Dimensioni e funzione dell'atrio sinistro: dall'eco alla risonanza.

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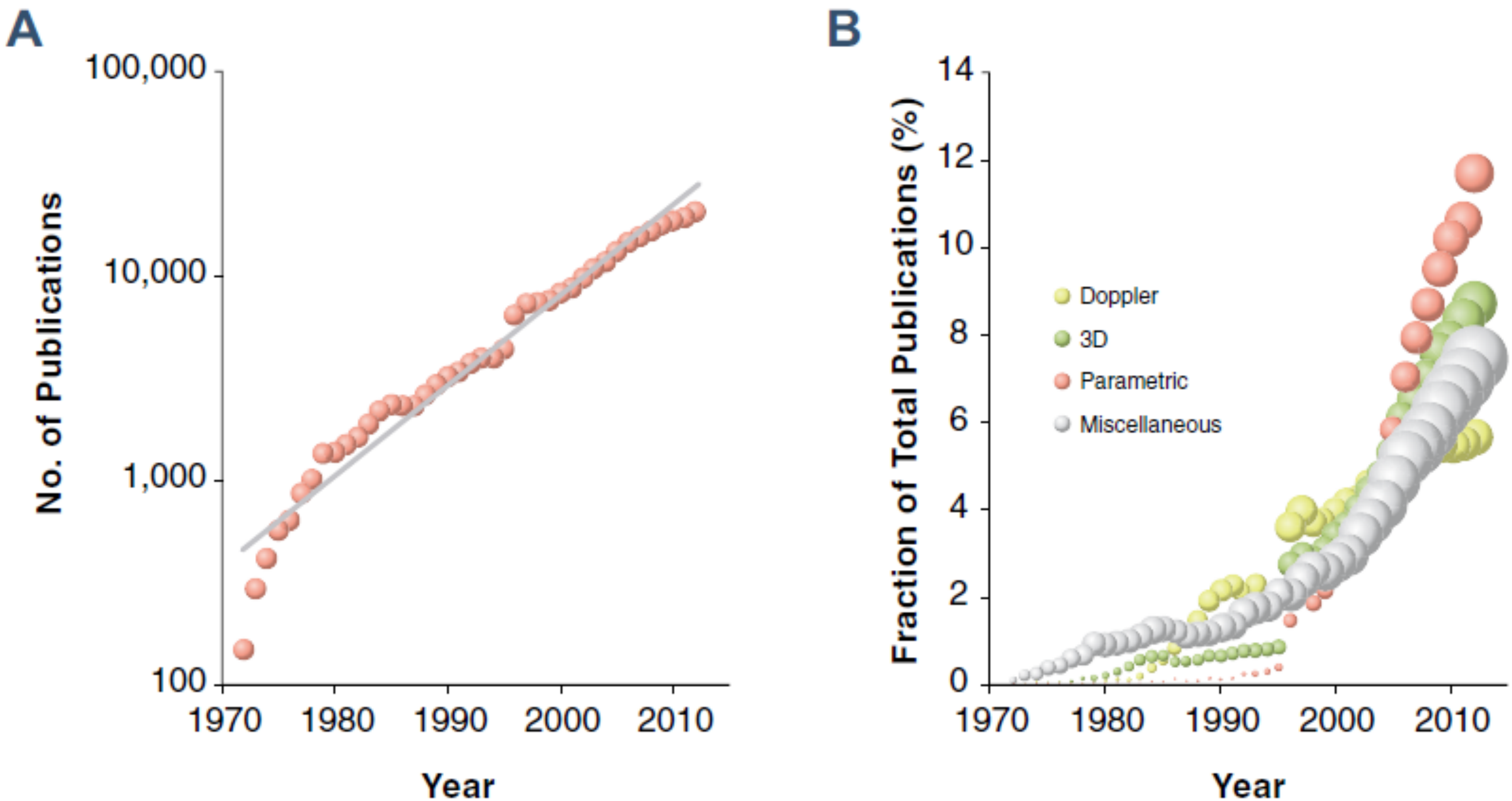
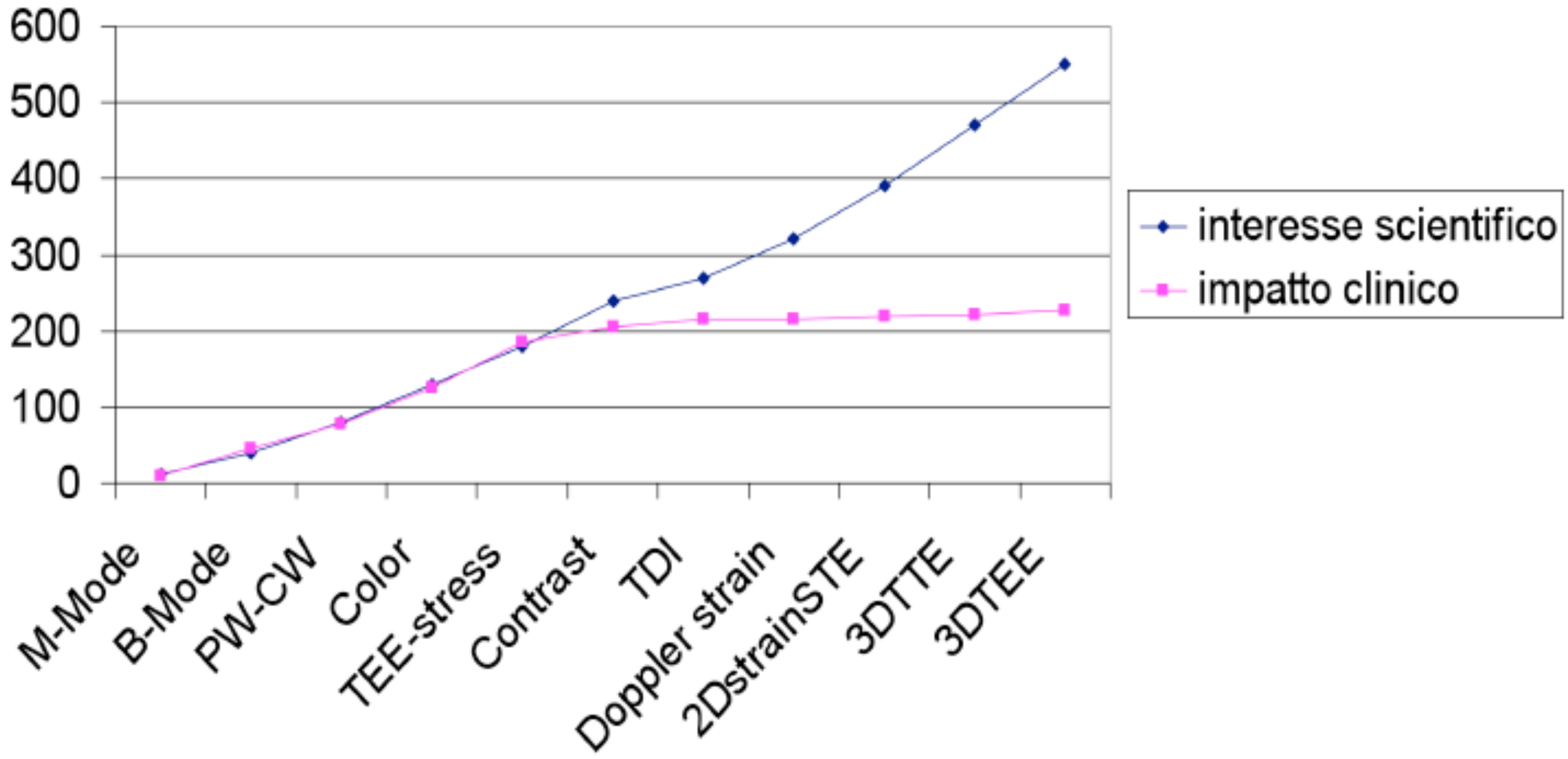
EMILIA-ROMAGNA
Azienda Ospedaliera Policlinico di Modena

