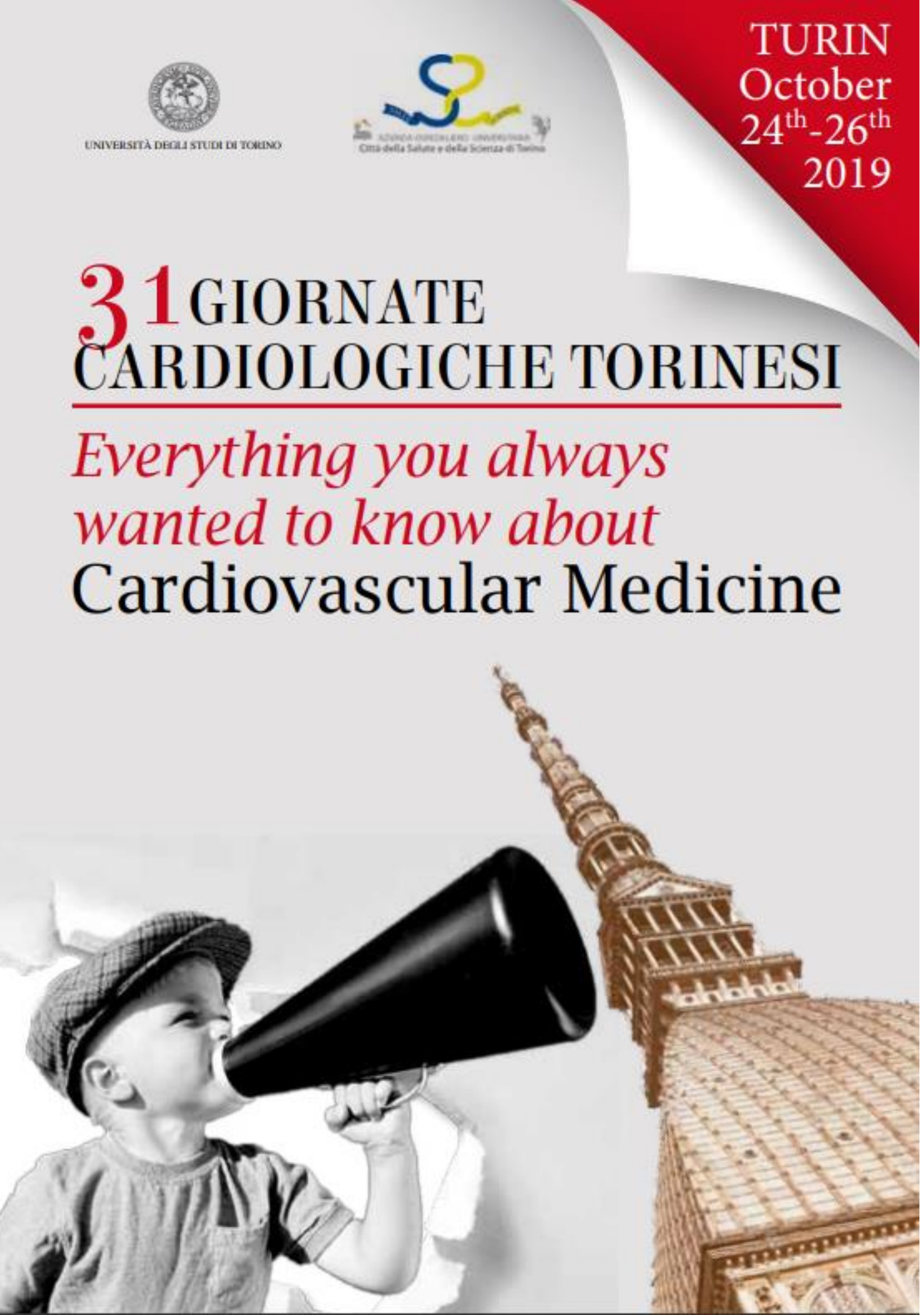

ROLE OF CARDIAC RM: WHAT’S MORE?

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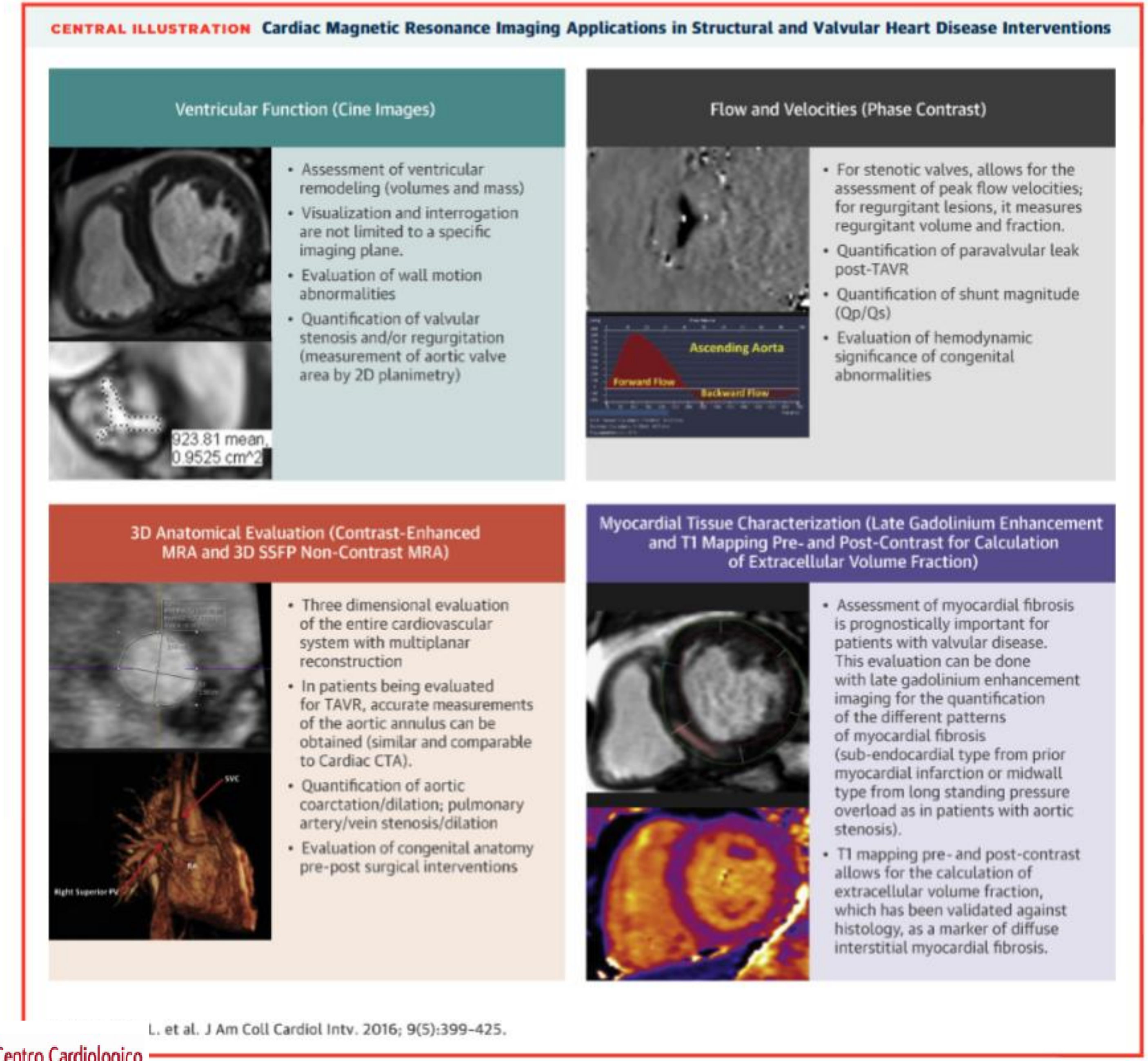

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STRUCTURAL HEART DISEASES

Non-coronary heart disease for which some therapy, surgical or percutaneous, exists

J Am Coll Cardiol. 2014;63:603-4

Overview

- CMR in valvulopathies

a) Aortic stenosis and TAVI

a) Mitral Regurgitation

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ESC European Society of Cardiology
European Heart Journal (2017) 38, 2739–2791
doi:10.1093/eurheartj/ehx391
ESC/EACTS GUIDELINES

