Assessing LV Systolic Function: when to use contrast or 3D echo

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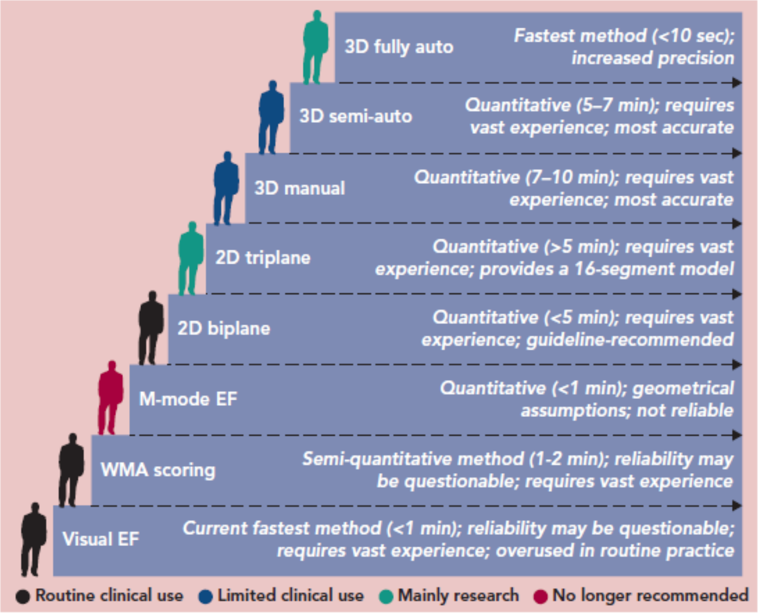
No disclosures

Figure 3: Stairway of Echocardiographic Methods for the Assessment of Left Ventricular Ejection Fraction



EF = ejection fraction; M-mode = mono-dimensional; WMA = wall motion abnormalities.

Spitzer et al. Cardiac Failure Review 2017;3:97-101

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LV function in clinical practice: role of echo

- **Diagnosis** – systolic and diastolic dysfunction
  - Etiology for symptoms
- Assessing **response** to treatment
- Assessing risk and **prognosis**
  - Need for interventions
    - Defibrillators, valve surgery, meds, CRT
  - Timing of interventions

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Assessing function of the LV pump

Myocardial deformation

- Vcf
- Isovolumic acceleration
- dP/dt
- Tissue Doppler
- Strain
- Strain rate
- Torsion
- Twist

Volume change

- Shortening fraction
- Stroke volume
- LVEF
- Stroke work
- Elastance
  - End systolic pressure-volume relation

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Quantitation of global LV systolic function: *how?*

Isovolumic indices

- dP / dt
- E_{max}

Ejection phase indices

- Area change
- Myocardial Performance Index (MPI, Tei index)
- Fractional shortening
- Velocity of circumferential fiber shortening (Vcf)
- LV EF

Assessing global systolic function by LV EF

- Has flaws but most commonly used measure
- Qualitative
  - Internal check
- Single dimension
  - Obsolete
- Volumetric
  - Simpson's Rule Method / Method of Discs
  - 2/3 Area length
    - When apical endocardium can't be traced
  - Three dimensional

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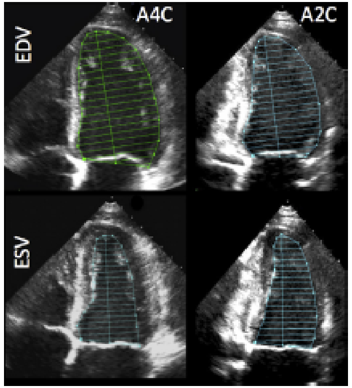
ASE Best Practice: LVEF should be calculated from LV volumes

Volumes.
Volume measurements are usually based on tracings of the blood-tissue interface in the apical four- and two-chamber views. At the mitral valve level, the contour is closed by connecting the two opposite sections of the mitral ring with a straight line. LV length is defined as the distance between the middle of this line and the most distant point of the LV contour.