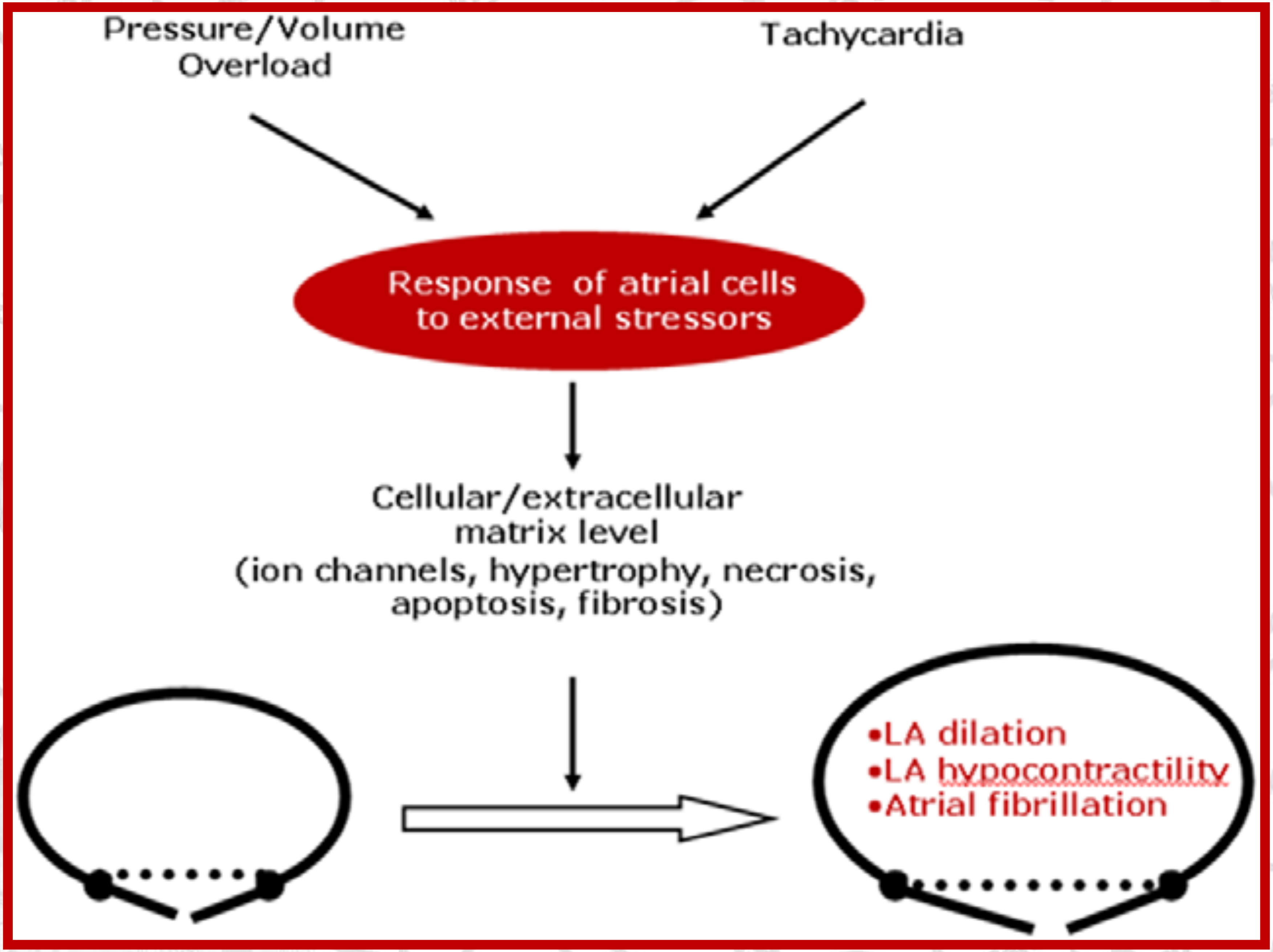
Growth of annual publications in CU



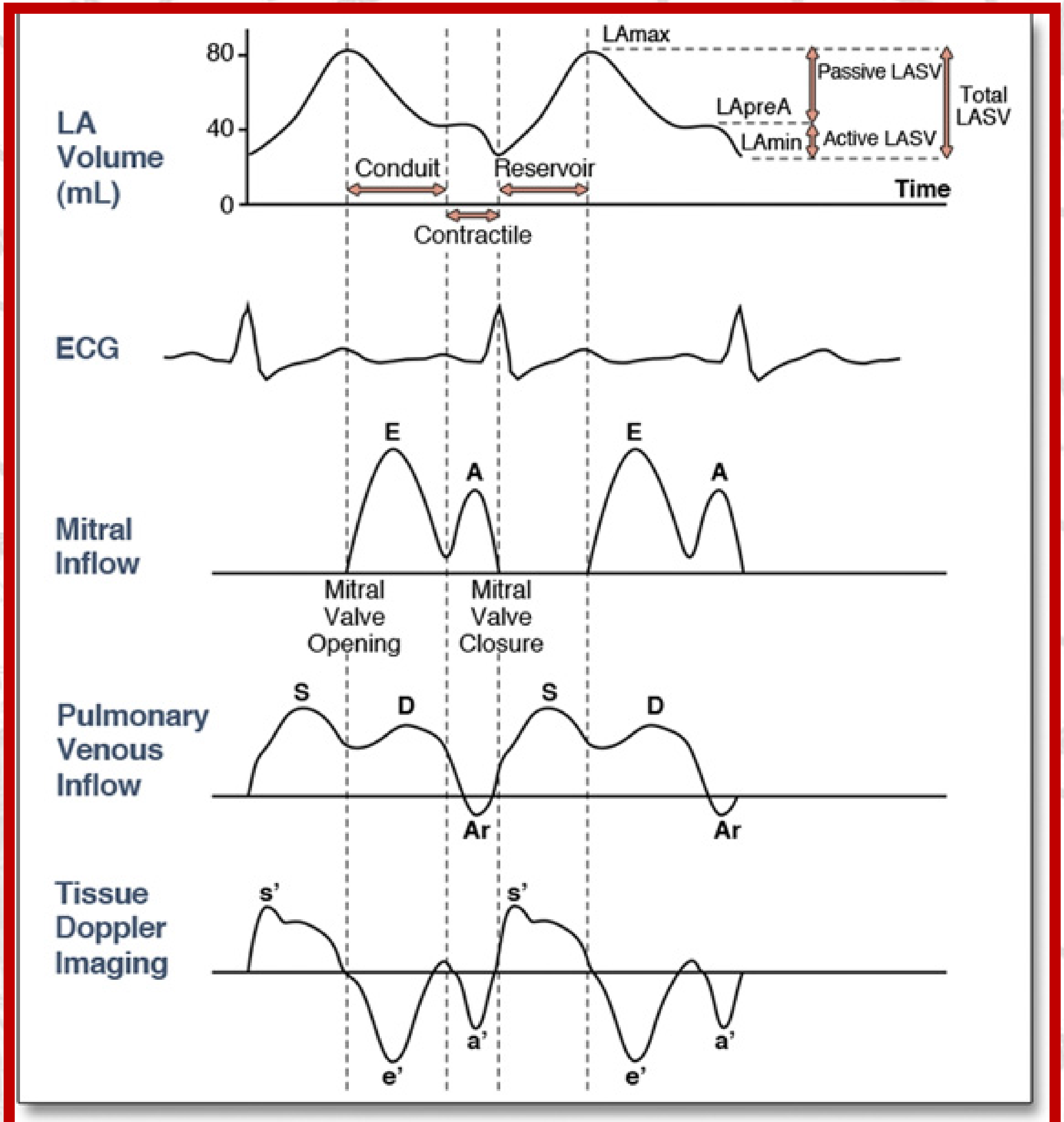
J Am Coll Cardiol Img 2013;6:1206–11



Antonini-Canterin F. SIEC ECHONEWS N. 21 Aprile 2015



Circ Heart Fail 2014;7:1042-1049



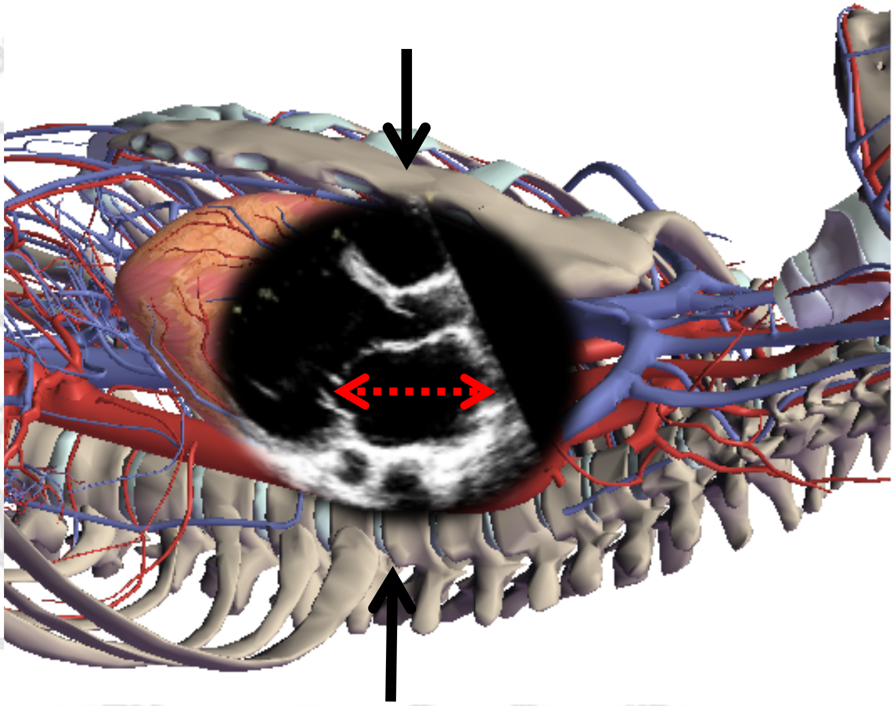
J Am Coll Cardiol Img 2011;4:788–98

Atrial geometrical abnormalities: static volumes

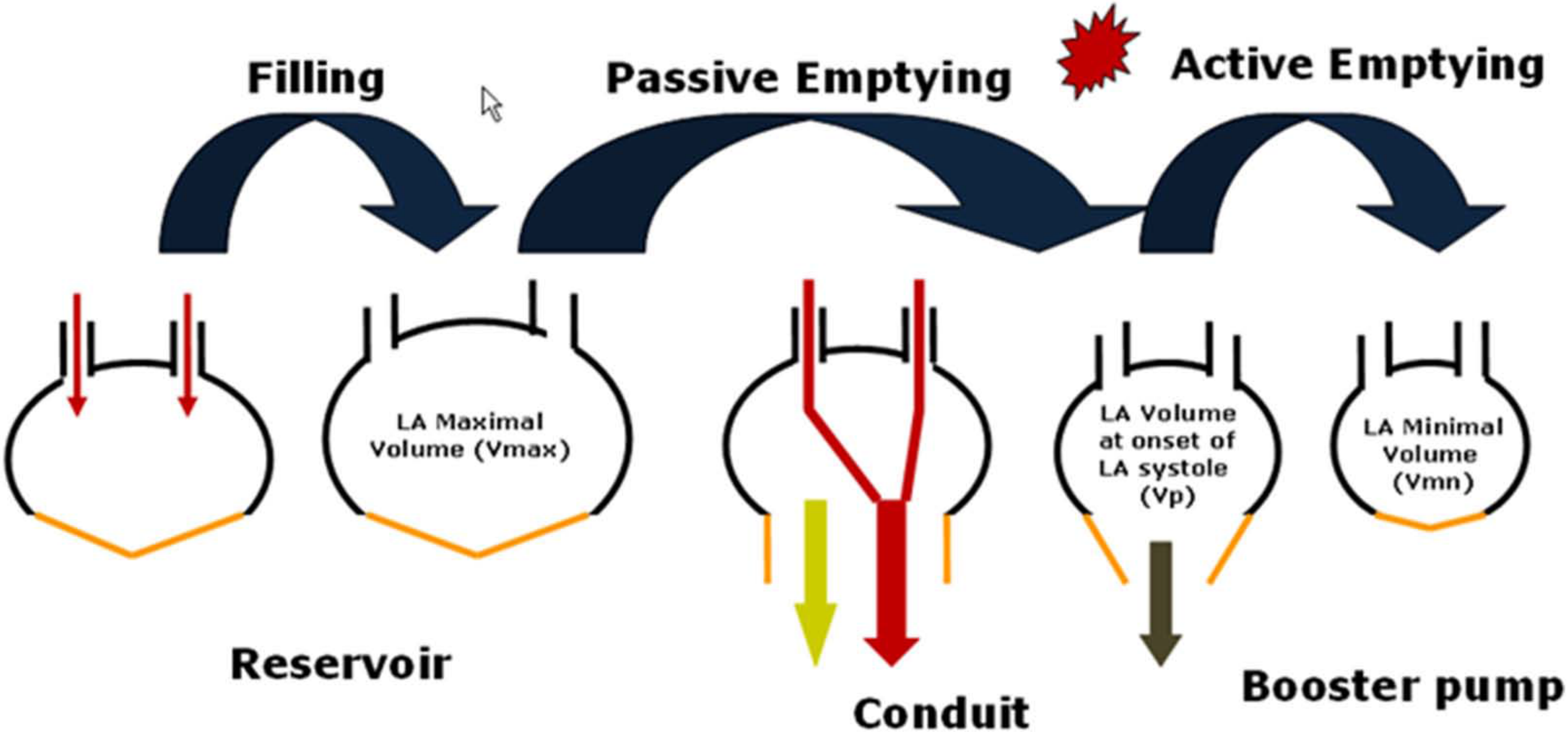
Quantification of Left Atrial Size

Asymmetrical LA Remodelling

LA enlargement does not occur uniformly in all directions!



Time



LA Passive Emptying Volume = Vmax - Vp

Conduit Volume = LV stroke volume – (Vmax-Vmin)

LA Active Emptying Volume = Vp - Vmin

Heart Fail Rev 2008;13:91–98

GUIDELINES AND STANDARDS

Recommendations for Cardiac Chamber Quantification by Echocardiography in Adults: An Update from the American Society of Echocardiography and the European Association of Cardiovascular Imaging

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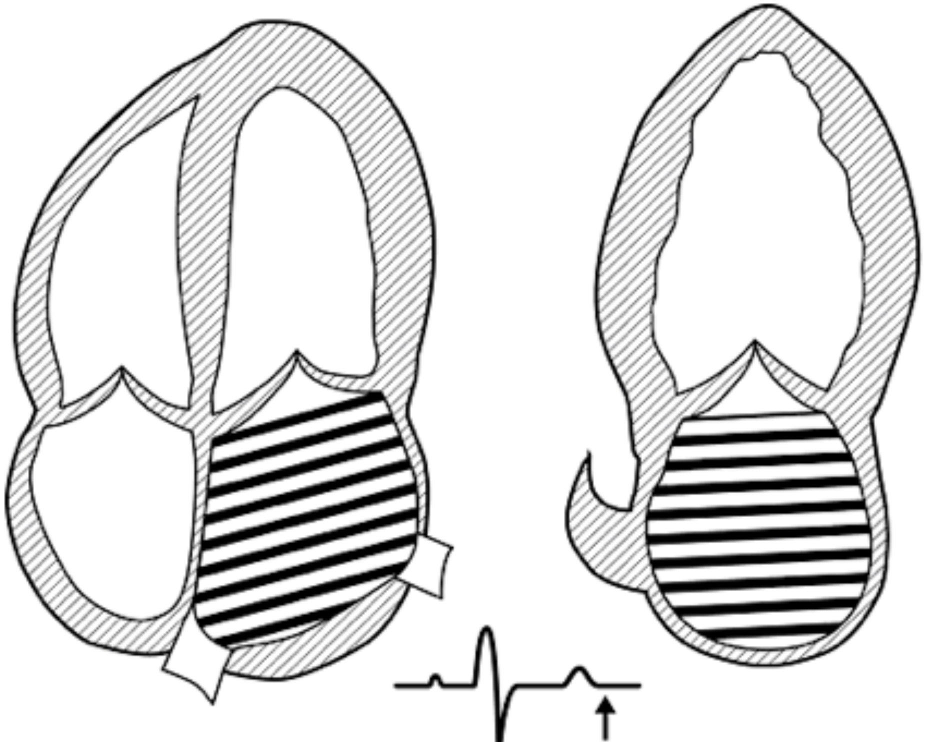
J Am Soc Echocardiogr 2015;28:1-39

Quantification of Left Atrial Size

Method of Discs (Simpson's Rule)

Simpson's rule: volume of a geometrical figure can be calculated from the sum of the volumes of smaller figures of similar shape.

Disk summation algorithm is based on the premise that a cavity can be divided into a series of stacked oval discs with a known height and orthogonal minor and major axes.



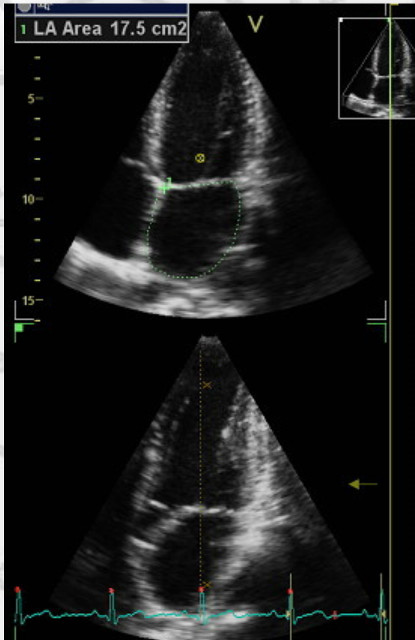
J Am Coll Cardiol 2006;47:2357-63

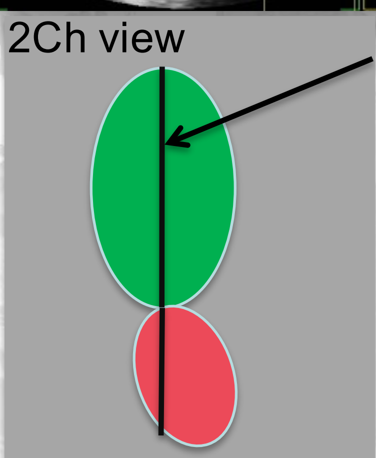
Step	Common Limitations/Errors	Suggestions
A. Optimize LA image quality	Atria are located in the far field of the apical views. Reduction of lateral resolution may result in apparently thicker LA walls.	Not improved by modifying the gain settings: Increase in gain will further reduce LA lumen size Decrease in gain may lead to image "drop out" and difficulties in planimetry of LA area Use high resolution sample box to increase pixel density and facilitate accurate tracing of the endocardial border Capture at least five beats for each cine loop to maximize likelihood of obtaining adequate image quality
B. Obtain maximal LA size	LA is foreshortened	Modify transducer angulation or location (place the transducer one intercostal space lower) until LA image is optimized and not foreshortened If discrepancy in the two lengths measured from the orthogonal planes is >5 mm, acquisition should be repeated until the discrepancy is reduced
C. Timing of maximum LA size	Correct frame for measurement is not selected	Choose frame just before mitral valve opening
D. LA area planimetry	LA border is inconsistently defined	Consistently adhere to convention: Inferior LA border—plane of mitral annulus (not the tip of leaflets) Exclude atrial appendage and confluences of pulmonary veins
E. Long-axis LA length	LA long axis is inconsistently delineated	Consistently adhere to convention: Inferior margin—midpoint of mitral annulus plane Superior (posterior) margin—midpoint of posterior LA wall
F. Interpretation	Qualitative categorization of LA size	LA volume indexed to body surface area is optimally interpreted as a continuous variable (using a reference point of 22 ± 5 ml/m^2 as "normal")

J Am Coll Cardiol 2006;47:2357– 63

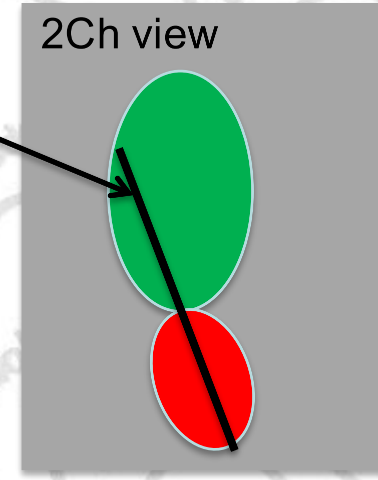
LA foreshortening (systematic bias)

Data set aligned for optimizing LV





4Ch plane optimized for LV



4Ch plane optimized for LA

Data set aligned for optimizing LA

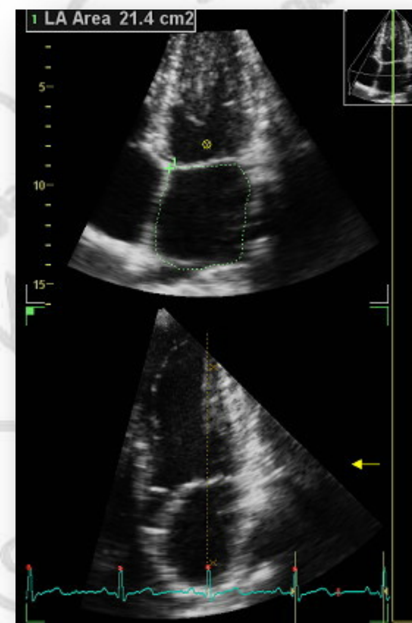


Table 4 Normal ranges and severity partition cutoff values for 2DE-derived LV EF and LA volume

	Male				Female			
	Normal range	Mildly abnormal	Moderately abnormal	Severely abnormal	Normal range	Mildly abnormal	Moderately abnormal	Severely abnormal
Maximum LA volume/BSA (mL/m^2)	16–34	35–41	42–48	>48	16–34	35–41	42–48	>48