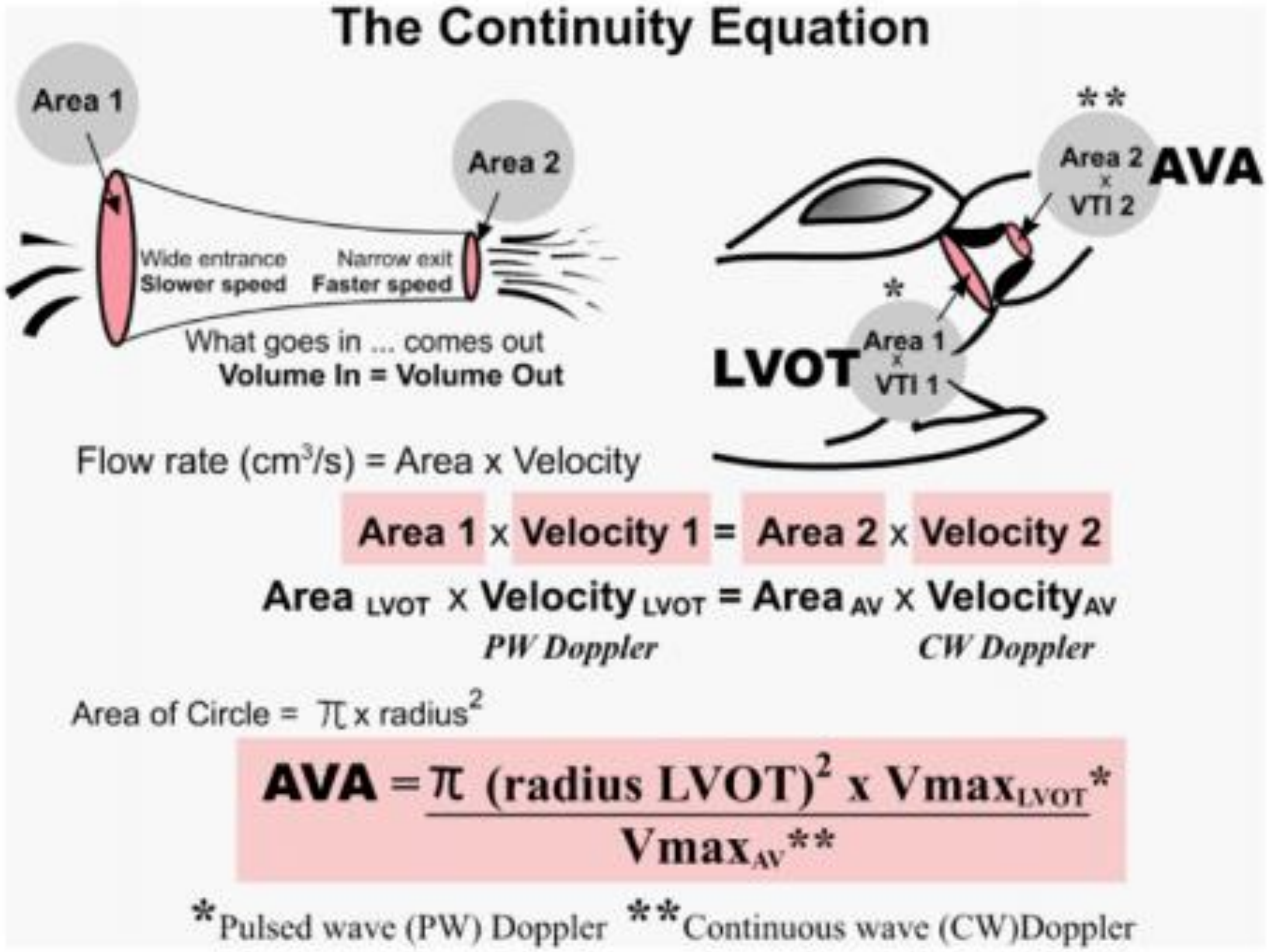

Fig. 11. The continuity equation and assumptions for measuring aortic valve area (AVA) in aortic stenosis.

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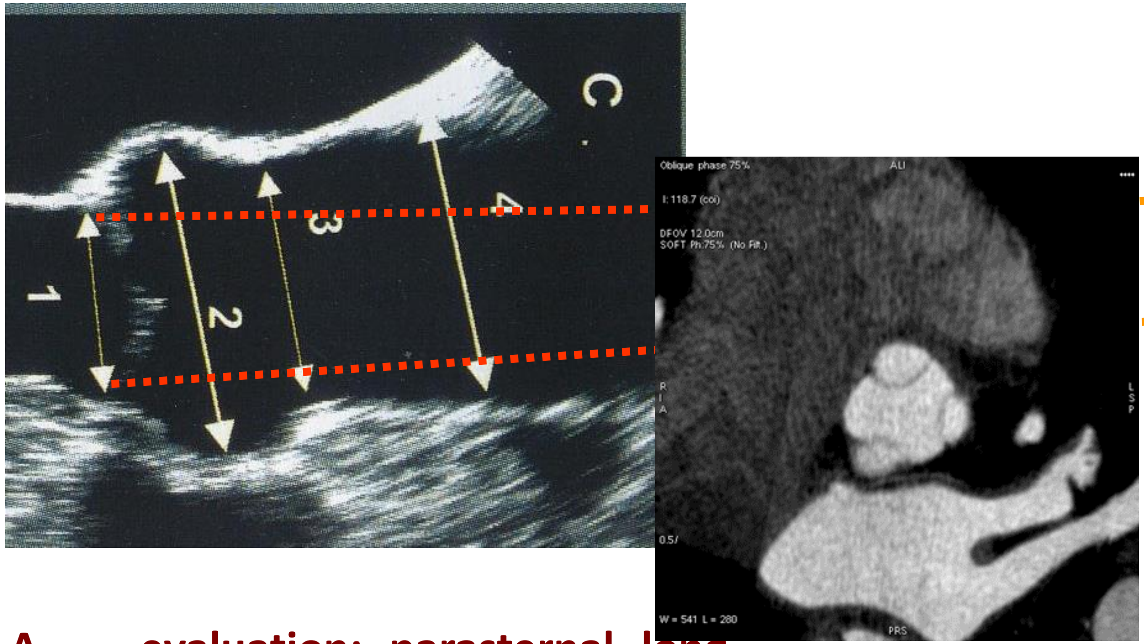
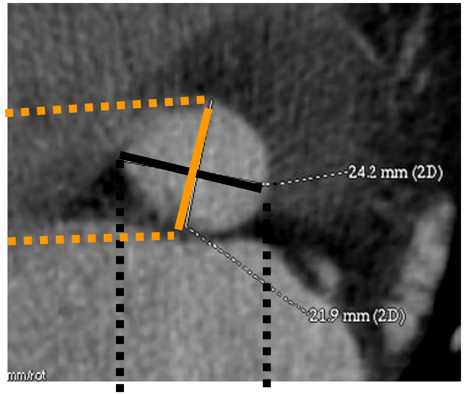
Baumgartner et al, EHJ 2017

AORTIC STENOSIS
Grading aortic stenosis – LVOT measurement

A_{TTE}

A_{MDCT}





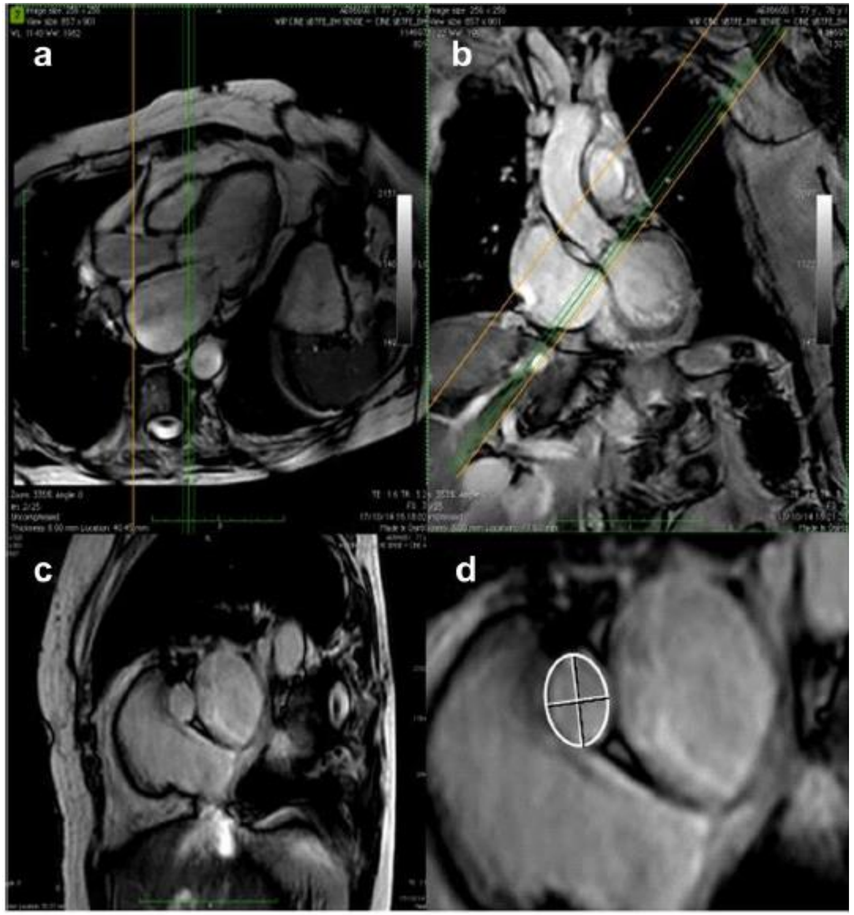
A_{TTE} evaluation: parasternal long axis view

Distance between the insertion of right coronary leaflet and non coronary leaflet at mid-systolic frame

We lost the maximum diameter

Pontone, Am Heart J 2011

AORTIC STENOSIS
Grading aortic stenosis – LVOT measurement



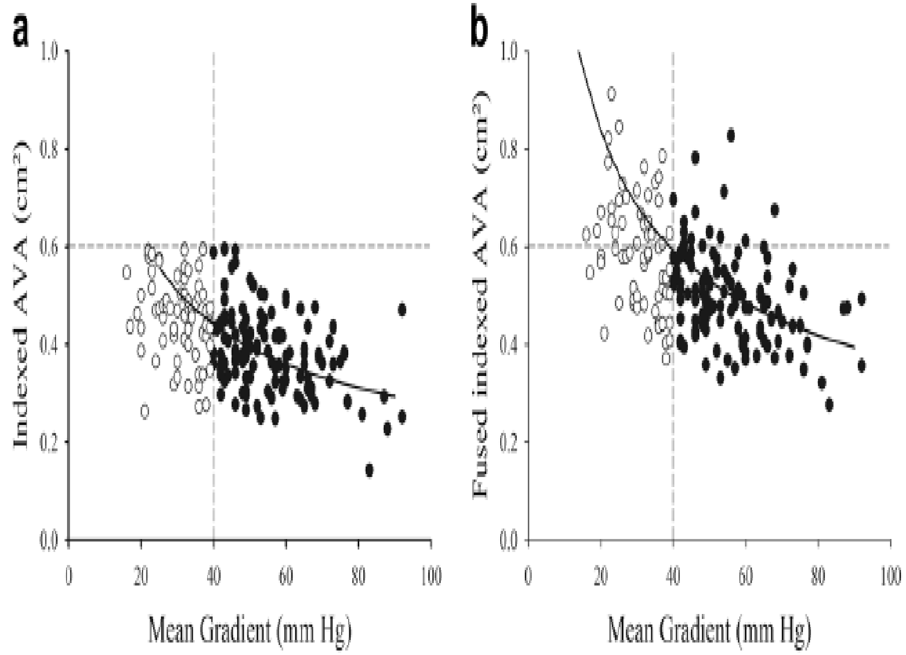


Fig. 5 Indexed AVA (panel **a**) and fused indexed AVA (panel **b**) vs. mean gradient among 120 with HG-SAS and 70 patients with paradoxical LG-SAS. The predicted values from the fitted *curve* of the study population are presented