Biplane disk summation

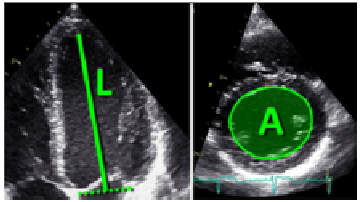


- Corrects for shape distortions
- Less geometrical assumptions compared with linear dimensions

Single plane ok if no WMA

- Apex frequently foreshortened
- Endocardial dropout
- Blind to shape distortions not visualized in the apical two- and four-chamber planes

Area-length



- Partial correction for shape distortion

- Apex frequently foreshortened
- Heavily based on geometrical assumptions
- Limited published data on normal population

MOD – trace interface between compacted and noncompacted myocardium

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Lang et al, JASE 2015;28:1-39

LV function guideline recommendations

Lang et al, JASE 2015;28:1-39

- LVEF from 2D volumes
  - < 52% for men abnormal
  - < 54% women abnormal

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Pitfalls of 2D LVEF

- 2D LVEF from biplane method of discs (MOD) or area length (AL) is a reasonable screen for relative degrees of dysfunction
  - AL assumes a geometric shape of the LV
  - MOD assumes elliptical shape of each disc
  - MOD requires accurate delineation of endocardial borders
  - MOD over-weights the size and motion of the LV from 2 apical views
- 2D LVEF may have reduced accuracy in remodeled LV, states with abnormal septal motion, focal RWMA, foreshortened LV
- Solutions
  - Ultrasound Enhancing Agents (aka Contrast)
  - 3D LV echo

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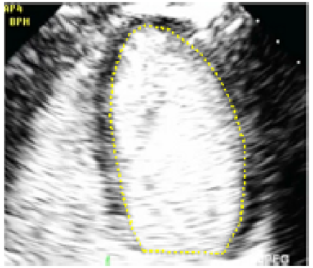
Enhancements to 2D LV volume measurement

- Contrast agents (aka ultrasound enhancing agents UEA)

Parameter and method	Technique	Advantages	Limitations
	Endocardial border enhancement 	• Helpful in patients with suboptimal acoustic window • Provides volumes that are closer to those measured with cardiac magnetic resonance	• Same limitations as the above non-contrast 2D techniques • Acoustic shadowing in LV basal segments with excess contrast

Lang et al, JASE 2015;28:1-39

- Many studies have documented beneficial effect of UEA on early outcomes in critically ill patients and cost effectiveness in those with suboptimal windows

- Appropriate use criteria
  - 2 or more contiguous segments not seen on noncontrast images

- Very low mechanical index imaging (MI < 0.2) RECOMMENDED
  - Non linear acoustic signal differentiated from tissue
  - High spatial and good temporal resolution
    - LVEF and RWMA
- Low MI (<0.3)
  - Harmonic techniques
- Intermediate MI (0.3-0.5)
  - Harmonic techniques
  - More destruction of microbubbles and swirling artifacts
    - Same problem with high MI (>0.5)

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Value of contrast – 2018 ASE guidelines

Porter et al, JASE 2018;31:241-74

- Details on agents
- Details on settings for various machines
- Details on indications
- Practical tips

Table 4 Location and description of VLMI imaging software on commercially available echocardiographic scanners

