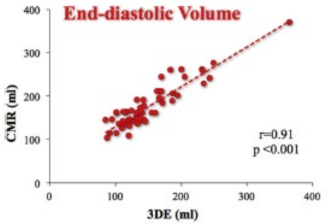
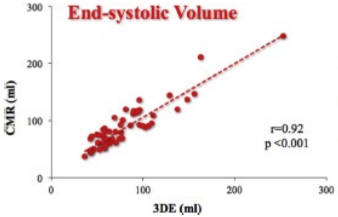
- Machine learning allows automated RV border detection and surface rendering of 3D volumes and calculation of RVEF
  - Based on a library of shape descriptions of the RV to optimally place the contours
- Comparison to same day CMR
  - Fully automated approach - 32% accurate (100% reproducible)
  - Manual editing improved the accuracy in the other 68%
- Look at the images for tracking - manual editing required





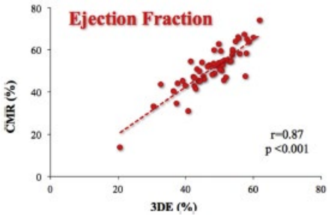
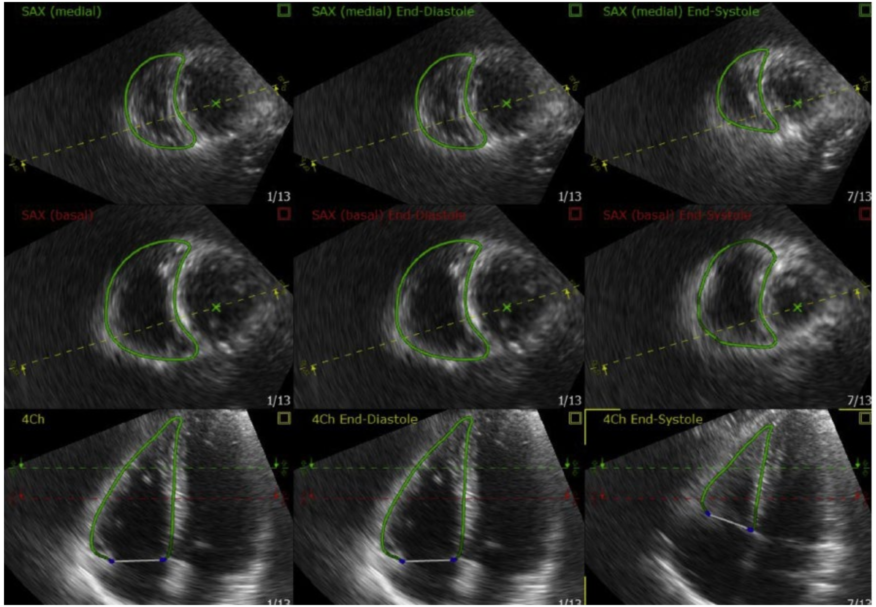


Table 5 Reproducibility of the ML-based software for 3DE measurements of RV volumes and function

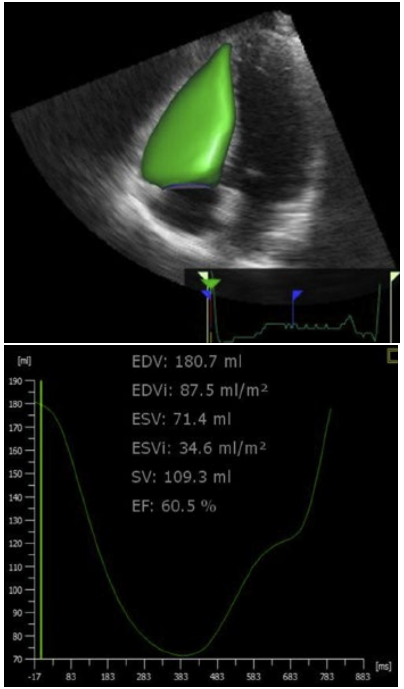
	Intraobserver variability		Interobserver variability	
	CoV, %	ICC	CoV, %	ICC
EDV	3.4 ± 4.1	0.99 [0.98-0.99]	6.1 ± 7.7	0.97 [0.94-0.98]
ESV	4.3 ± 4.9	0.99 [0.99-1.00]	6.5 ± 8.2	0.98 [0.96-0.99]
EF	3.1 ± 4.0	0.96 [0.94-0.98]	3.8 ± 4.7	0.95 [0.91-0.97]