Fig. 1 Reprentatives examples of 2 orthogonal *long-axis* (panels **a** and **b**) and the resulting *short-axis* (panels **c** and **d**) images of the LVOT by CMR illustrating its *elliptical shape*

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Maes F et al JCMR 2017

Comparison of Accuracy of Aortic Root Annulus Assessment With Cardiac Magnetic Resonance Versus Echocardiography and Multidetector Computed Tomography in Patients Referred for Transcatheter Aortic Valve Implantation

Gianluca Pontone, MD[a,*], Daniele Andreini, MD[a,b], Antonio L. Bartorelli, MD[a,b], Erika Bertella, MD[a], Saima Mushtaq, MD[a], Paola Gripari, MD[a], Monica Loguercio, MD[a], Sarah Cortinovis, MD[a], Andrea Baggiano, MD[a], Edoardo Conte, MD[a], Virginia Beltrama, MD[a], Andrea Annoni, MD[a], Alberto Formenti, MD[a], Gloria Tamborini, MD[a], Manuela Muratori, MD[a], Andrea Guaricci, MD[c], Francesco Alamanni, MD[a,b], Giovanni Ballerini, MD[a], and Mauro Pepi, MD[a]

Pontone G et al Am J Cardiol 2014

AORTIC STENOSIS
Pre-TAVI assessment

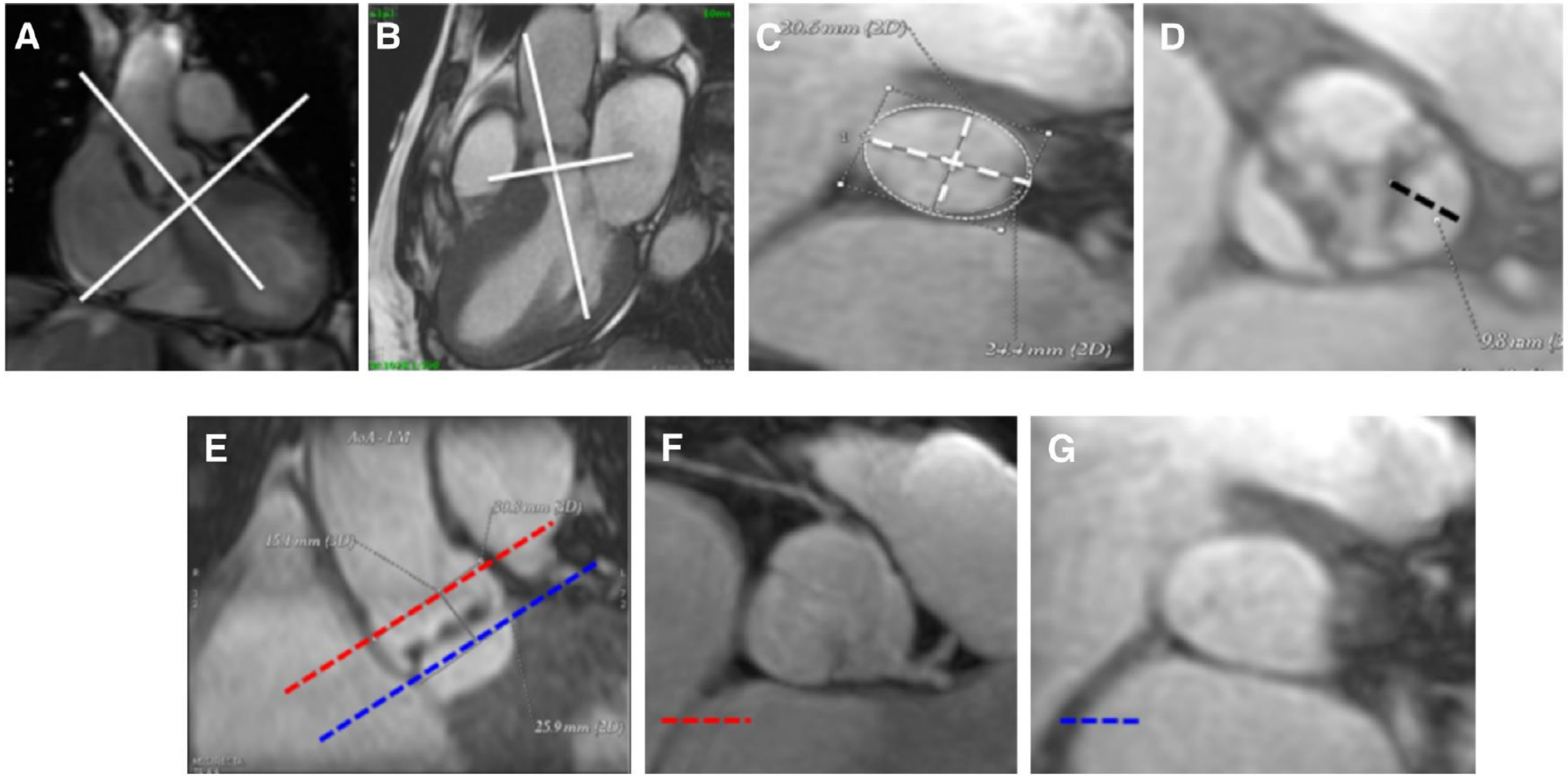

Figure 3. Methods for assessing AoA size, aortic leaflet size, and coronary artery ostia using CMR. Measurements of AoA *(A to C)*: AoA is defined as a virtual ring formed by joining the basal attachments of aortic valve leaflets. For each AoA, maximum diameter, minimum diameter, and area *(white dot line)* were measured in an orthogonal plane on the center line of the aorta obtained in oblique-coronal and oblique-sagittal views, respectively. Measurements of leaflet length *(D)*: the distance between the basal attachment and the apex of the leaflets *(black dot line)* is determined. Measurement of coronary ostia height *(E to G)*: a coronal view *(E)* and 2 short axes of the ascending aorta (*F* and *G*) at the level of the left main coronary ostium *(red line)* and AoA *(blue line)* are obtained. The distance between these 2 lines corresponds to the coronary ostium height.

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Pontone G et al Am J Cardiol 2014

AORTIC STENOSIS
Pre-TAVI Assessment

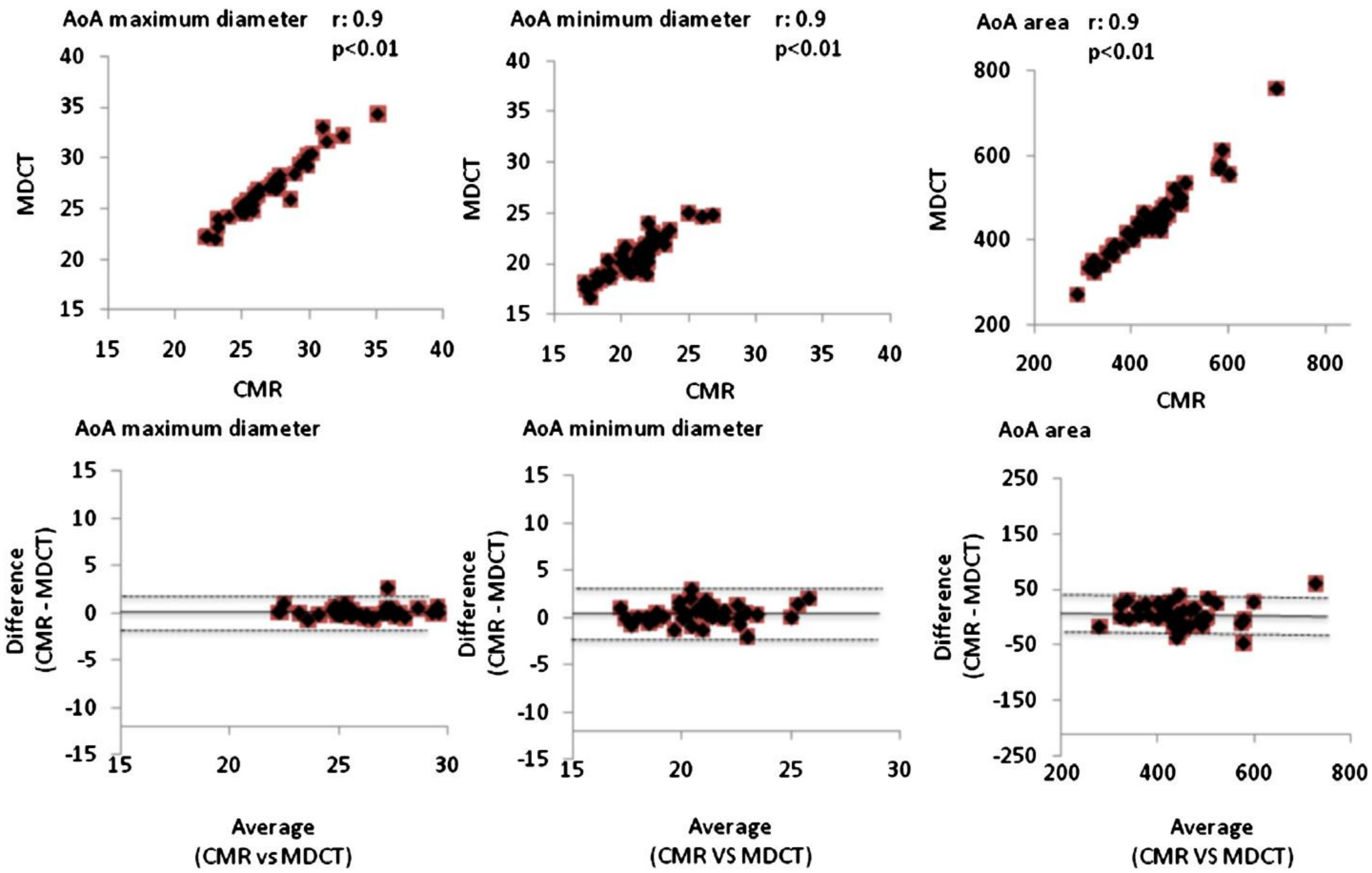

Figure 6. Pearson correlation *(upper panels)* and Bland-Altman analysis *(lower panels)* between CMR and MDCT assessment of AoA maximum diameter, minimum diameter, and area.