Manufacturer	Platform and portability*	Location and name of enhanced imaging software on front end	High-MI "flash" impulse location on front end	Specific pulse sequence scheme used (dominant nonlinear activity detected)	Frequency/MI recommended for VLMI imaging
Philips	iE33 Not portable	Contrast key On/off LVO and low-MI choices	Touch screen/ flash label	Amplitude modulation and pulse inversion (fundamental and harmonic)	<2.0 MHz/MI < 0.2 (GEN or PEN setting)
Philips	Epiq Not portable	Contrast key On/off Low-MI and LVO choices	Touch screen/ flash label	Amplitude modulation and pulse inversion (fundamental and harmonic)	<2.0 MHz/MI < 0.2 (GEN or PEN setting)
Philips	CX50 Portable	Contrast key On/off LVO choice	Control panel	Amplitude modulation (harmonic)	<2.0 MHz/MI < 0.3
GE	Vivid E95 Not portable	Advanced contrast option	Touch screen/ flash label	Pulse inversion 1.5/3.0 and 1.6/3.2 MHz and 1.7/ 3.4 MHz (harmonic) Amplitude modulation 2.1 and 2.4 MHz (fundamental and harmonic)	1.5–1.7 MHz/MI < 0.2 2.1–2.4 MHz/MI < 0.2
Siemens	SC2000 Not portable		Not available; need to use "color Doppler" knob	Pulse inversion and alternating polarity/amplitude (fundamental and harmonic)	2.0 MHz/MI < 0.2
Toshiba	Aplio i900 Not portable	Touch screen/ CHI label	Control panel	Pulse subtraction (amplitude modulation; harmonic)	h3.5/MI < 0.2 (PEN setting)
Toshiba	Aplio 500 Not portable	Touch screen/ low label	Touch screen/ flash label	Pulse subtraction (amplitude modulation; harmonic)	h2.8–h3.6/MI < 0.2
Esaote	MyLabEight Not portable	Contrast key On/off LVO choice	Touch screen/ flash label	Phase cancellation	PEN frequency/MI < 0.2
Esaote	MyLabSeven Not portable	Contrast key On/off LVO choice	Touch screen/ flash label	Phase cancellation	1.5 MHz/MI < 0.2
Esaote	MyLabAlpha Portable	Contrast key On/off LVO choice	Touch screen/ flash label	Contrast tuned imaging	1.5 MHz/MI < 0.2

Where to end tracing; where is the MV annulus ?

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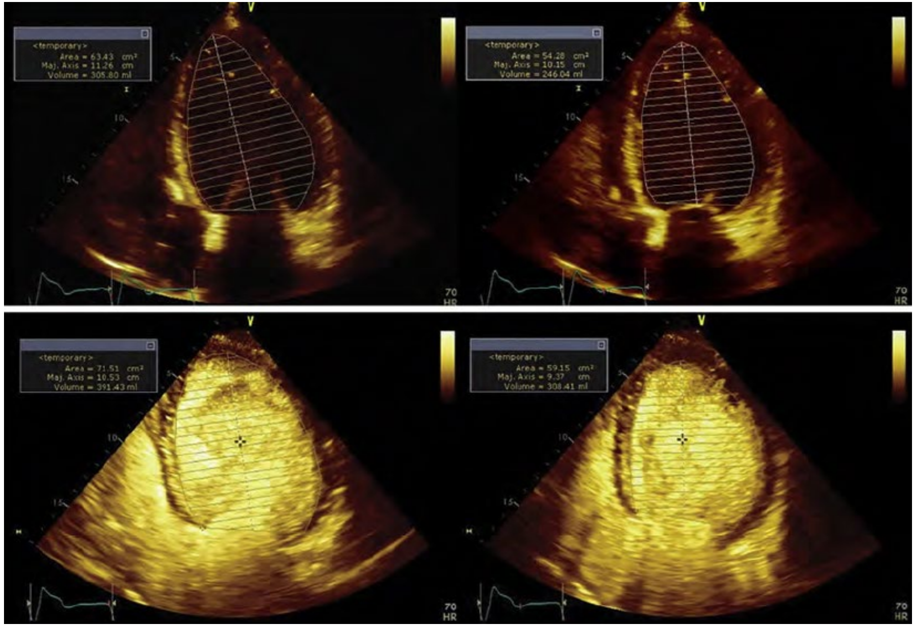
Contrast for LV systolic function - volumes

- Contrast enhanced LV volumes will be larger than unenhanced
    - Less foreshortening
    - Better delineation of the border between non-compacted and compacted myocardium
- Larger ULN for LV volume
    - EDV
        - Women 81 ml/sq m
        - Men 98 ml/sq m
            - Better agreement with CMR