J Am Soc Echocardiogr 2015;28:1-39

URL 34 ml/m2

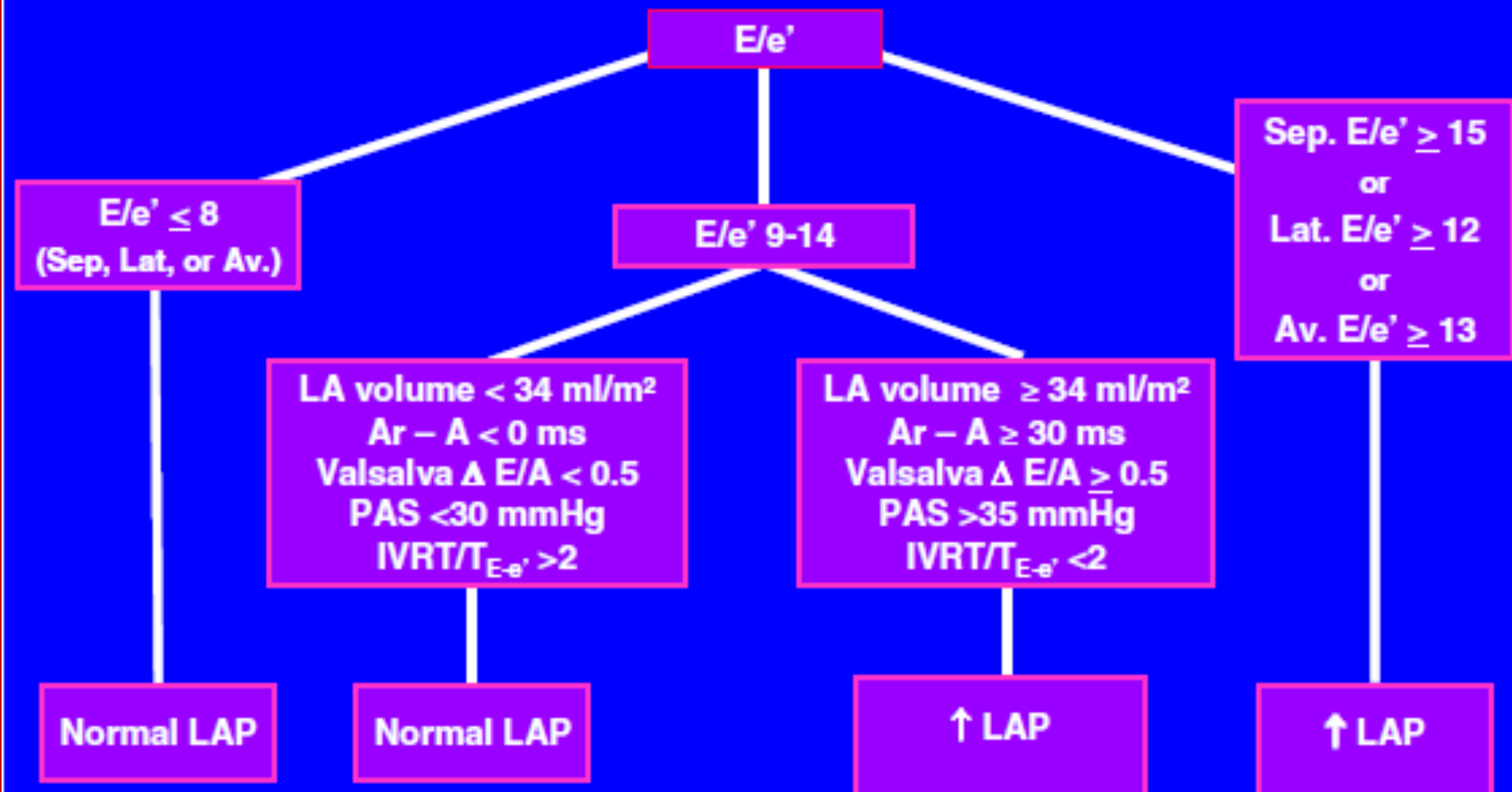
Table 9 Reference limits and partition values for left atrial dimensions/volumes

	Women				Men			
	Reference range	Mildly abnormal	Moderately abnormal	Severely abnormal	Reference range	Mildly abnormal	Moderately abnormal	Severely abnormal
LA volume/BSA, mL/m^2	*22 ± 6*	*29–33*	*34–39*	*≥40*	*22 ± 6*	*29–33*	*34–39*	*≥40*

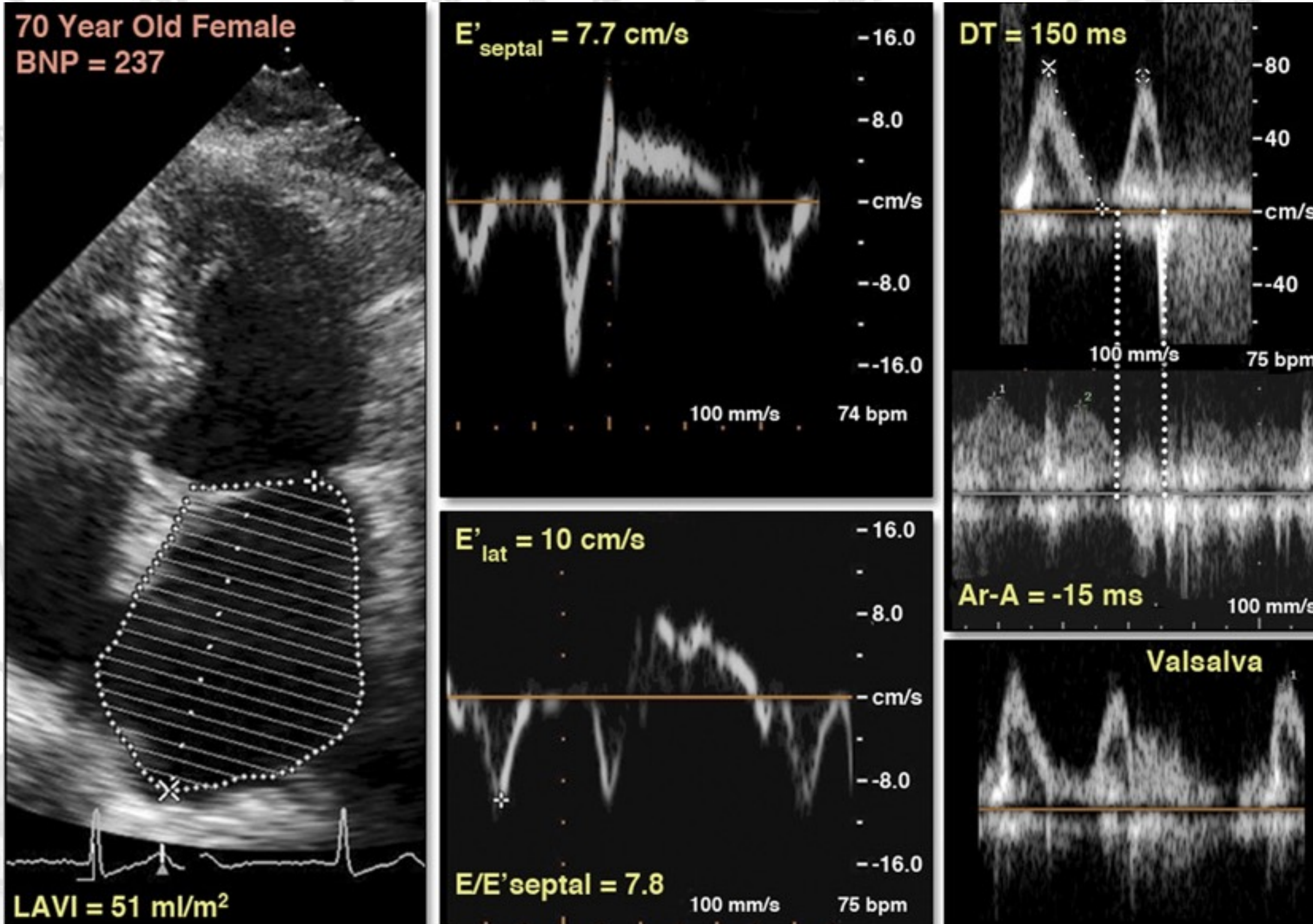
URL 28 ml/m2

J Am Soc Echocardiogr 2005;18:1440-1463

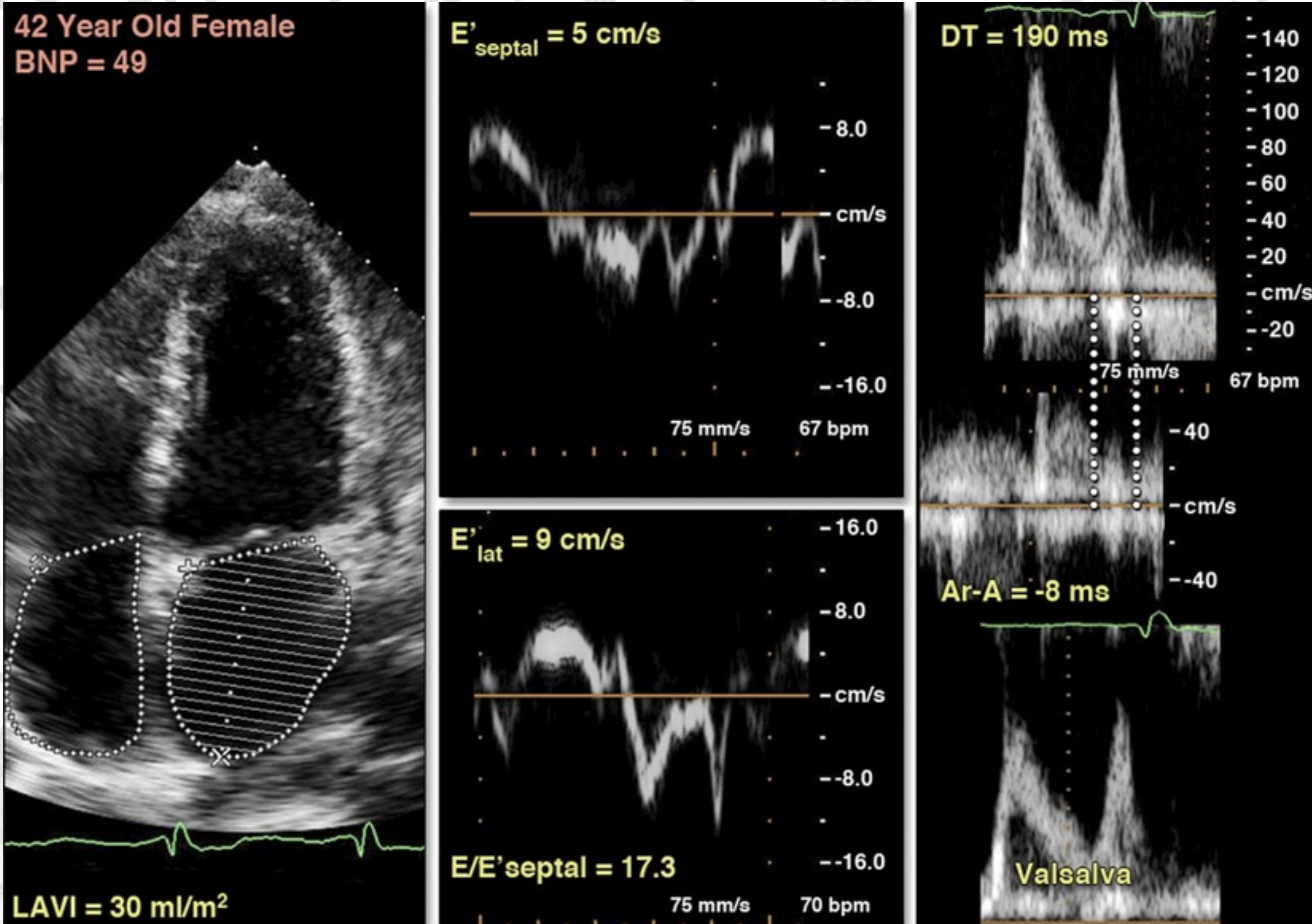
Estimation of Filling Pressures in Patients with Normal EF



J Am Soc Echocardiogr 2009;22:107-33



J Am Coll Cardiol Img 2011;4:460 –7

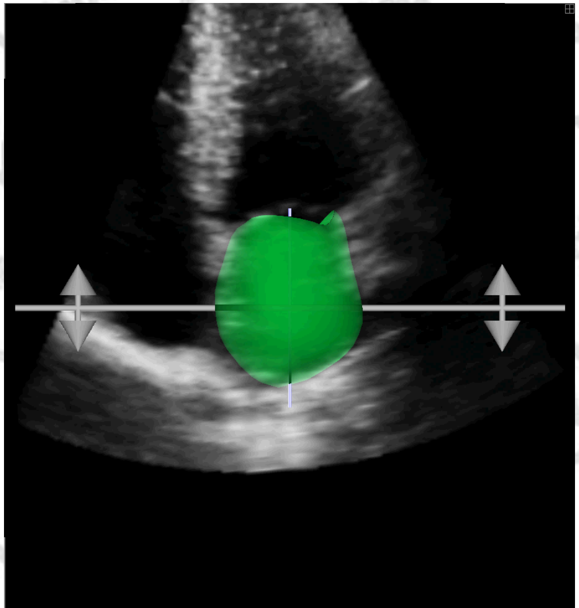


J Am Coll Cardiol Img 2011;4:460 –7

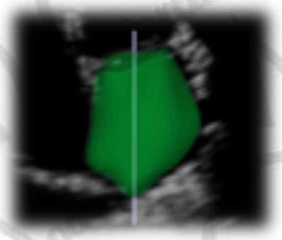
3D Echo

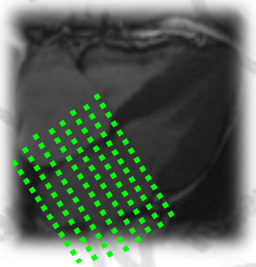
- **Higher accuracy** - measurements with no geometric assumptions about LA shape
- **Increased reproducibility** - semi-automated endocardial border identification, volumetric acquisition with no dependency on plane selection
- **Acceptable temporal resolution (30-50 vps)** in comparison with CT/CMR

•**3D single-beat acquisitions** feasible for pts with arrhythmias



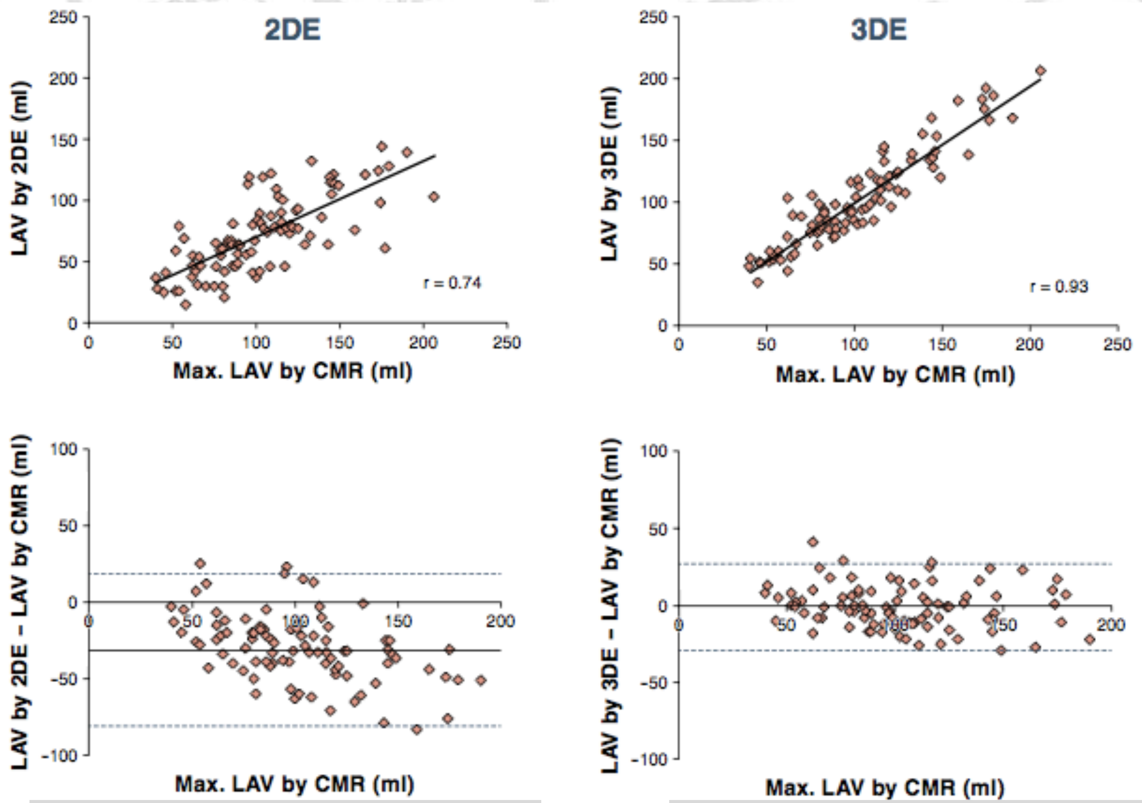
Quantification of Left Atrial Size





Real-Time 3D Echocardiographic Quantification of Left Atrial Volume: Multicenter Study for Validation with CMR