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Pontone G et al Am J Cardiol 2014

AORTIC STENOSIS
Pre-TAVI assessment

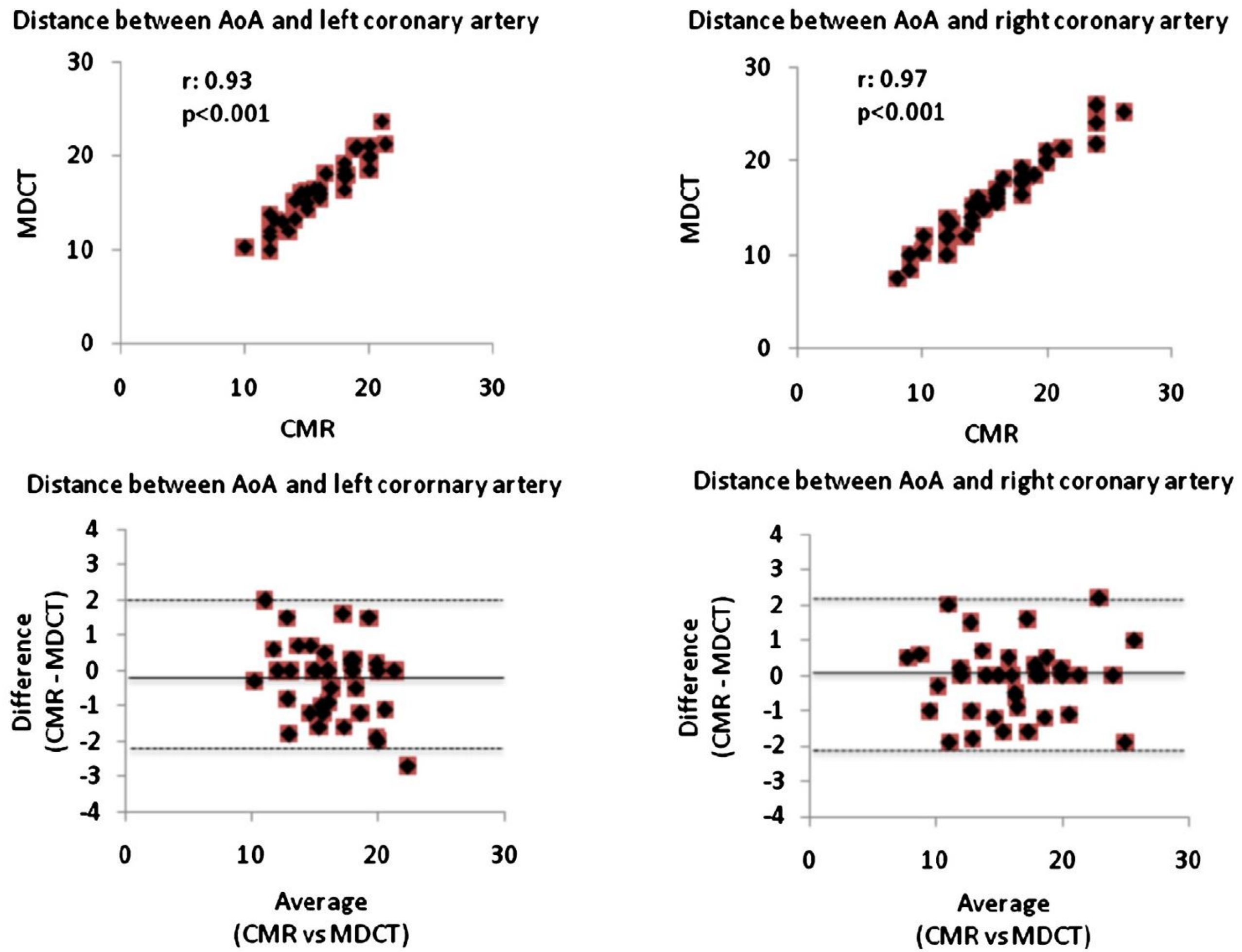

Figure 8. Pearson correlation *(upper panels)* and Bland-Altman analysis *(lower panels)* between CMR and MDCT assessment of the distance between aortic annulus and left main coronary artery and right coronary artery ostia.

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Pontone G et al Am J Cardiol 2014

AORTIC STENOSIS
Pre-TAVI assessment

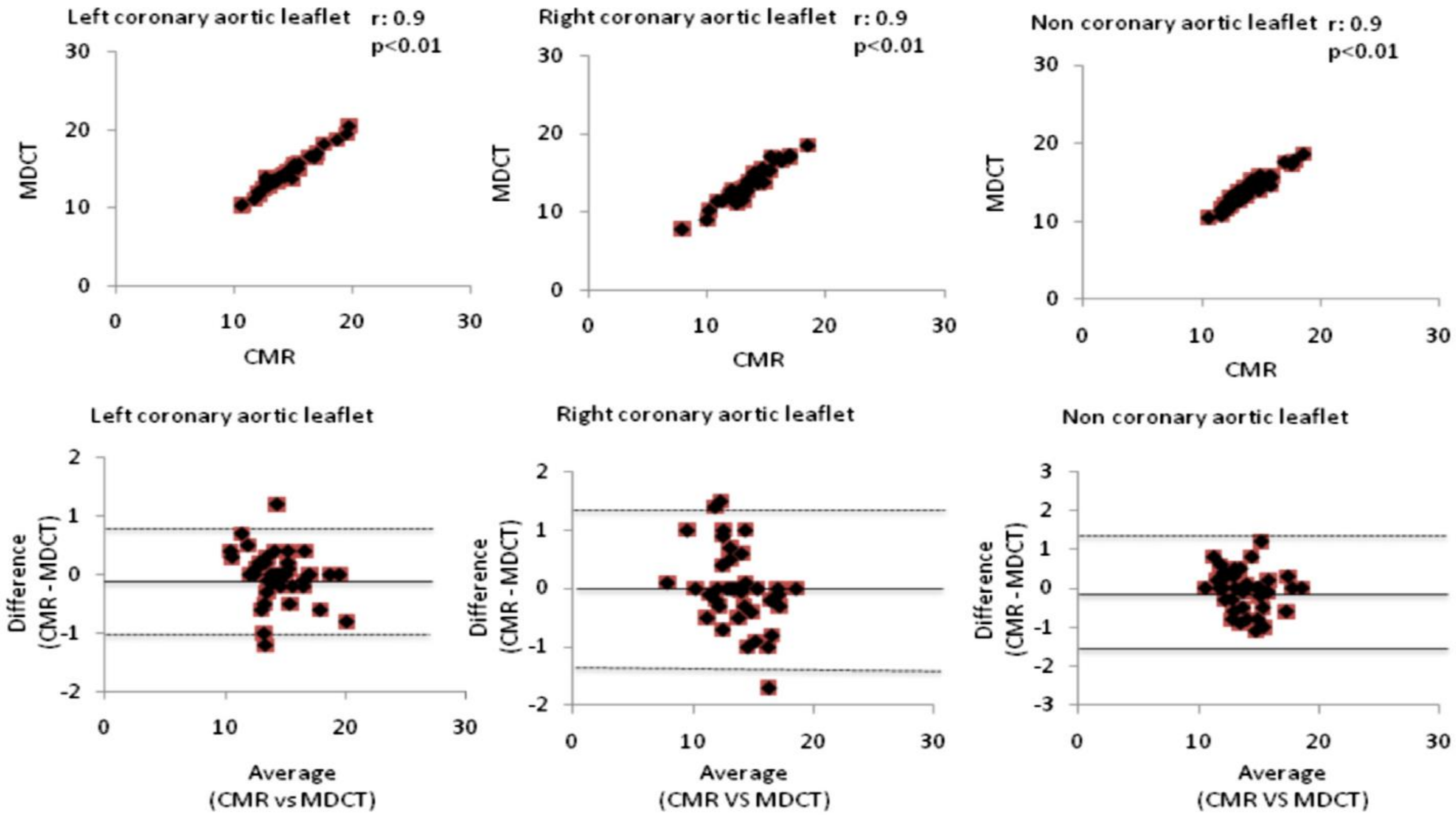

Figure 7. Pearson correlation *(upper panels)* and Bland-Altman analysis *(lower panels)* between CMR and MDCT assessment of left coronary, right coronary, and noncoronary aortic leaflets lengths.