Porter et al, JASE 2018;31:241-74

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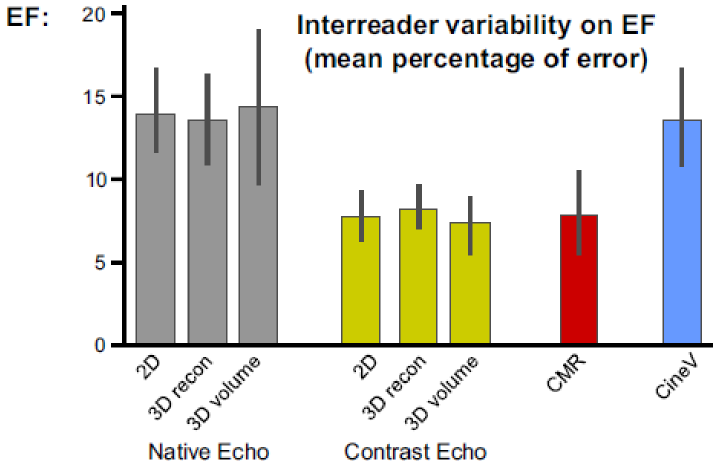
Contrast for LVEF

- Improved accuracy (CMR gold standard)
- Reduced interobserver variability
- Therefore, value when precise quantification of LVEF required
  - Defibrillator, CRT, Chemotherapy follow up, valve disease intervention timing



Hoffmann et al, JASE 2014;27:292-301

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Routine use of contrast on admission TTE for heart failure reduces rate of repeat echoes

Lee et al JASE 2021;34:1253-61

- 9,115 HF admissions over 4 year period
  - 5,600 UEA on 1st TTE, 3,515 no UEA
    - 104 repeat TTEs during hospital stay considered unjustified
      - 77% were in the no contrast 1st TTE
      - As rate of contrast increased over 4 year period
        - » Unjustified TTE rate decreased
  - Use of contrast associated with reduced LOS

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Overcoming barriers to use

- IV placement
  - Various models
    - Sonographers place IV
    - Echo lab nurse for IV
- Should we use contrast for all LVEF assessments even when image quality is optimal ?
  - Benefit Study

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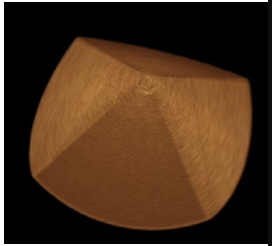
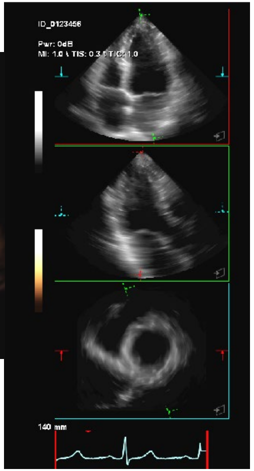
3D echo for volume and EF





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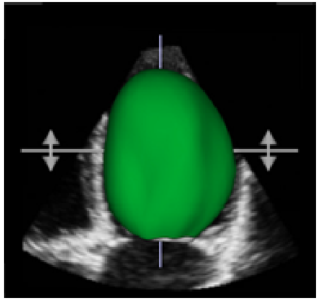
Enhancements to LV volume measurement

3D data sets



- No geometrical assumption
- Unaffected by foreshortening
- More accurate and reproducible compared to other imaging modalities

- Lower temporal resolution
- Less published data on normal values
- Image quality dependent

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Lang et al, JASE 2015;28:1-39

3D normal values

- Volumes larger than 2D
- EF range different

Table 3 Normal values for LV parameters obtained with 3DE

	Aune *et al.* (2010)	Fukuda *et al.* (2012)	Chahal *et al.* (2012)	Muraru *et al.* (2013)
Number of subjects	166	410	978	226
Ethnic makeup of population	Scandinavian	Japanese	51% European white, 49% Asian Indian	White European
EDVi (mL/m^2)				
Men, mean (LLN, ULN)	66 (46, 86)	50 (26, 74)	White: 49 (31, 67); Indian: 41 (23, 59)	63 (41, 85)
Women, mean (LLN, ULN)	58 (42, 74)	46 (28, 64)	White: 42 (26, 58); Indian: 39 (23, 55)	56 (40, 78)
ESVi (mL/m^2)				
Men, mean (LLN, ULN)	29 (17, 41)	19 (9, 29)	White: 19 (9, 29); Indian: 16 (6, 26)	24 (14, 34)
Women, mean (LLN, ULN)	23 (13, 33)	17 (9, 25)	White: 16 (8, 24); Indian: 15 (7, 23)	20 (12, 28)
EF (%)				
Men, mean (LLN, ULN)	57 (49, 65)	61 (53, 69)	White: 61 (49, 73); Indian: 62 (52, 72)	62 (54, 70)
Women, mean (LLN, ULN)	61 (49, 73)	63 (55, 71)	White: 62 (52, 72); Indian: 62 (52, 72)	65 (57, 73)