- **4 different institutions** (4 countries, 3 continents)
- A total of **92 pts** (35♀, 48±18 years, BSA 1.72±0.34 ml/m²)
- Wide range of LA sizes (CMR LAV: 40 – 206 ml)
- 2DE, 3DE and CMR images acquired on the same day



2DE: bias = -31 ml

95% LOA = ±50 ml

3DE: bias = -1 ml

95% LOA = ±28 ml

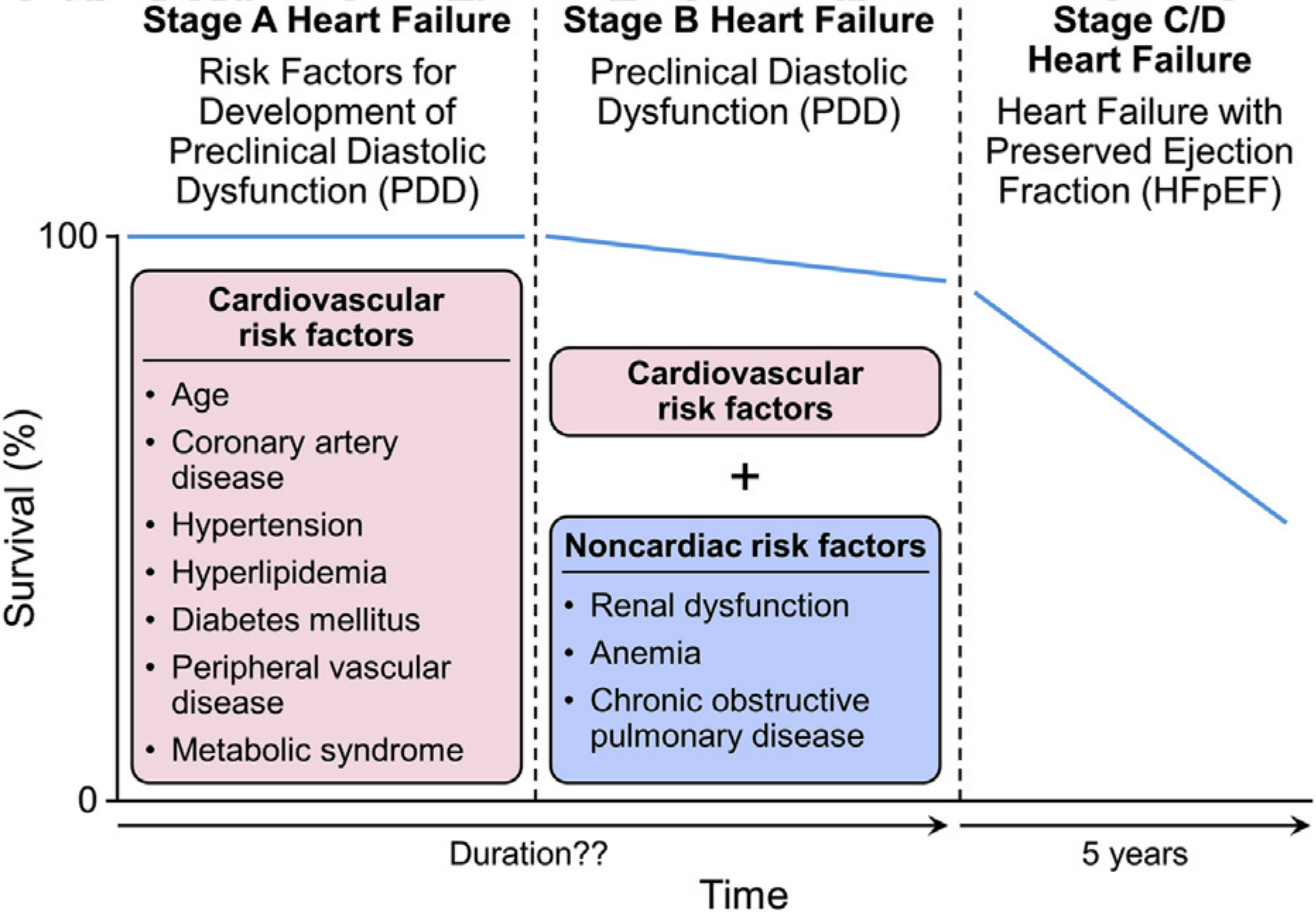
JACC Cardiovasc Imaging 2012;5:769-77

3D data sets 	• No geometrical assumption about LA shape • More accurate when compared to 2D measurements	• Dependent on adequate image quality • Lower temporal resolution • Limited data on normal values • Patient's cooperation required

J Am Soc Echocardiogr 2015;28:1-39

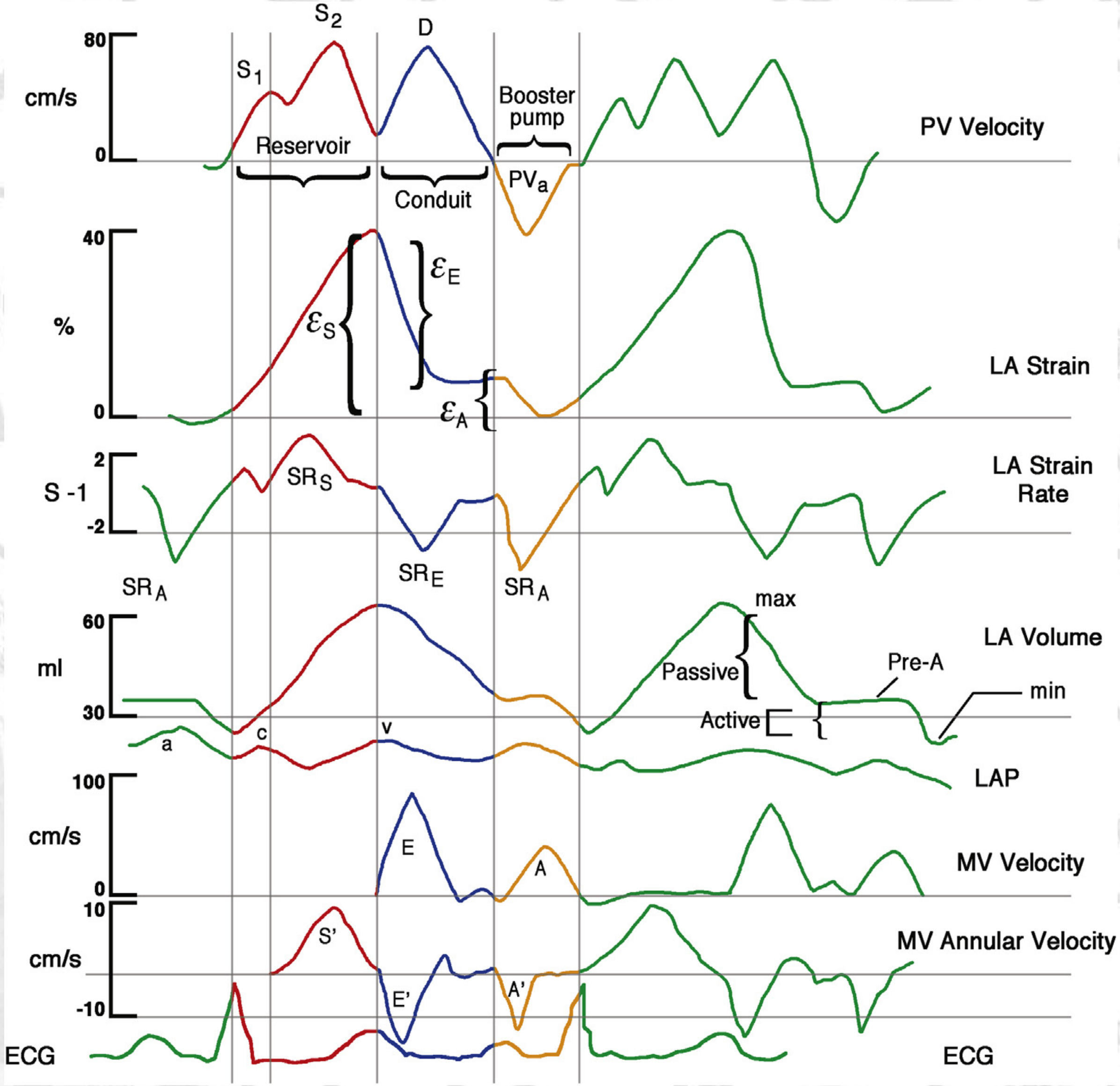
1. Relatively poor spatial resolution
2. Underestimation compared with CMR
3. Availability of LA-specific software
4. Clinically relevant normative values and thresholds need to be established with standardized and validated methodology
5. The incremental clinical benefit of 3D assessment over 2D methods needs to be further established

Beyond maximal LA volume: LA phasic volumes and myocardial mechanics



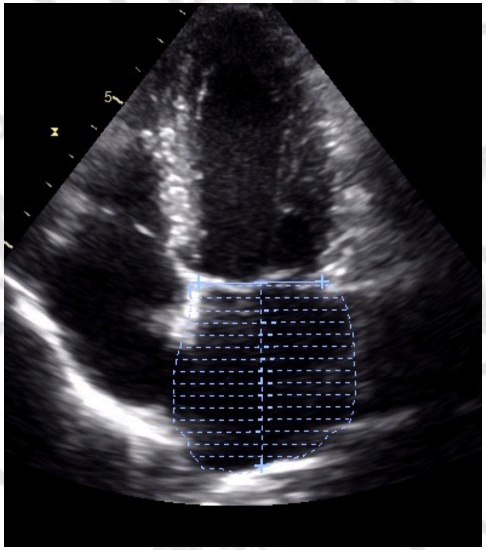
J Am Coll Cardiol 2014;63:407–16

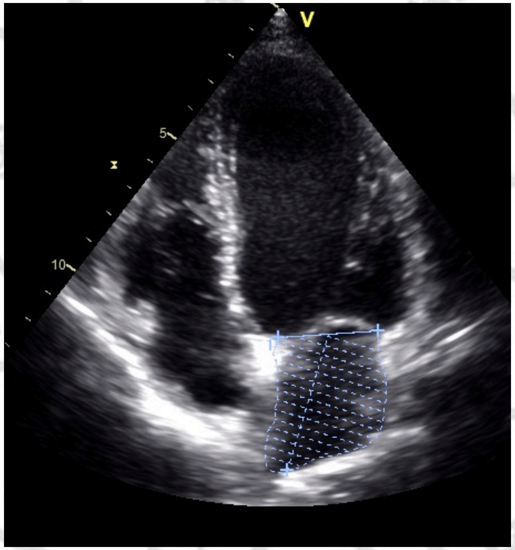
Quantification of Left Atrial Function

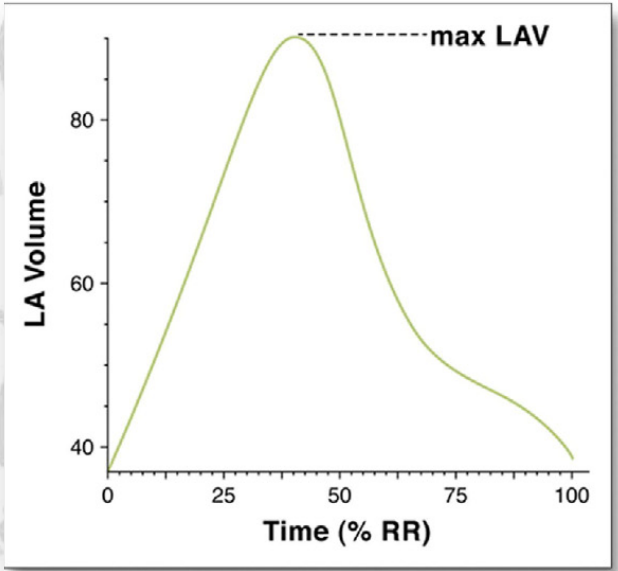


J Am Coll Cardiol 2014;63:493-505

Quantification of Left Atrial Function
Volumetric Analysis



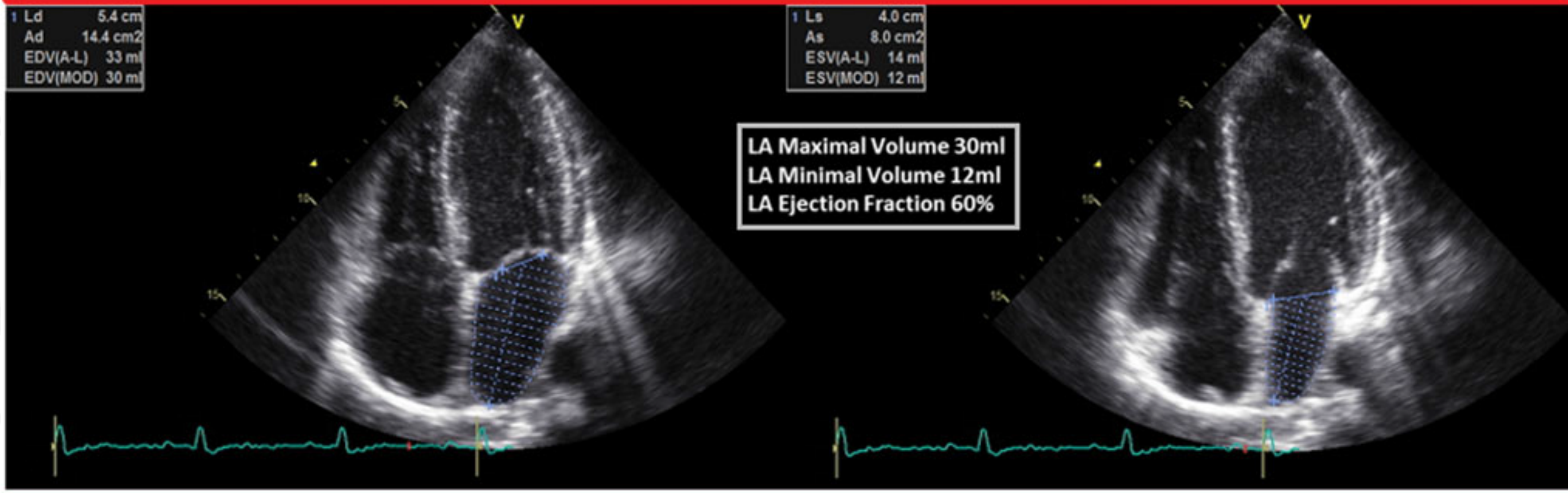




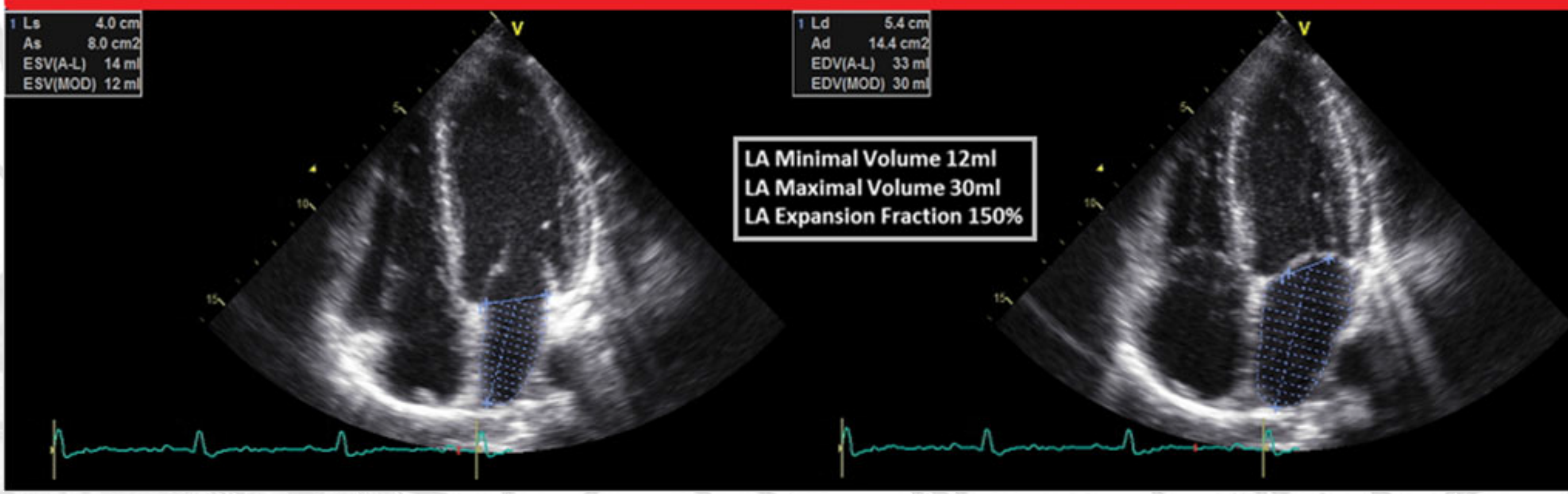
LA Function	LA Volume Fraction	Calculation
Global function; reservoir	LA EF (or total EF)	$[(LA_{max} - LA_{min})/LA_{max}]$
Reservoir function	Expansion index	$[(LA_{max} - LA_{min})/LA_{min}]$
Conduit*	Passive EF	$[(LA_{max} - LA_{pre\text{-}A})/LA_{max}]$
Booster pump	Active EF	$[(LA_{pre\text{-}A} - LA_{min})/LA_{pre\text{-}A}]$