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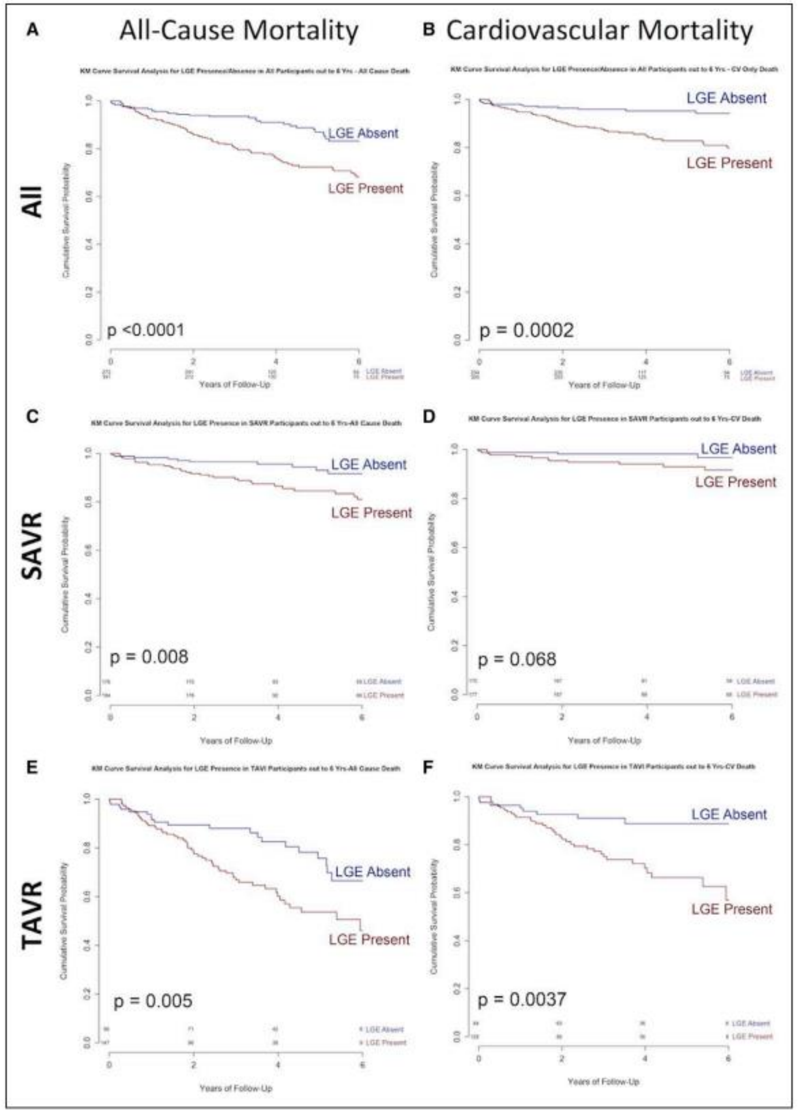
Pontone G et al Am J Cardiol 2014

AORTIC STENOSIS
Tissue Characterization



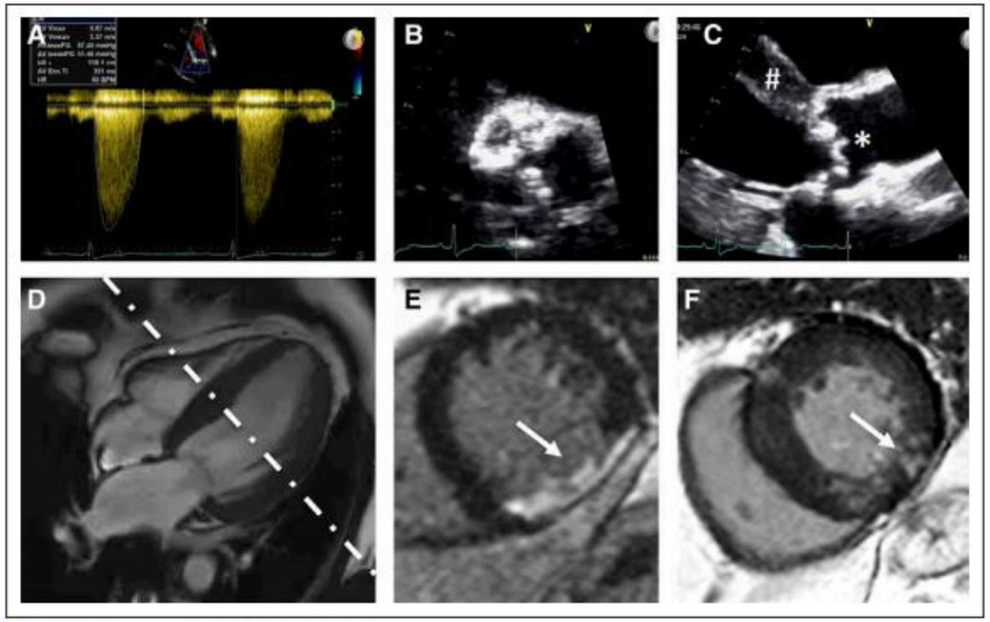
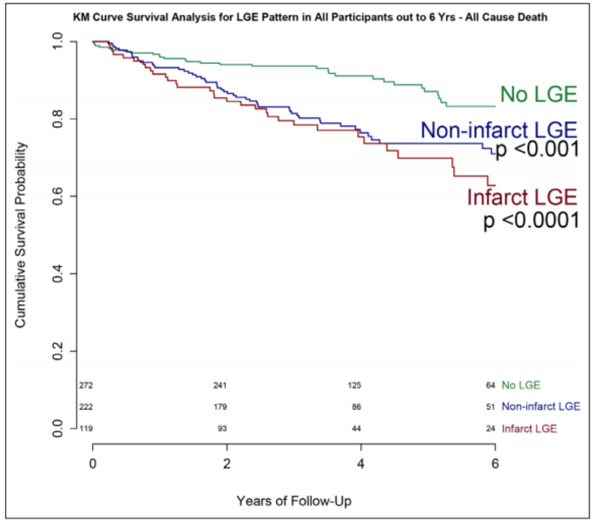


Figure 1. Multimodality assessment of aortic stenosis (AS).
Assessment of AS by transthoracic echocardiography (TTE; **A**–**C**) and cardiovascular magnetic resonance (**D**–**F**). **A**, Continuous Doppler trace across the aortic valve in the apical 5-chamber demonstrating hemodynamic parameters consistent with severe AS (peak velocity, 4.67 m/s; peak gradient, 87 mm Hg; mean gradient, 51 mm Hg). **B**, Short-axis TTE image of a severely calcified aortic valve. **C**, Parasternal long-axis image demonstrating left ventricular hypertrophy (#) and a calcified aortic valve (*). **D**, Four-chamber balanced steady-state free precession cine image demonstrating left ventricular hypertrophy; white dotted line demonstrates the axis of acquisition of the short axis (**E** and **F**). **E**, Late gadolinium enhancement (LGE) image in a midventricular short axis showing transmural LGE of a full-thickness myocardial infarct (arrow). **F**, LGE image in a midventricular short axis showing patchy nonischemia LGE in the mid inferolateral segment (arrow) and more subtle LGE in the inferoseptum and right ventricular insertion points.



Musa et al, Circulation 2019

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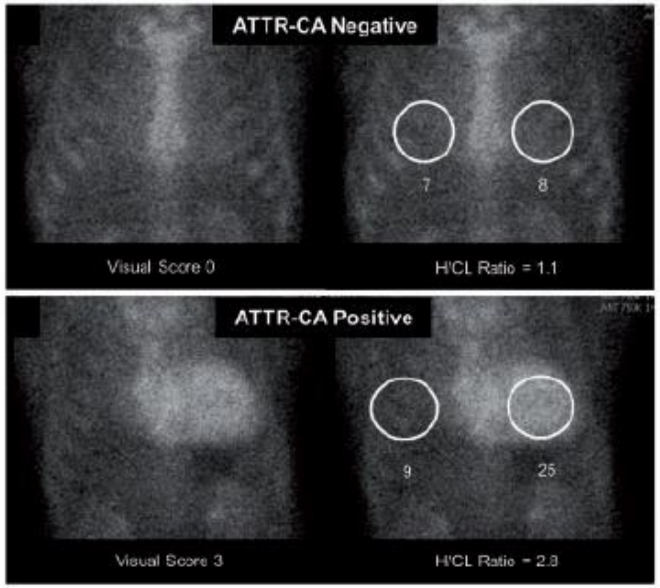
AORTIC STENOSIS
Tissue Characterization: Subclinical Amyloidosis



Predictors of ATTR-CA in elderly patients undergoing transcatheter aortic valve replacement. Quantitative assessment of technetium- 99m pyrophosphate myocardial uptake (A) is shown in a patient with (bottom) and without ATTR-CA (top) with corresponding H/CL ratio

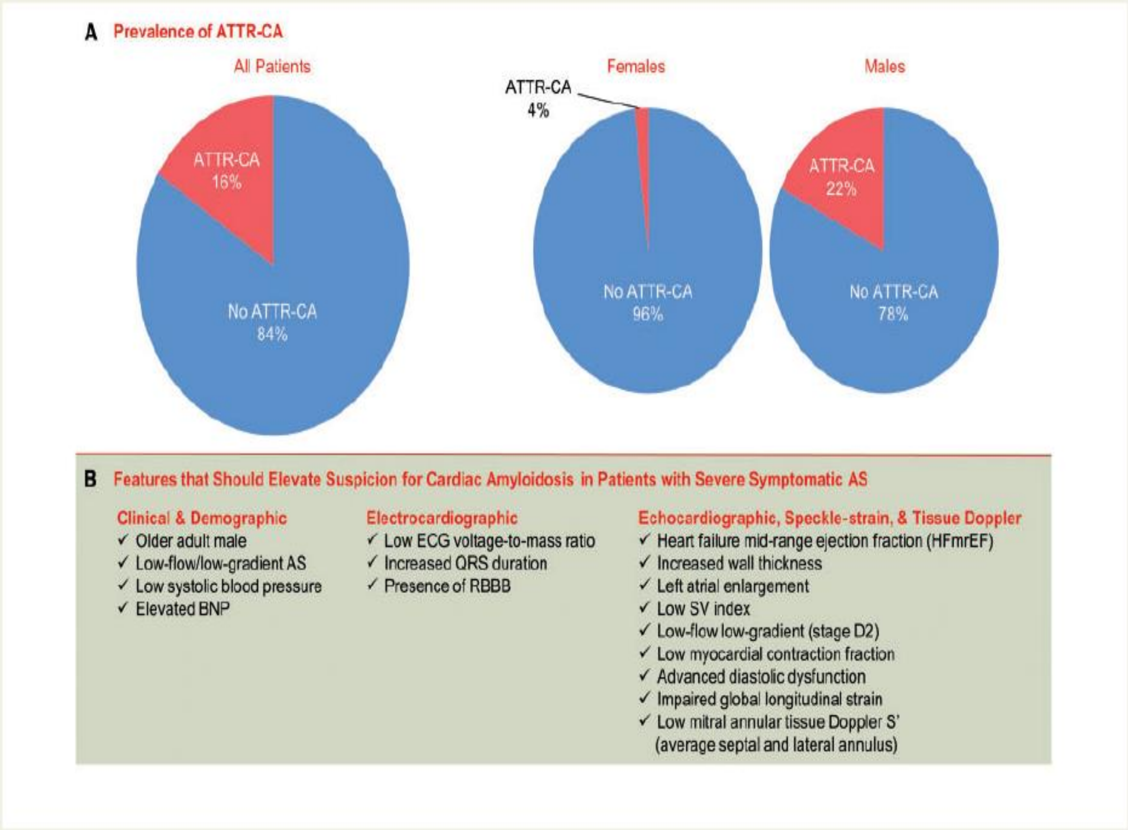


Figure 4 Prevalence and phenotype of ATTR-CA among patients undergoing transcatheter aortic valve replacement at our institution. ATTR-CA, transthyretin cardiac amyloidosis.