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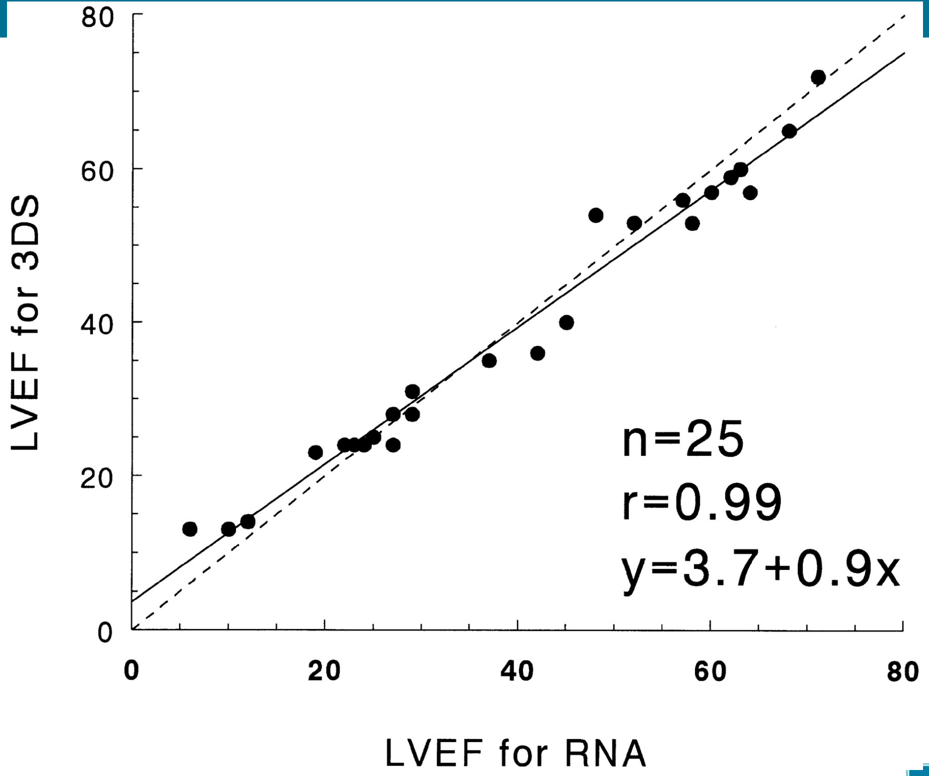
Lang et al, JASE 2015;28:1-39

Linear regression of LVEF in all patients, measured by 3D echocardiography by Simpson's method (3DS) vs radionuclide angiography (RNA)



Nosir, Y. F.M. et al. Circulation 1996;94:460-466

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Accuracy of 3D echo for LV volume

- function of image quality:
  - the number of elements in the matrix array transducer
  - the voxel size
  - the spatial resolution of the image
  - Temporal resolution

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Challenges to using 3D LVEF in clinical practice

- Since normal range is different than 2D how do you deal with teaching your referring clinicians how they should interpret the different tests
  - An LVEF of 50% on 3D is normal but if the MD is used to the 2D range they may think of it as abnormal