J Am Coll Cardiol 2014;63:493-505

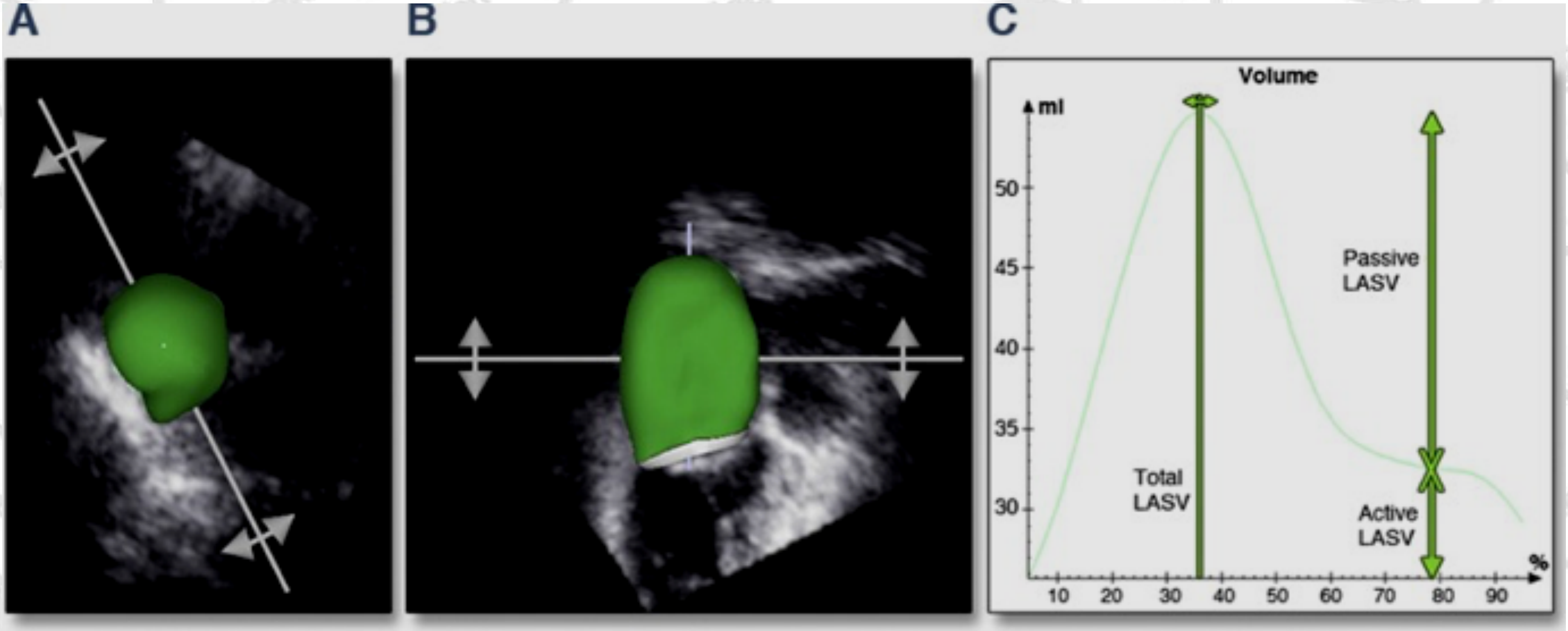
Left Atrial Ejection Fraction



Left Atrial Expansion Fraction



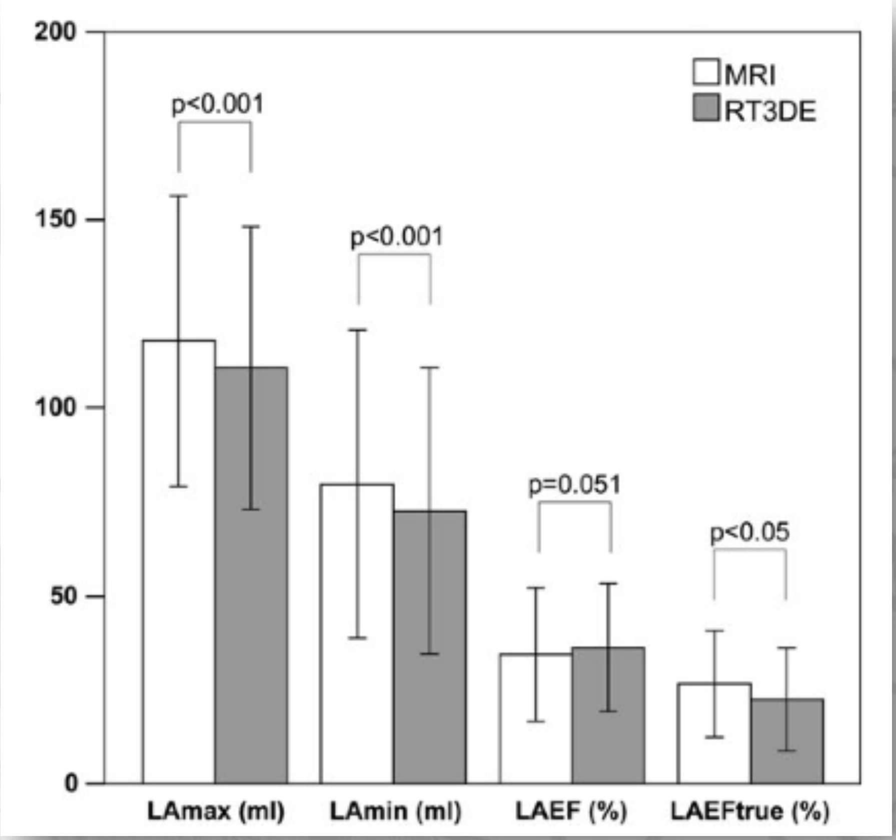
Eur Heart J Cardiovasc Imaging 2015;16:364–372

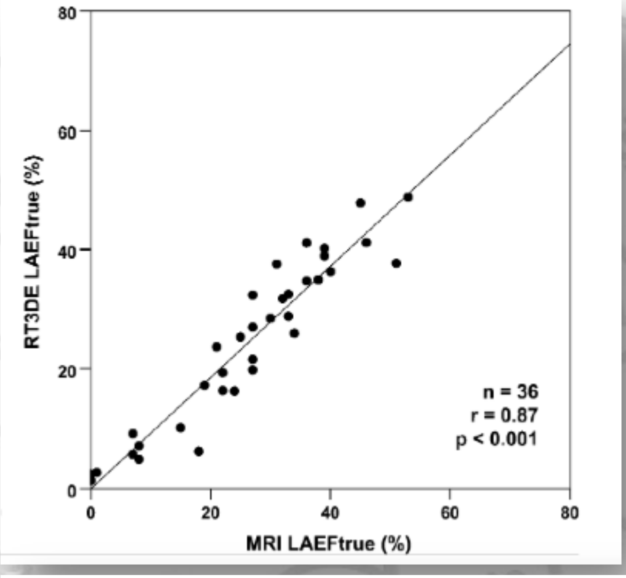


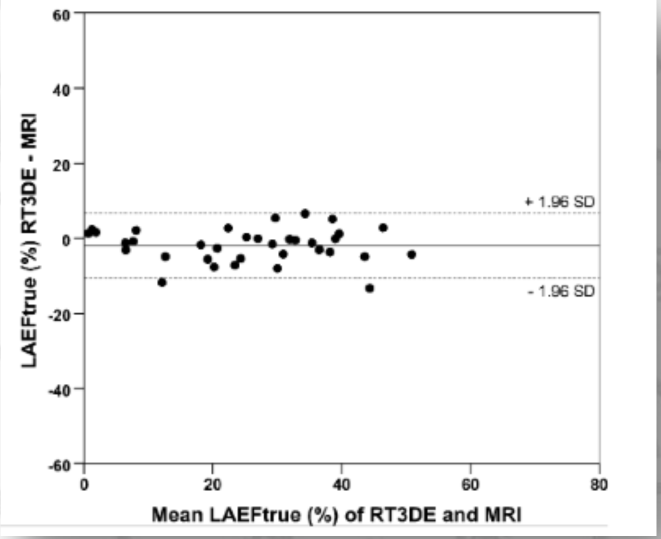
J Am Coll Cardiol Img 2011;4:788–98

3D LA phasic function: validation against MRI

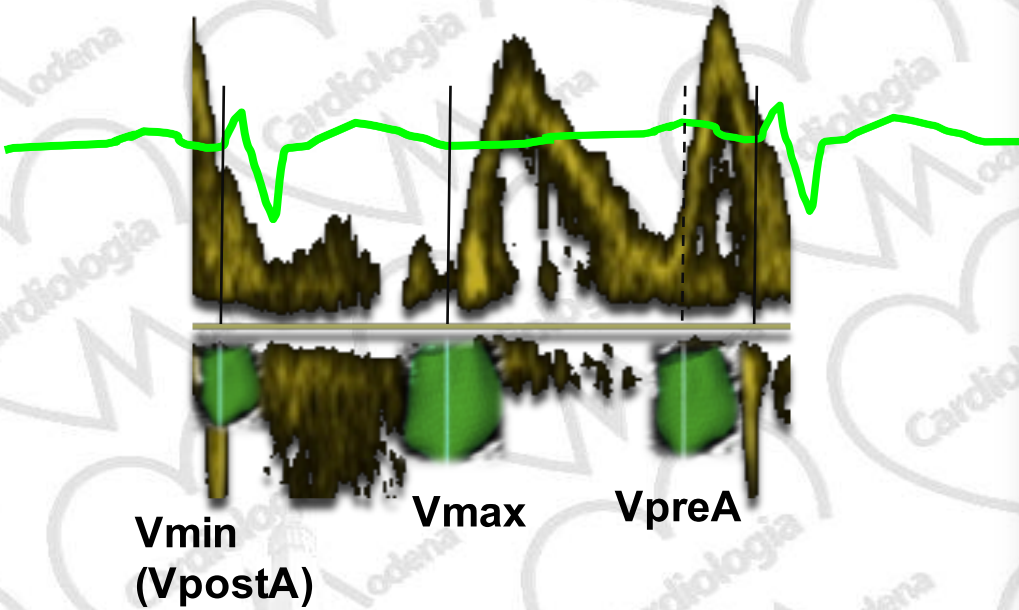
N = 55 patients undergoing cardiac MRI and 3DE before PV isolation

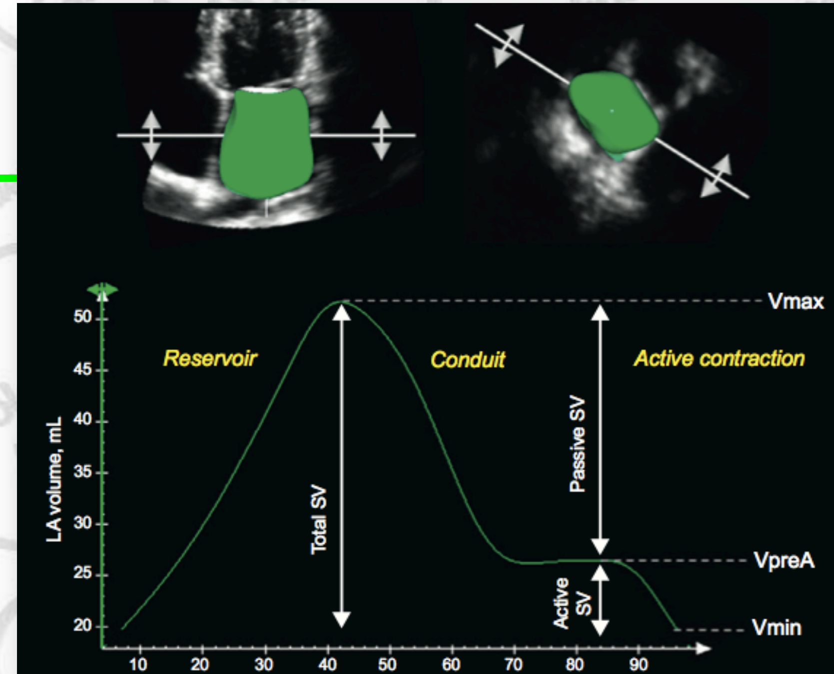






Int J Cardiovasc Imaging 2013;29:601-8



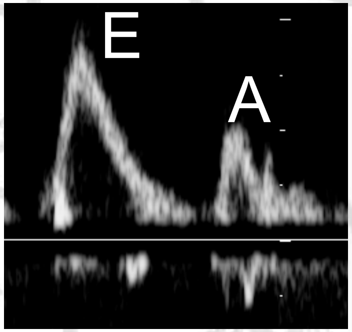


- Total emptying fraction = Total emptying volume/Vmax
- Passive emptying fraction = Passive emptying volume/Vmax
- Active emptying fraction = Active emptying volume/VpreA

VMIN	23.58 ml
VMAX	72.47 ml
TOTAL SV	48.89 ml
TOTAL EF	67.46 %
VMIN SI	79.11 %
VMAX SI	90.04 %
VpreA	30.69 ml
VpostA	23.58 ml
ASV	7.11 ml
TrueEF	23.16 %

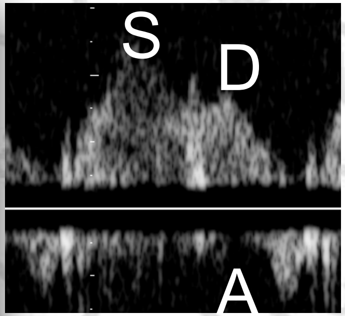
Badano LP. Eur Heart J Cardiovasc Imaging 2013

Spectral Doppler indexes of LA function



LA Function	Transmitral Flow	Pulmonary Venous Flow	Composite Indexes
Global function			LAFI
Reservoir		S velocity	
Conduit	E velocity, E/A	D velocity	
Booster pump	A velocity, E/A, AFF	PVa	Ejection force, LAKE

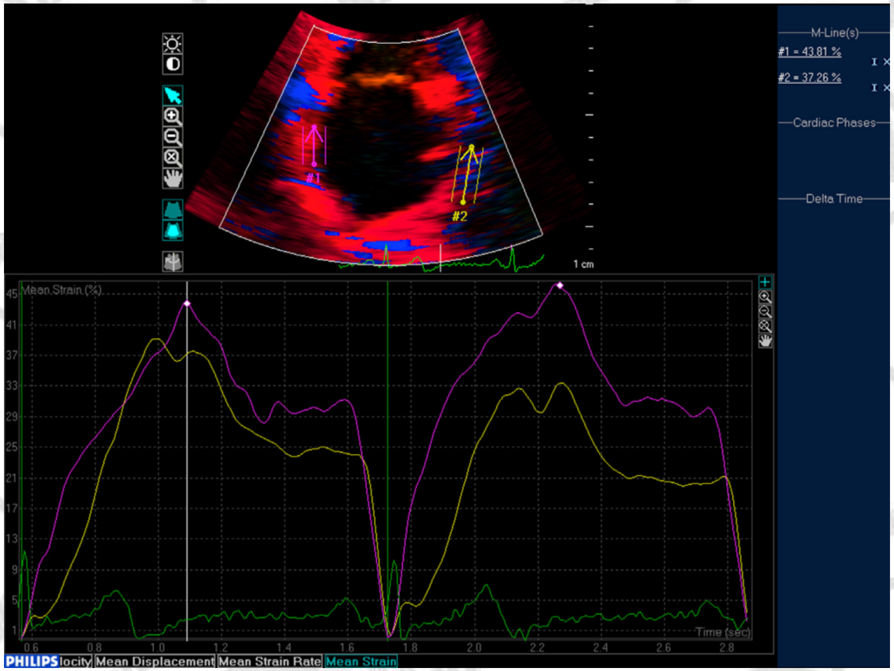
AFF = atrial filling fraction; LA = left atrial; LAFI = left atrial functional index; LAKE = left atrial kinetic energy; PVa = pulmonary venous reversal velocity.