Castano EHJ 2017

AORTIC STENOSIS
Tissue Characterization: Subclinical Amyloidosis

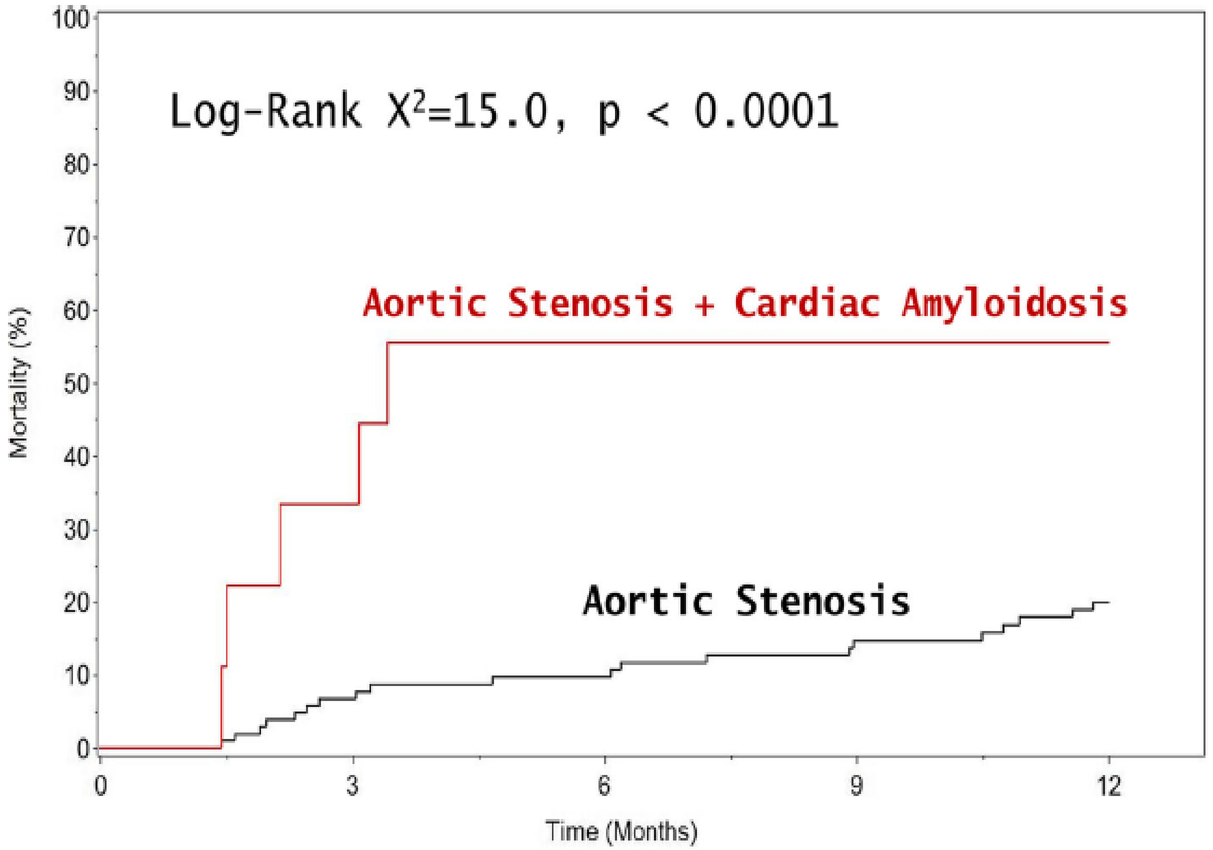


Fig. 3 Kaplan-Meier Curves Comparing All-Cause Mortality in AS vs. AS + CA Patients

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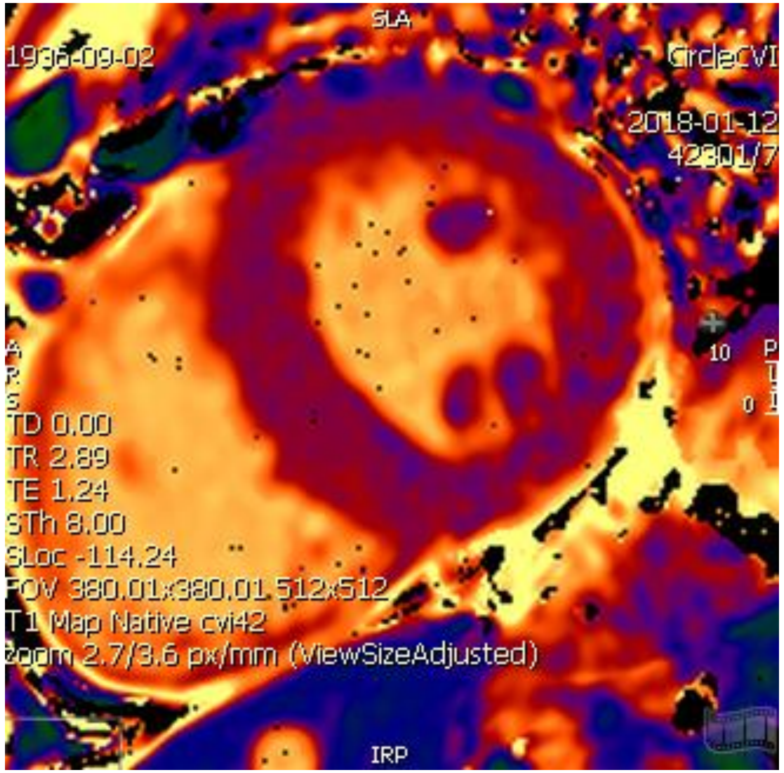
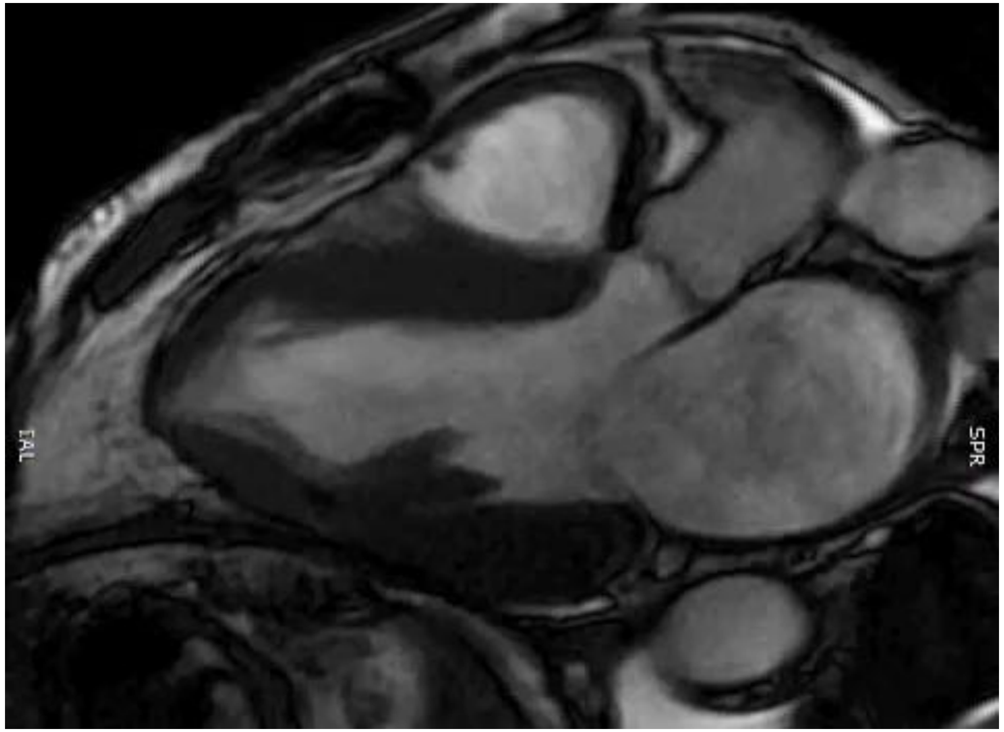
Cavalcante JCMR 2017

AORTIC STENOSIS
Tissue Characterization: T1 mapping





Native T1 = 1200 msec

AORTIC STENOSIS
TAVI FOLLOW UP: Aortic Regurgitation

Effect of Aortic Regurgitation Following Transcatheter Aortic Valve Implantation on Outcomes

See Hooi Ewe, MBBS[a,b,c], Manuela Muratori, MD[d,e], Frank van der Kley, MD[a,b], Mauro Pepi, MD[d,e], Victoria Delgado, MD, PhD[a,b], Gloria Tamborini, MD[d,e], Laura Fusini, MS[d,e], Arend de Weger, MD, PhD[a,b], Paola Gripari, MD[d,e], Antonio Bartorelli, MD[d,e], Jeroen J. Bax, MD, PhD[a,b], and Nina Ajmone Marsan, MD, PhD[a,b,*]

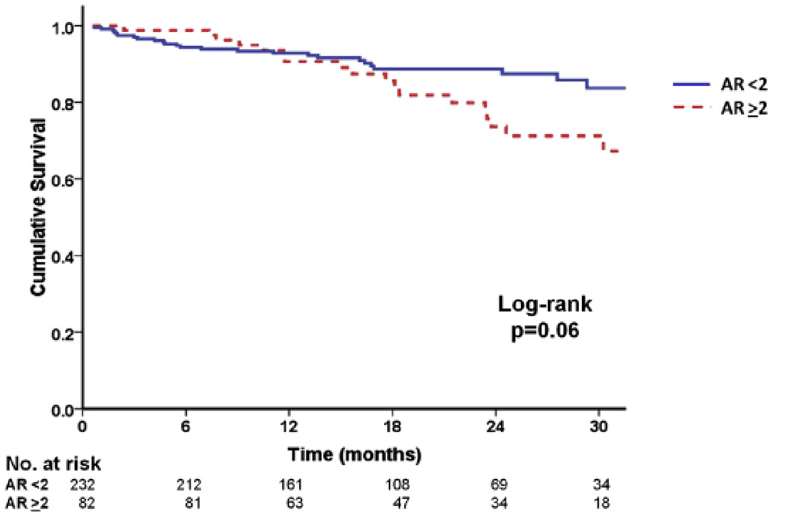


Figure 1. Survival Kaplan-Meier curves for patients with post-TAVI AR grade ≥2 or <2 before hospital discharge.