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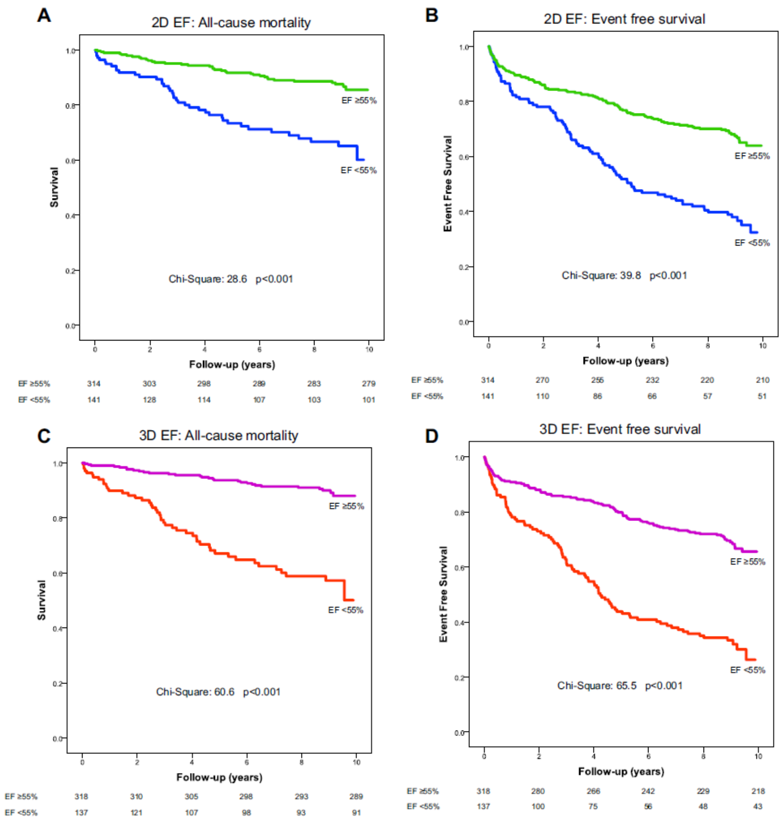
3D EF stronger association with outcomes than those from 2D

Stanton et al, JASE 2014;27:65-73



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Automated 3D echo LVEF performance

Spitzer et al. Cardiac Failure Review 2017;3:97-101

Table 1: Comparisons Among Fully Automated 3D Methods and Either Cardiac Magnetic Resonance or Manual Echocardiography

Authors	Reference	Software	n	Feasibility	LVEDV bias (ml)	LVESV bias (ml)	LVEF bias (%)
Thavendiranathan, et al., 2012[15] (I)	CMR	eSie LVA™ (Siemans Healthcare)	101	66 %	−18 ± 54	−10 ± 36	−0 ± 6
Thavendiranathan, et al., 2012[15] (II)*	2D Simpson	eSie LVA	27	89 %	2 ± 16	4 ± 13	−2 ± 4
Ren, et al., 2014[19]	Manual 3D	eSie LVA	48	85 %	−3 ± 23	−2 ± 14	−0 ± 9
Otani, et al., 2016[31,*]	2D Simpson	HeartModel (Philips Healthcare)	10	100 %	−3 ± 26	−1 ± 17	−0 ± 10
Tsang, et al., 2016[30] (I)	CMR	HeartModel	69	94 %	2 ± 40	10 ± 40	−6 ± 16
Tsang, et al., 2016[30] (II)	Manual 3D	HeartModel	104	90 %	−24 ± 50	−13 ± 58	−2 ± 18
Spitzer, et al., 2017[32]	Manual 3D	HeartModel	72	93 %	−6 ± 39	−2 ± 39	−1 ± 15
Levy, et al., 2017[33]	CMR	HeartModel	63	86 %	−22 ± 34	−13 ± 33	−1 ± 7
Medvedofsky, et al., 2017[34,†]	Manual 3D	HeartModel	180	100 %	−14 ± 20	−6 ± 16	−2 ± 7
Medvedofsky, et al., 2017[34,†,‡]	Manual 3D	HeartModel	300	66 %	−3 ± 22	1 ± 16	0 ± 10

**Atrial fibrillation; †Including patients with arrhythmias; ‡Consecutive patients. I and II describe two reference modalities used in a single report. CMR = cardiac magnetic resonance; LVA = left ventricle analysis; LVEDV = left ventricle end-diastolic volume; LVEF = left ventricle ejection fraction; LVESV = left ventricle end-systolic volume.*