Genovese et al, JASE 2019;3:969-77

Automated endocardial contouring along RV short and long axis of the 3D data set



RV surface rendering and volume calculations



3D RV speckle tracking for volume, EF and longitudinal strain c/w CMR

Li et al, JASE 2021;34:472-82

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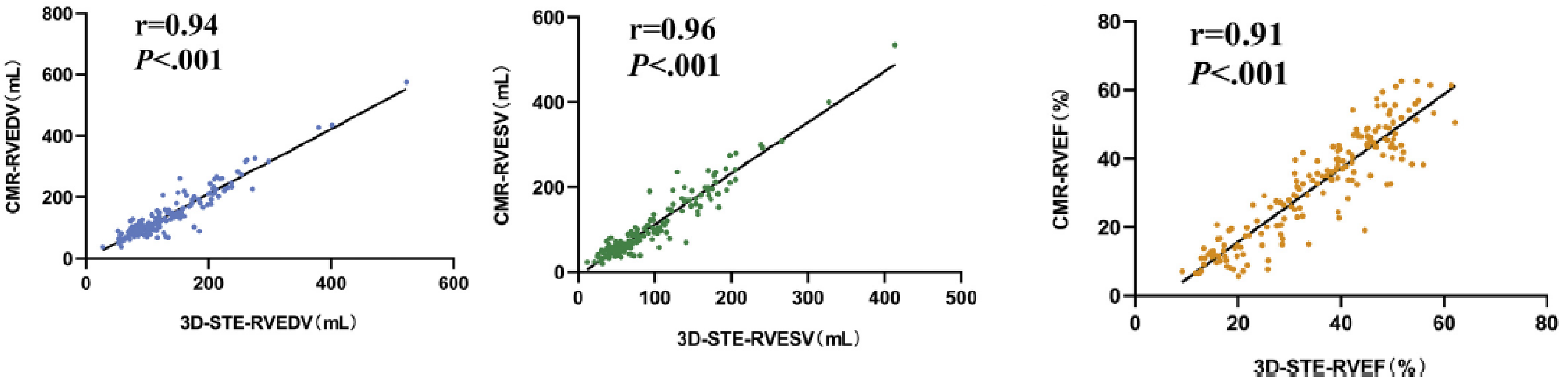
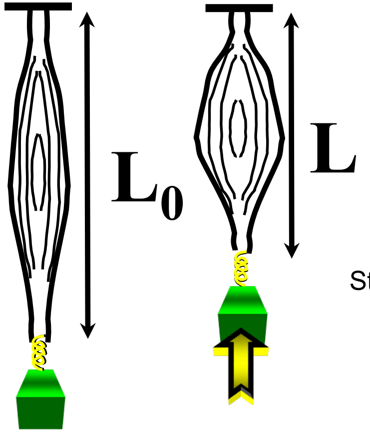


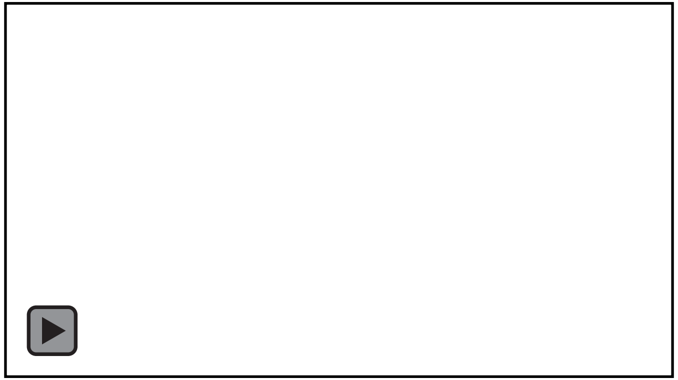
RV strain

- Same concepts as discussed for LV strain
  - Frame by frame tracking of natural acoustic markers
  - Angle independent
  - Less influenced by translational movements + tethering