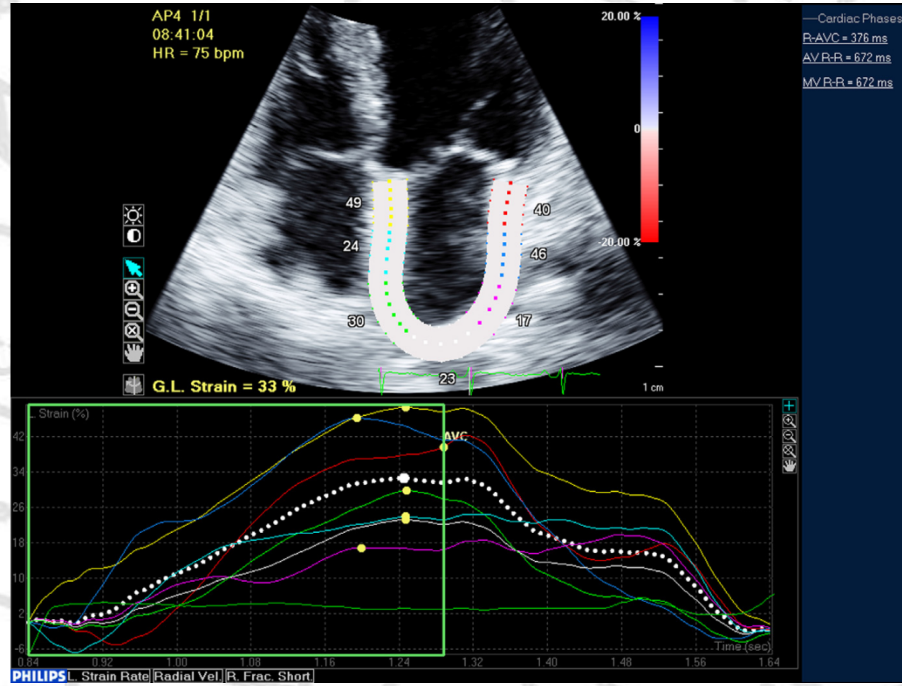


- **Advantages**: availability and simplicity in acquisition and interpretation
- **Major disadvantage**: nonspecificity, because changes may be due to LV diastolic dysfunction, mitral valve disease, or abnormal hemodynamic status: difficult interpretation in sinus tachycardia, conduction system disease, and arrhythmia (a.f.).

J Am Coll Cardiol 2014;63:493-505

TDI and deformational Indexes

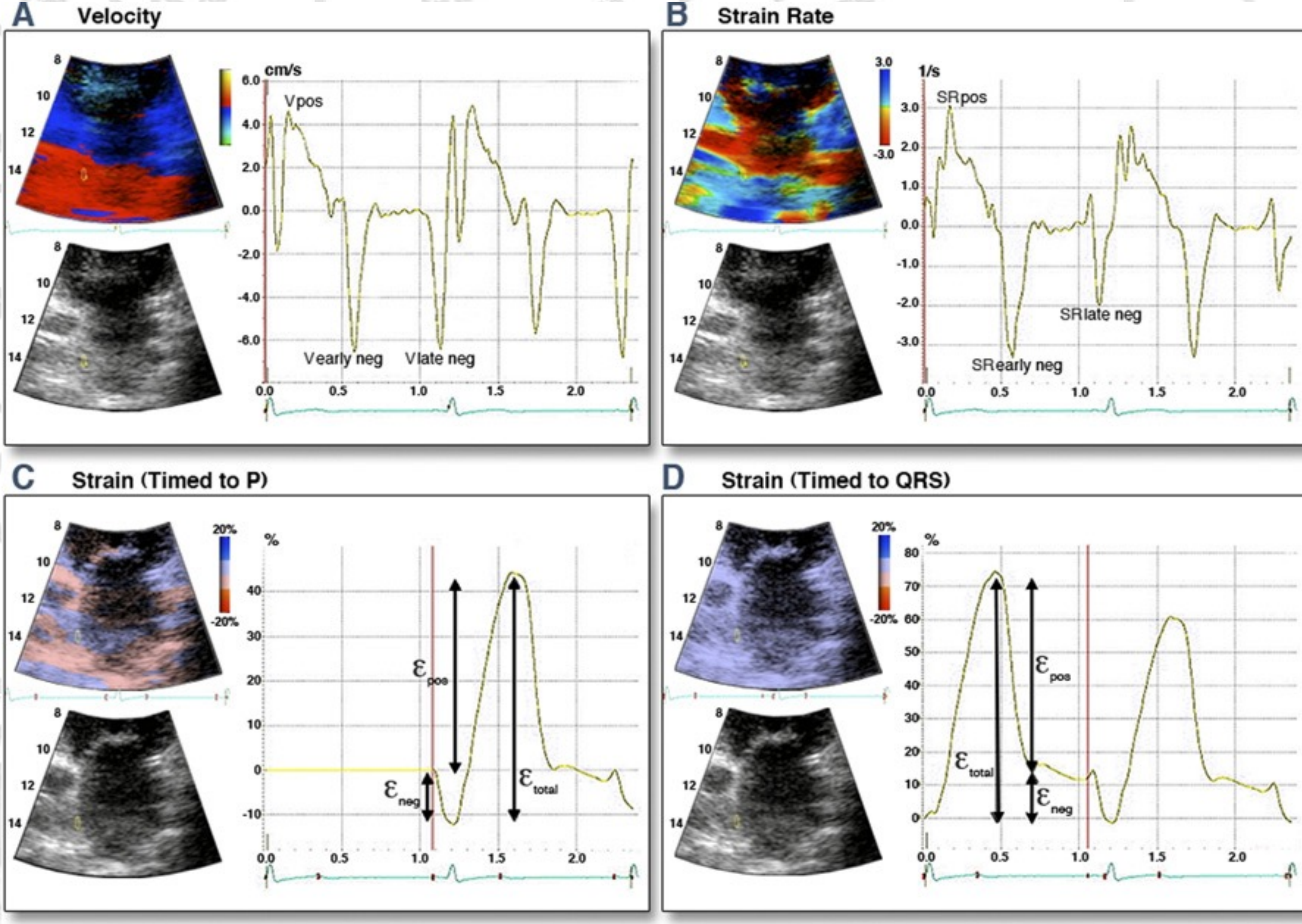




LA Function	Tissue Velocity	Strain	Strain Rate
Reservoir	S′	εs, εtotal	SR-S
Conduit	E′	εe, εpos	SR-E
Booster pump	A′	εa, εneg	SR-A

ε = strain; LA = left atrial; neg = negative; pos = positive; SR = strain rate.

J Am Coll Cardiol 2014;63:493-505



J Am Coll Cardiol Img 2011;4:788–98

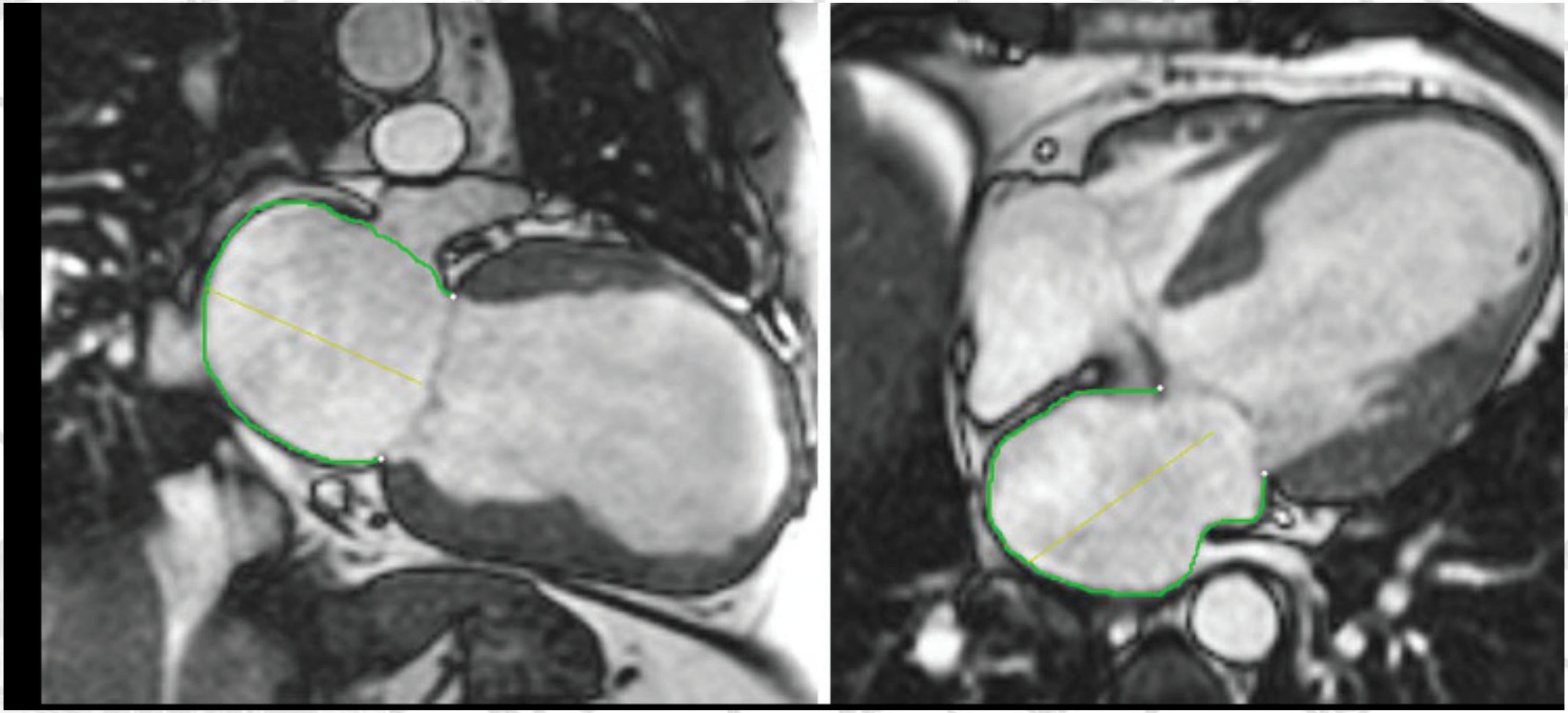
The challenges with adapting strain imaging to the LA

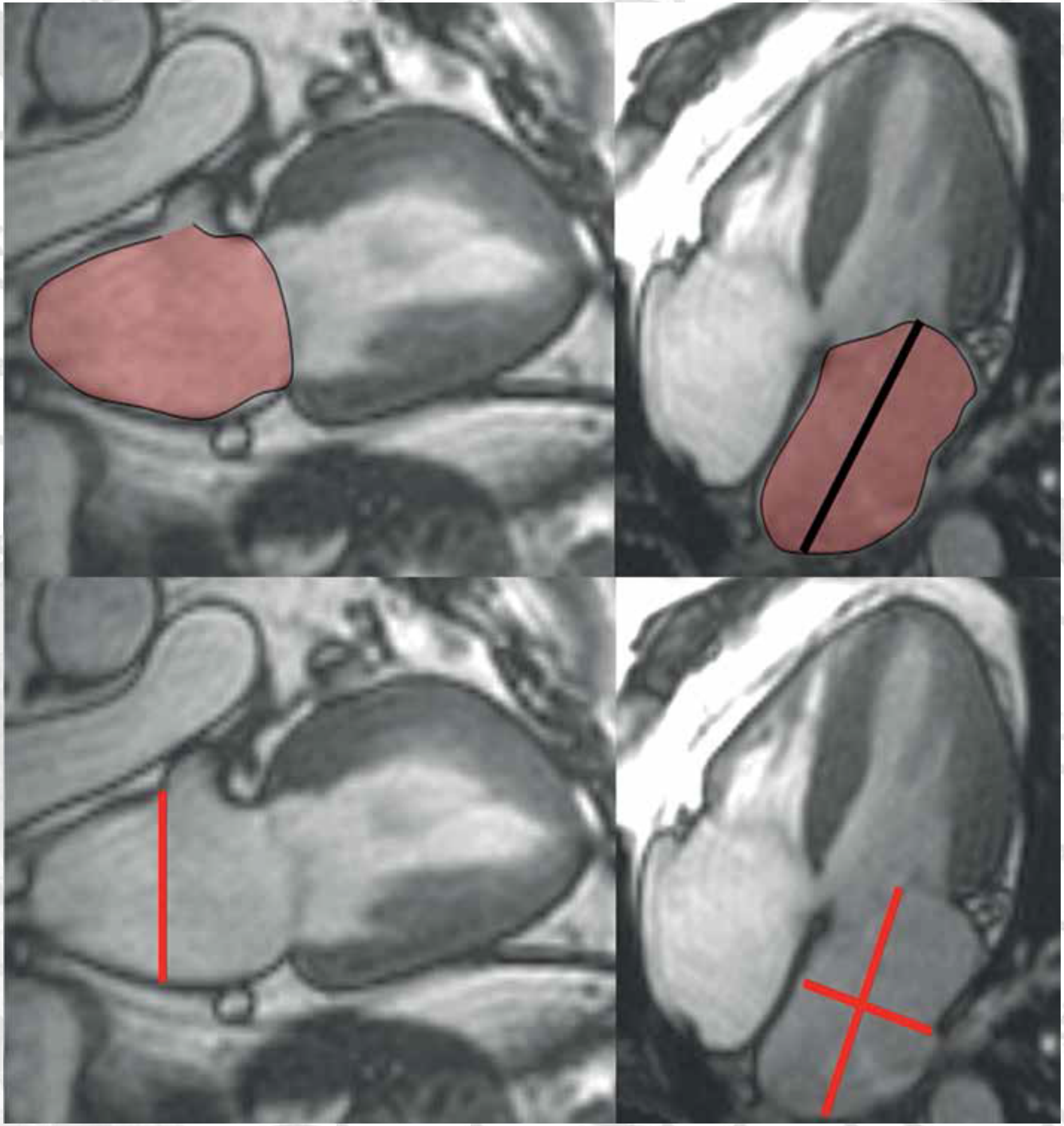
- Somewhat *similar* to the ones applicable to the LV
- *Unique challenges*:
- thinner LA wall
- higher signal noise from surrounding structures
- location of the LA in the far field of transthoracic echocardiogram
- complex LA motion during the cardiac cycle
- regional LA differences in contraction