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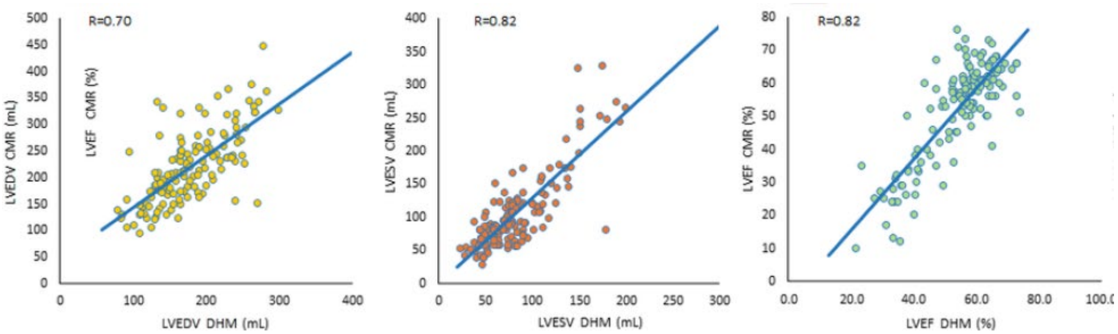
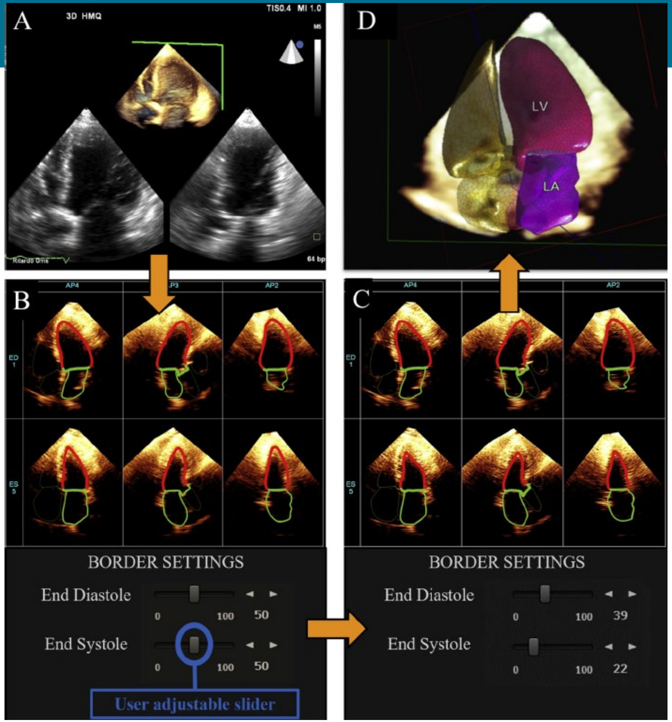
Automated machine learning-based 3D quantification of LV volume and function

Italiano et al, DOI ***10.21203/rs.3.rs-355587/v1***

- Automated LV border detection and surface rendering
  - Based on library of shape descriptions of the LV optimally place the contours
- 600 unselected patients (12% AF)
  - 140 with CMR
  - 88% feasibility
  - 64% accurate borders (9% major border corrections required)
    - Small LVs, distorted shapes





Tamborini et al JASE 2017;30:1049-58

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Contrast for 2D LVEF

- When endocardial border not delineated on 2 or more contiguous segments
- LV volumes will be larger than unenhanced LV images
  - EFs are equivalent
- Patience and practice required to identify mitral annular plane for biplane method of disc tracings
- Of particular benefit when precise LV volumes or EF are needed for serial assessment and clinical decision making

3D for LV systolic function:

- Limitations
  - Image quality
  - Rhythm (use single beat capture)
  - Lower temporal resolution than 2D
  - Less published data for normal values

- Advantages
  - Better precision than 2D especially in asymmetric LVs
    - Can pick up subtle differences on serial studies
    - Follow course of a disease

- BENEFITS OUTWEIGH LIMITATIONS

Thank you

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