$$\text{Strain (\%)} = \frac{(L - L_0)}{L_0}$$

- RV longitudinal strain
  - Typically endocardial change in length
  - Global
    - 6 segments
      - 3 free wall, 3 septal
        - » Base, mid, apical
  - RV free wall
    - 3 segments



RV longitudinal strain normal values

Addetia et al, JASE 2021;34:1148-57

- 1,913 normal subjects (51% male)
  - -25.4% +/-3.8

- Men
  - -24.4% +/- 3.6
- Women
  - -26.5% +/-3.7

Incremental value of RV strain post PCI for AMI

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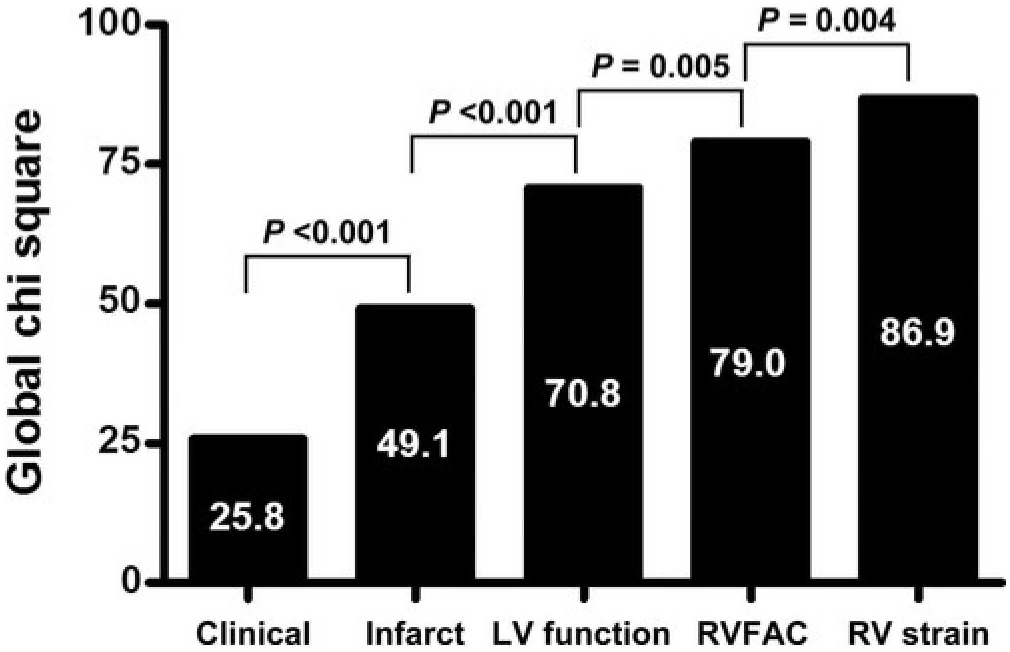

Antoni et al Circ Img 2010;3:264-271

Pitfalls of GLS

- Many use LV software

- Algorithms vary by vendor
  - Normal values will vary slightly

- Region of interest will influence the GLS
  - Width of ROI, incorrect position of annulus
  - Only 6 segments (or 3) so if 1 is incorrect the data are influenced

- Reliance on just the number rather than looking at the ventricle
  - Is the output peak strain, peak systolic strain, etc

- Intra-vendor reproducibility better than inter-vendor
  - Assessing serial changes
  - Test-retest reliability not comprehensively studied