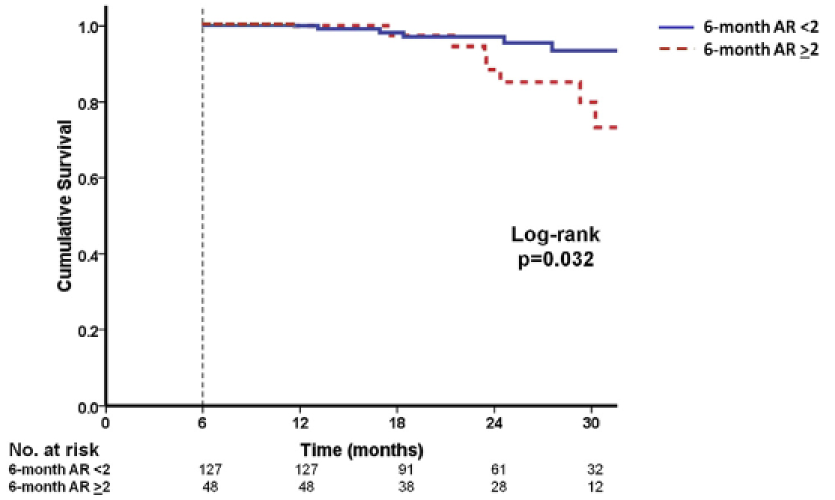
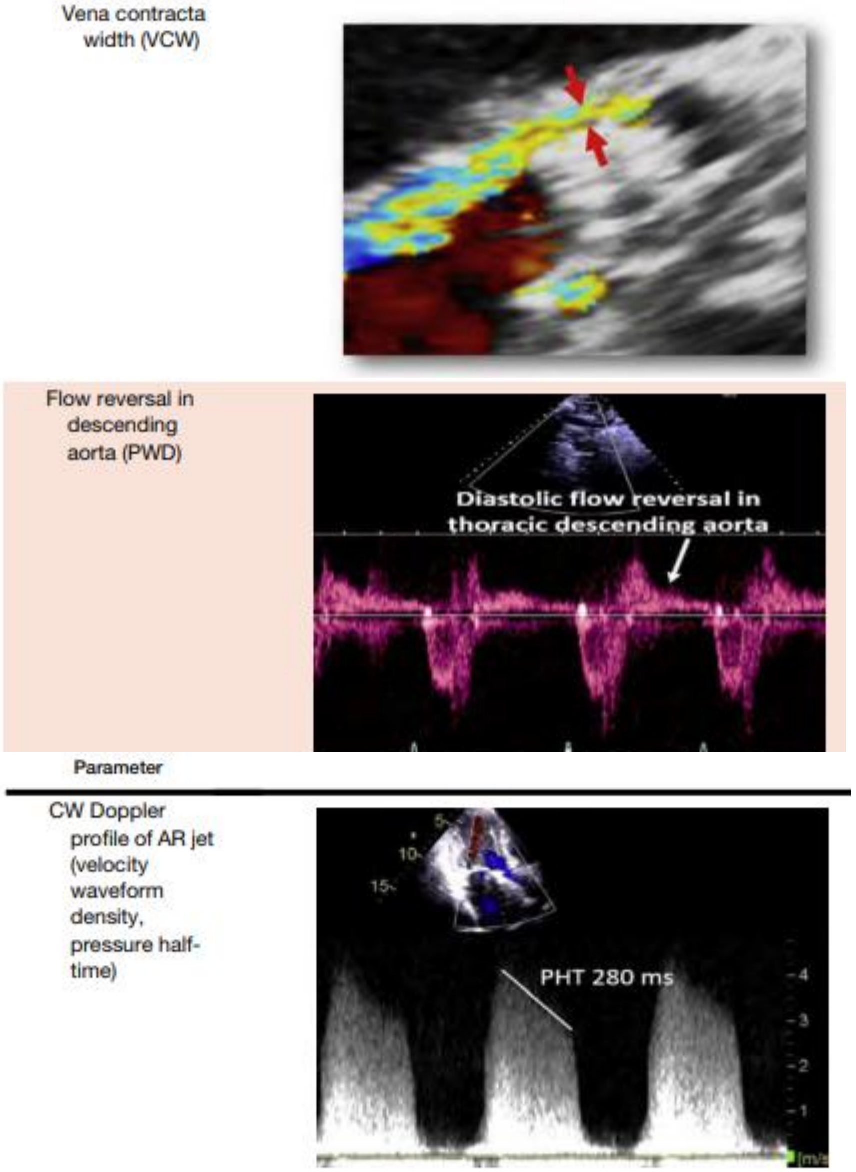
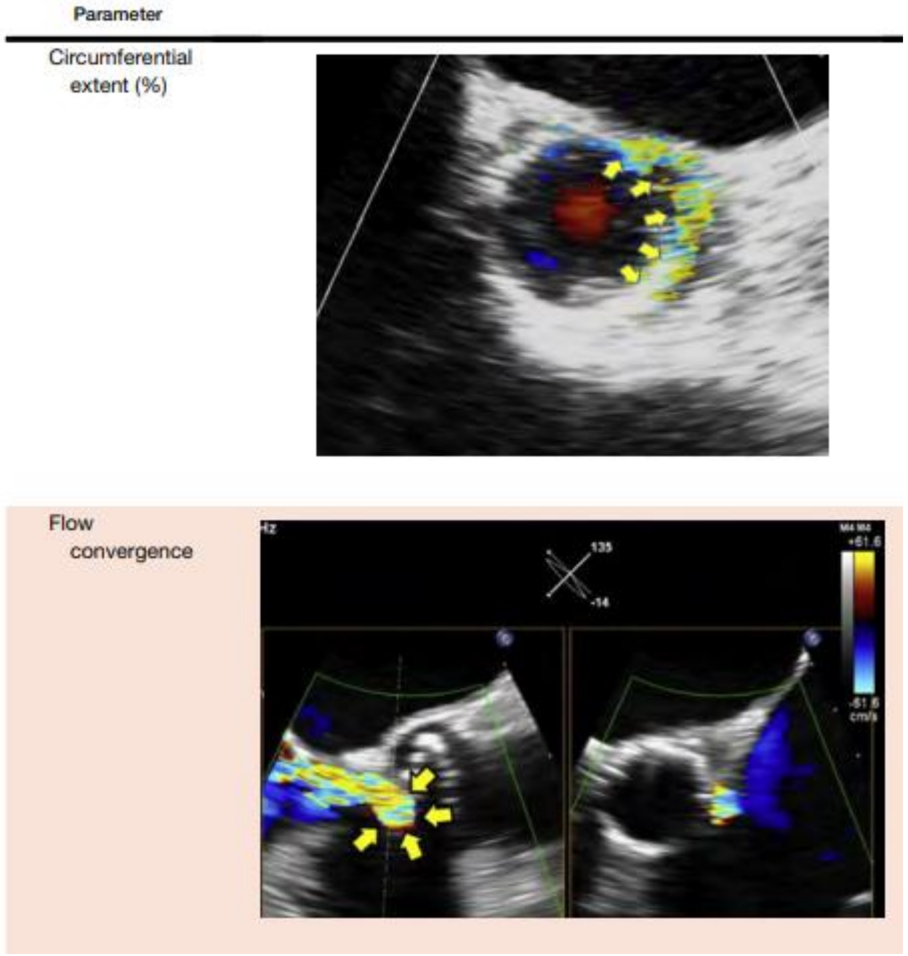


Figure 4. Survival Kaplan-Meier curves for patients with 6-month AR ≥2 or AR <2 after TAVI.