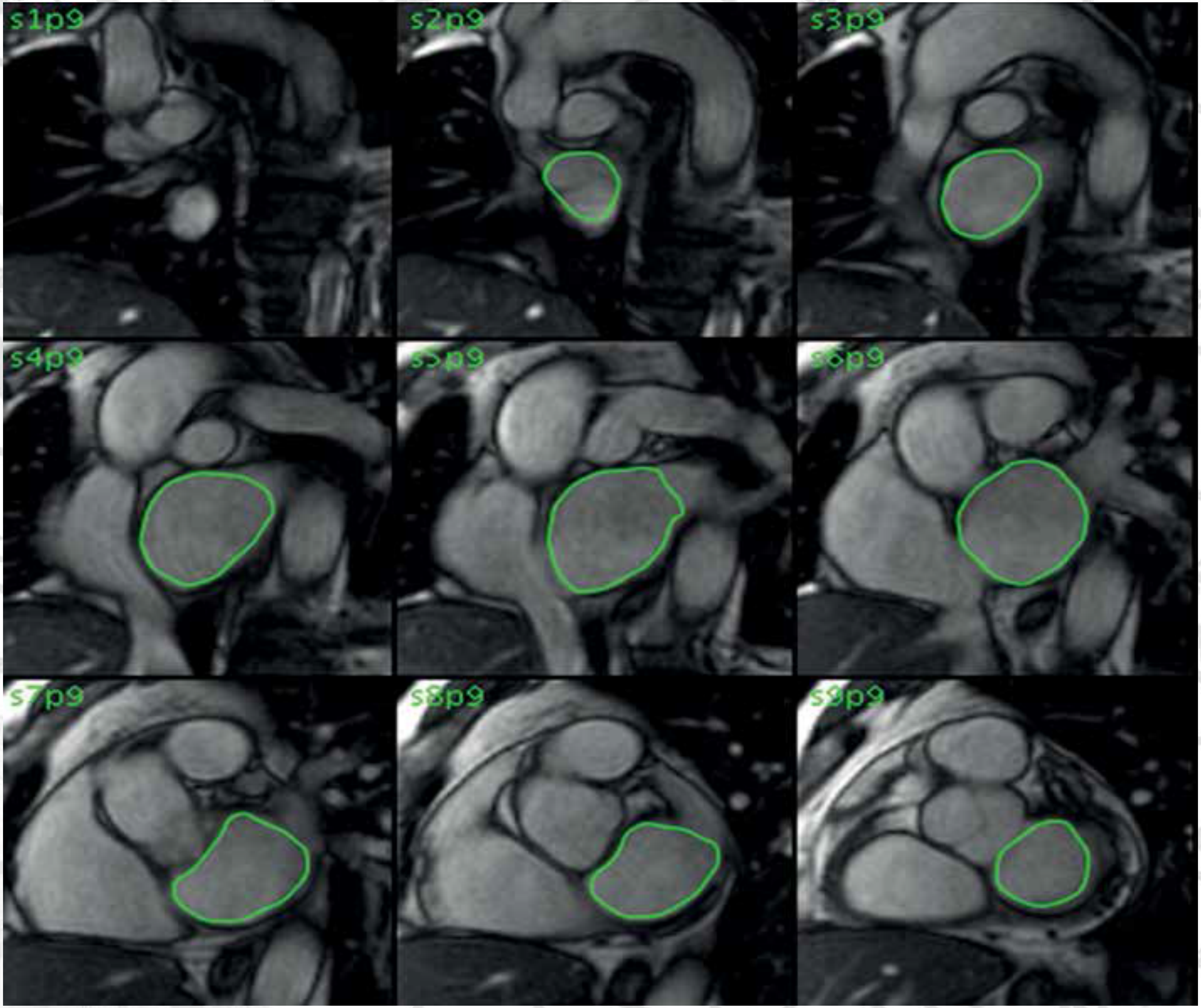
J Am Coll Cardiol Img 2011;4:788–98

Eur Heart J Cardiovasc Imaging 2014;15:793–799

CMR—beyond LV volume



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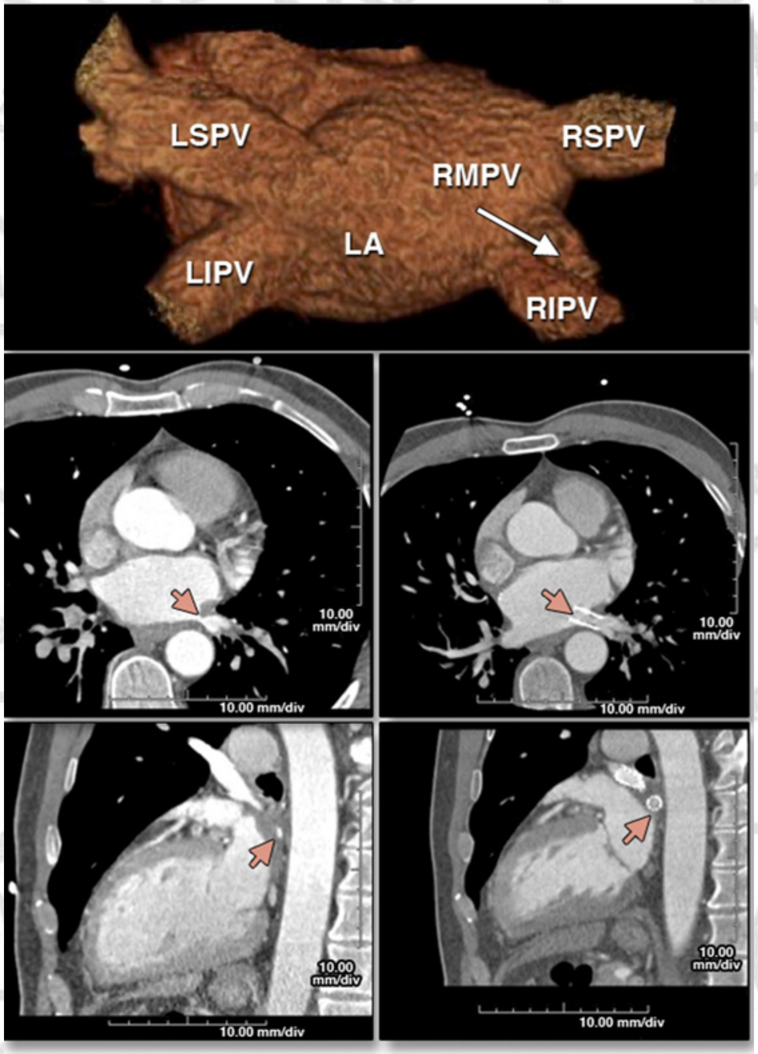
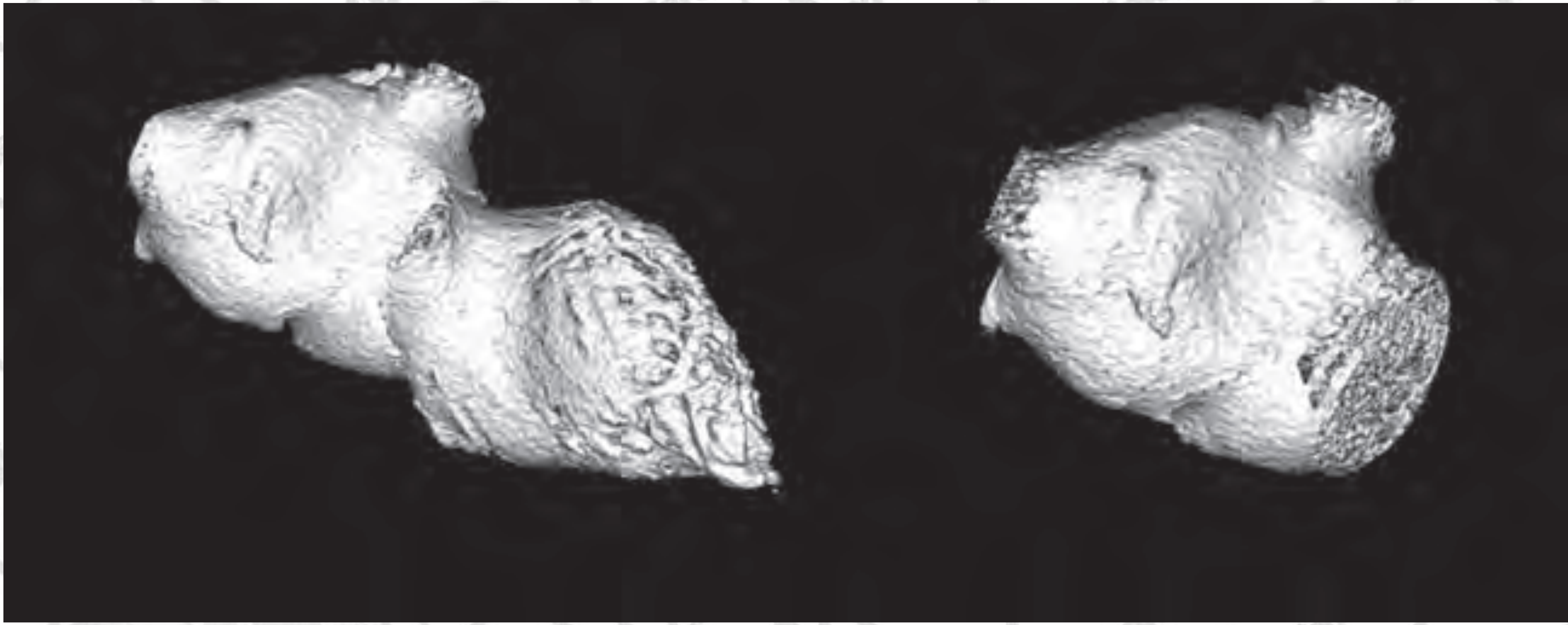
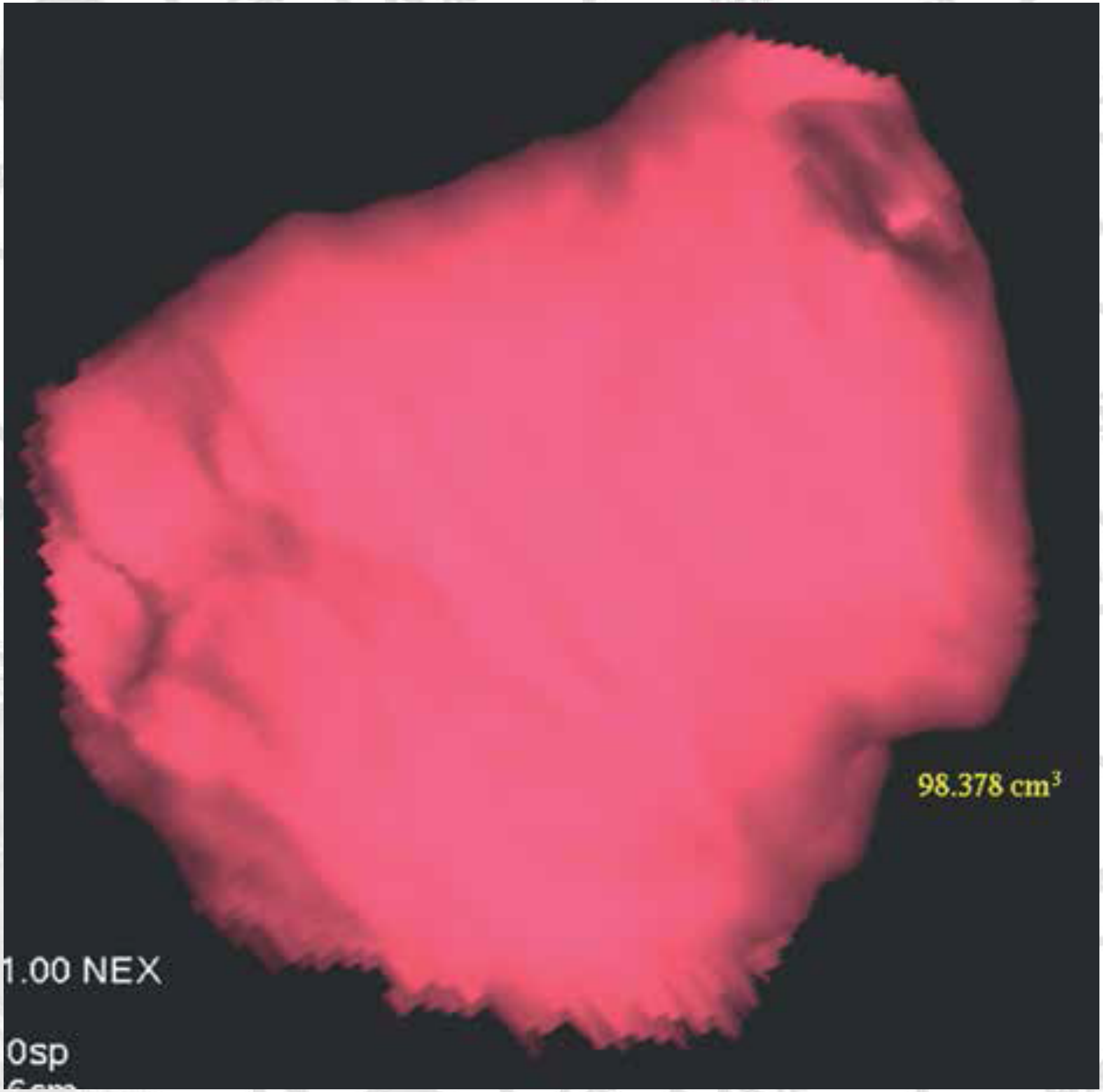
Cardiac CT—beyond pulmonary vein anatomy