Peak strain vs. peak systolic strain

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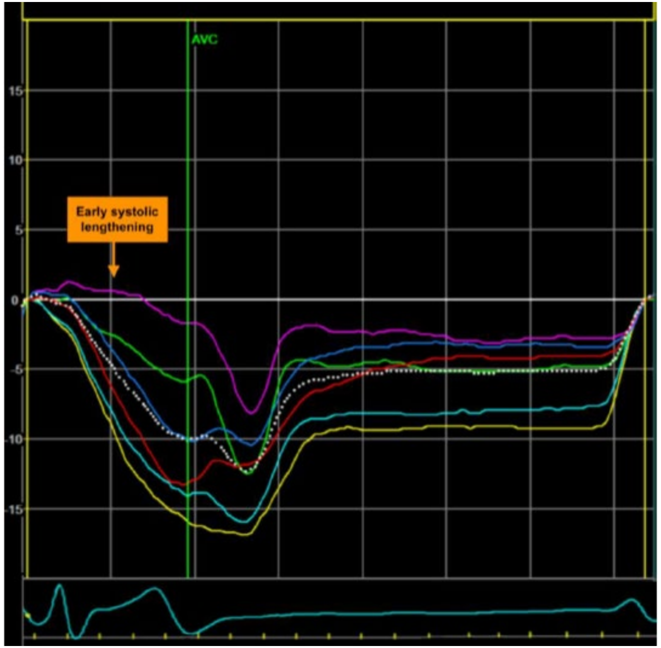

If default setting incorrect value reported will be incorrect

More pitfalls

- Tracking quality depends on relationship between frame rate and heart rate
  – Ideal is FR/HR > 0.7

- DICOM assessment vs. raw data assessment
  – Conversion to DICOM results in compression of frame rate
    - Could influence GLS at higher heart rates

Data at acquisition frame rate

DICOM converted to a lower FR

- Afterload impacts longitudinal strain
  - High pulmonary vascular resistance leads to lower GLS regardless of the myocardial contractility
    - Solution for the LV is myocardial work, no equivalent yet for the RV

Future

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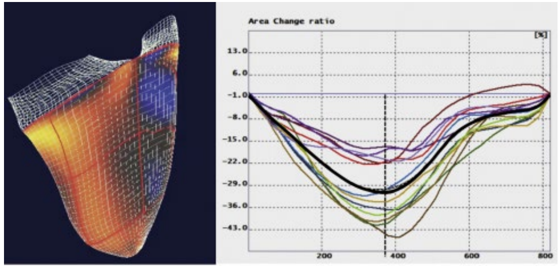
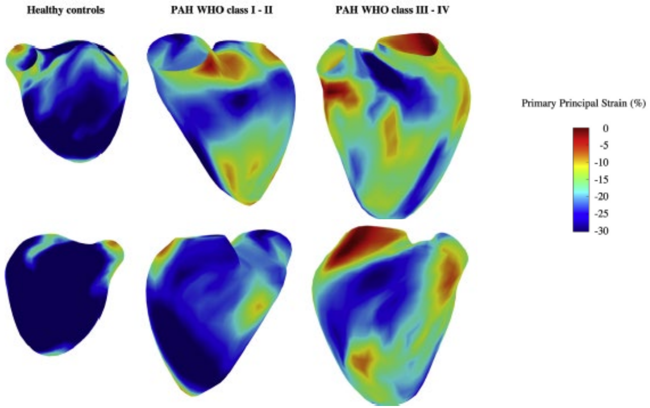
- 3D speckle tracking for RV deformation analysis
  - circumferential strain
  - out of plane motion, shear motions
  - segmental assessments
  - principal strain analysis
    - Measure strain along the dominant angle it occurs



Atsumi et al, JASE2016;29:402-11



Summary

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- 2D echo assessment of RV systolic function
  - A good starting point to screen
- 3D echo EF better than 2D assessments of function
  - When image quality allows accurate RV endocardial border detection
- 2D RV strain
  - Best assessment of longitudinal function/deformation
    - Understand pitfalls !
- 2D strain and 3D echo of the RV make echo assessments of the RV competitive with CMR
  - Especially when patient unable to under CMR

Thank you

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