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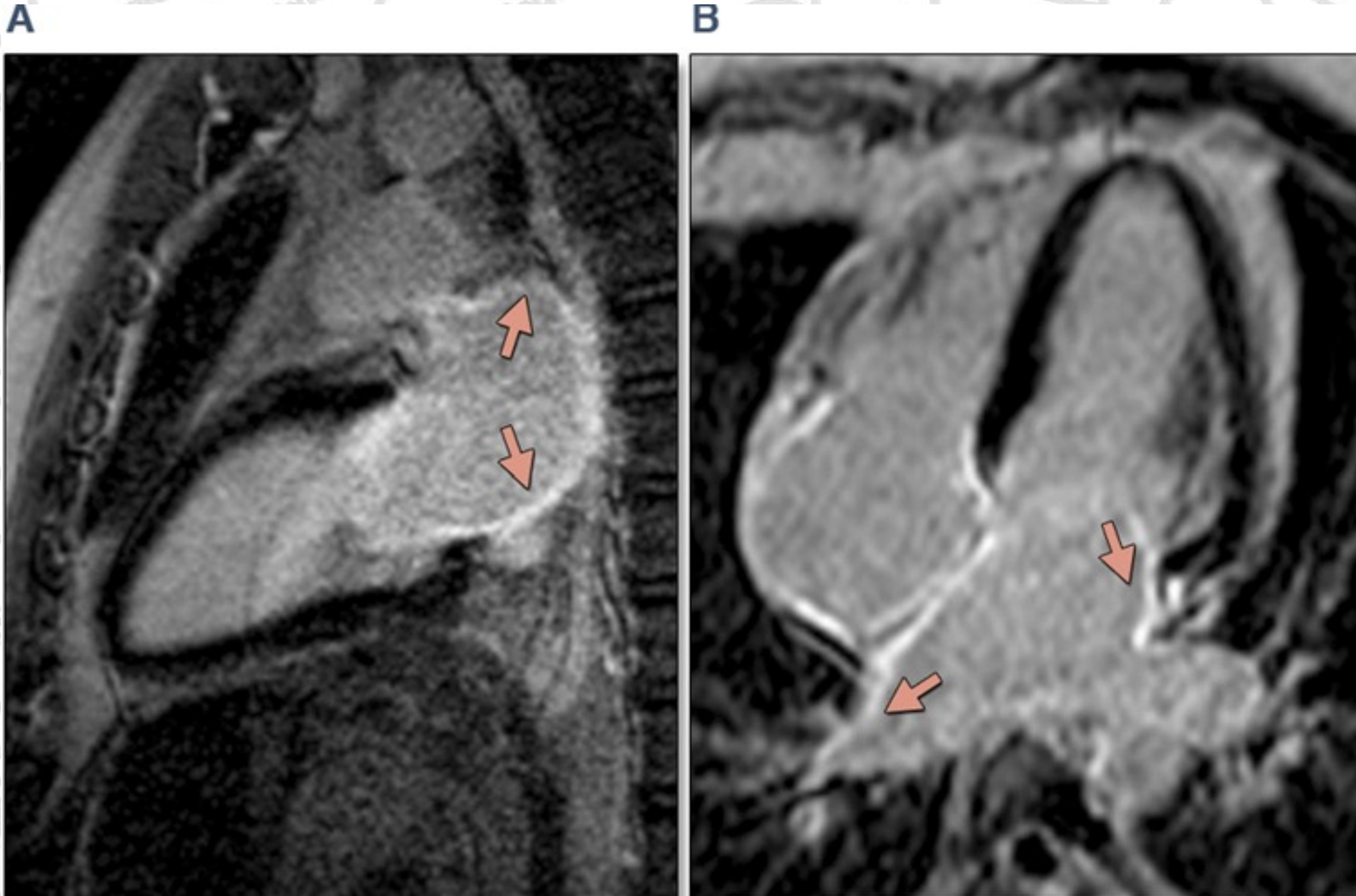
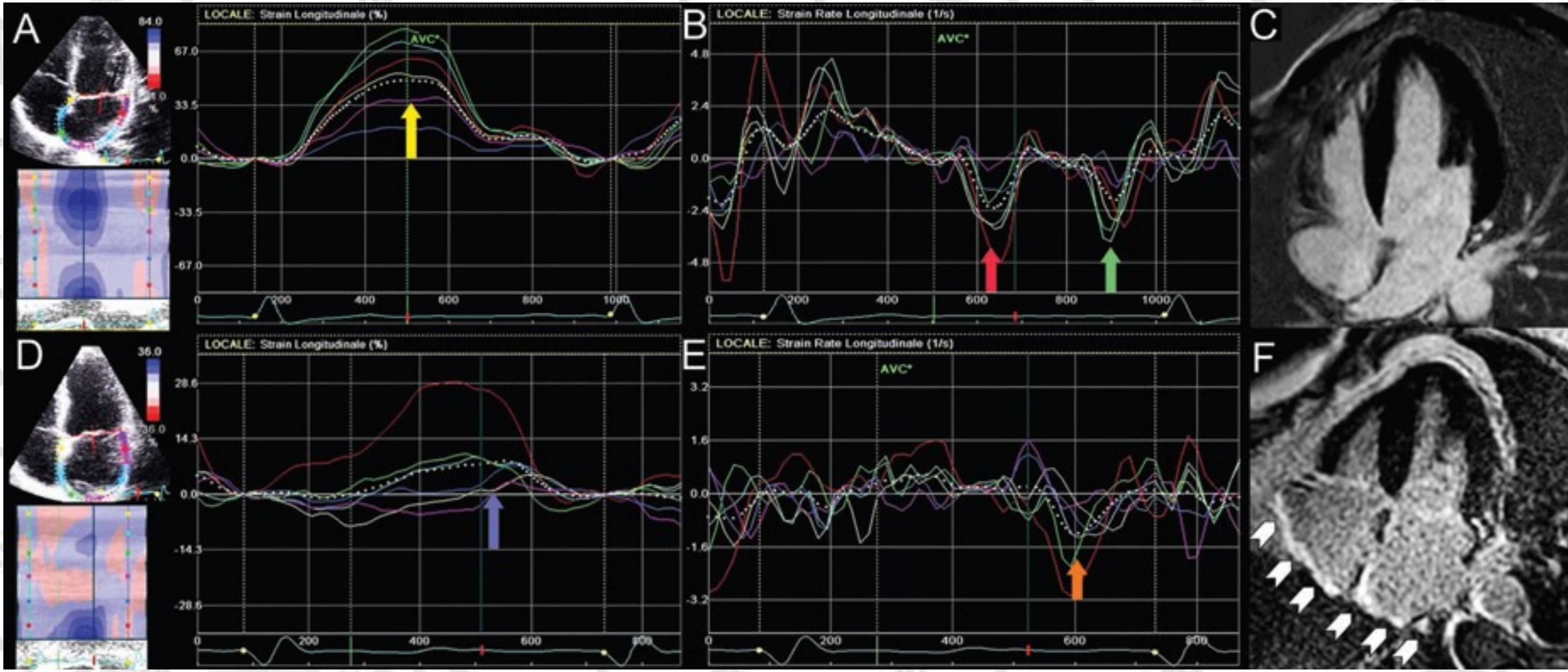
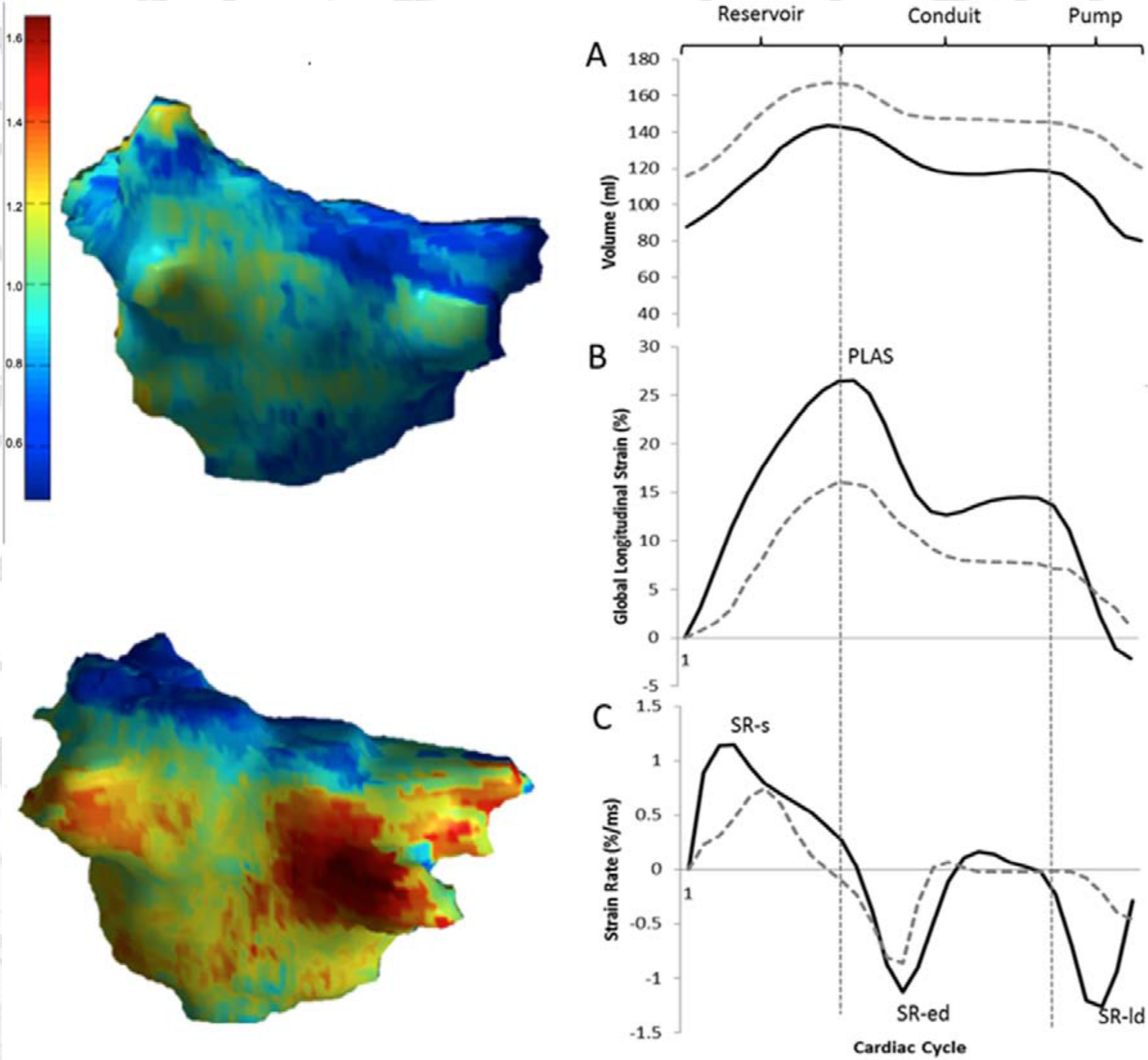
LA scar imaging: perform a more patient-tailored approach



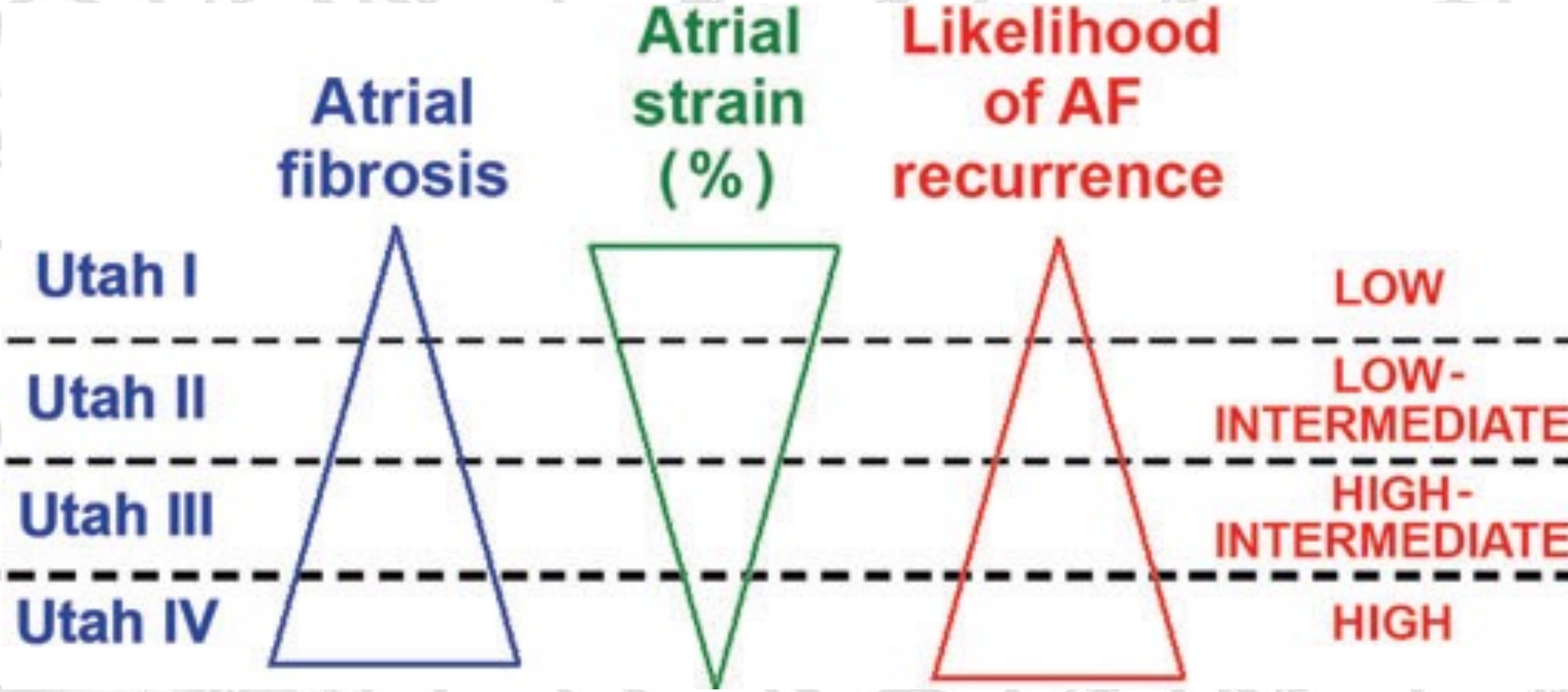
J Am Coll Cardiol Img 2011;4:788–98



Eur Heart J Cardiovasc Imaging 2014;15:1–5



Circ Cardiovasc Imaging 2015;8:e002769



Eur Heart J Cardiovasc Imaging 2014;15:1–5

	Echocardiography	Cardiac CT	CMR
Technical considerations			
Temporal resolution*	2D = 10–20 ms 3D = 50–75 ms TDI = 5–10 ms Speckle = 10–20 ms	75–250 ms	25–50 ms
Spatial resolution*	2D = 0.5–1 mm 3D = 1–2 mm	0.5–2 mm	1–2 mm
Limitation with imaging window	Yes	No	No
True 3D dataset	Only with 3D	Yes	Selected sequences only
Real-time imaging	+++	−	+
Tissue characterization	+	+	+++
Availability	+++	++	+
Typical scan duration, min	30	10	30–50
Cost	Low	Moderate	High
Safety	Contrast	Radiation risk Iodinated contrast	Gadolinium contrast and renal failure Contraindications with pacemaker and defibrillators Hemodynamically stable patients only
Usefulness in the assessment of the left atrium			
LA size			
Static	+++	+++	+++
Phasic	+++	+	++
LA mechanics	+++	−	+
LA structure	+	+	+++
Current indications	First-line diagnostic evaluation and follow-up	Accurate 3D dataset for electroanatomic mapping Diagnosis and follow-up of pulmonary vein stenosis	Diagnostic evaluation and follow-up for patients with poor echocardiographic windows Accurate 3D dataset for electroanatomic mapping in patients with concern over radiation risk Diagnosis and follow-up of pulmonary vein stenosis in patients with concern over radiation risk
Potential indications	Serial monitoring of LA phasic volumes Detailed functional assessment of LA phasic function		Characterization of post atrial fibrillation ablation scarring Serial monitoring of LA phasic volumes

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Key point-LA volumes

1. Good correlations between imaging modalities
2. Imaging modalities are not interchangeable
3. 2DE is the most accessible, but consistently underestimates
4. The choice of imaging modality should be tailored for specific indication and clinical need
5. Standardization and normative data and classification criteria for grades of enlargement needs to be established for each imaging modality

Key point-LA function

1. Promising tools for predicting c.v. events in a wide range of patient populations (reservoir function)
2. Robust clinical outcome data from large prospective outcome trials are needed
3. Standardization of equipment and analytic techniques are needed
4. Development of age- and sex-adjusted normal reference values on a larger scale are needed