Ewe Am J Card 2015

AORTIC STENOSIS
TAVI FOLLOW UP: Grading Aortic Regurgitation





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Bloomfield GS JACC CI 2012

AORTIC STENOSIS
TAVI FOLLOW UP: The emerging role of CMR in grading AR

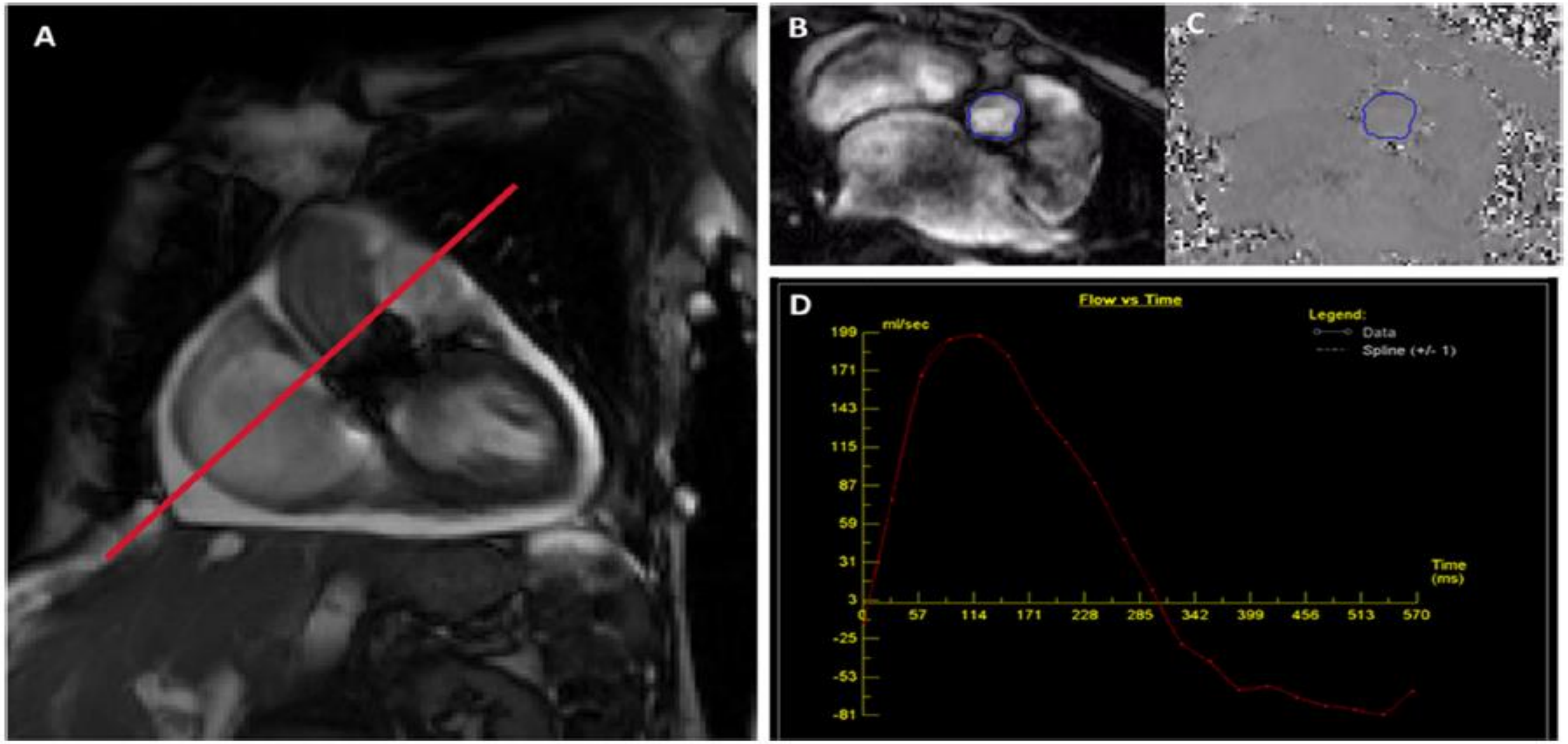

Figure 2 Measurement of paravalvular leak (PVL) regurgitant fraction (RF) by cardiovascular magnetic resonance (CMR). The positioning of the scan plane is demonstrated for the balloon-expandable prosthesis in the aortic root 2-3 mm above the valve stent frame **(A)**. The regions of interest are traced on the magnitude images (anatomical scan; **B**) and the phase images (flow scan; **C**). The regions of interest include the entire intra-luminal, cross sectional area of flow just above the transcatheter valve. The flow through the region of interest is calculated throughout the cardiac cycle **(D)**, with the area under the curve (above baseline) representing forward flow volume and the area above the curve (below baseline) representing reverse flow volume. The aortic regurgitant fraction was calculated by dividing the reverse flow volume by the forward flow volume (mild ≤ 20%, moderate 21-39%, severe ≥40%).

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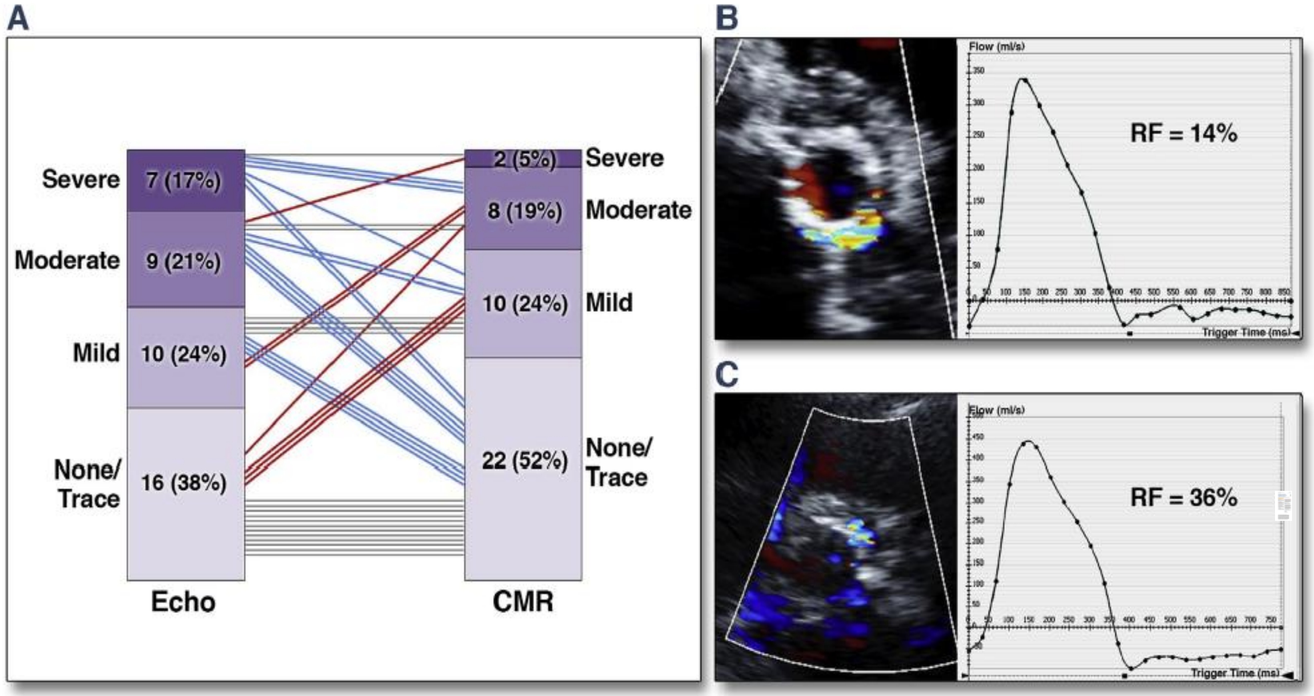
Hartlage GR et al JCMR 2014

AORTIC STENOSIS
TAVI FOLLOW UP: Grading Aortic Regurgitation

FIGURE 7 **Comparison of PVR Severity Assessed With the Jet Circumferential Extent by Doppler-Echocardiography vs. the Regurgitation Fraction by CMR Imaging**



(A) Shows the comparison of AR severity based on the PVR circumferential extent by Doppler echocardiography versus the regurgitant fraction (RF) by cardiac magnetic resonance (CMR). **(B and C)** Show 2 examples where circumferential extent overestimated **(B)** and underestimated **(C)** the AR severity as assessed by CMR RF. Adapted with permission from Ribeiro et al. (21). Abbreviations as in **Figure 1**.

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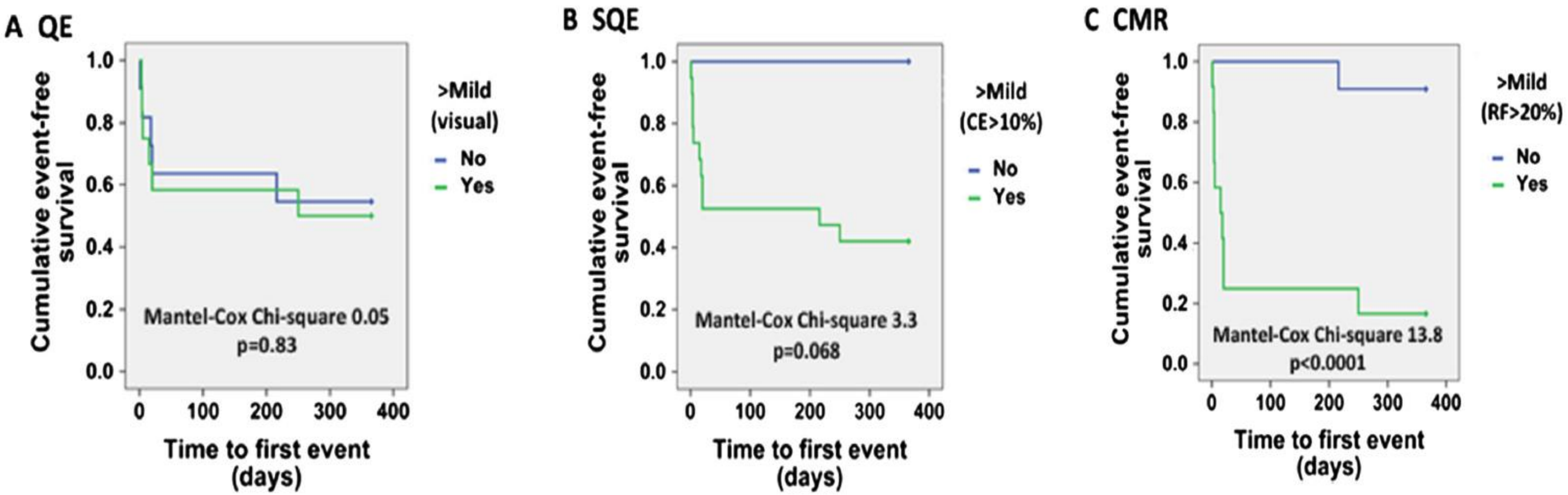
Pibarot P et al , JACC CI 2015

AORTIC STENOSIS
TAVI FOLLOW UP: The emerging role of CMR in grading AR

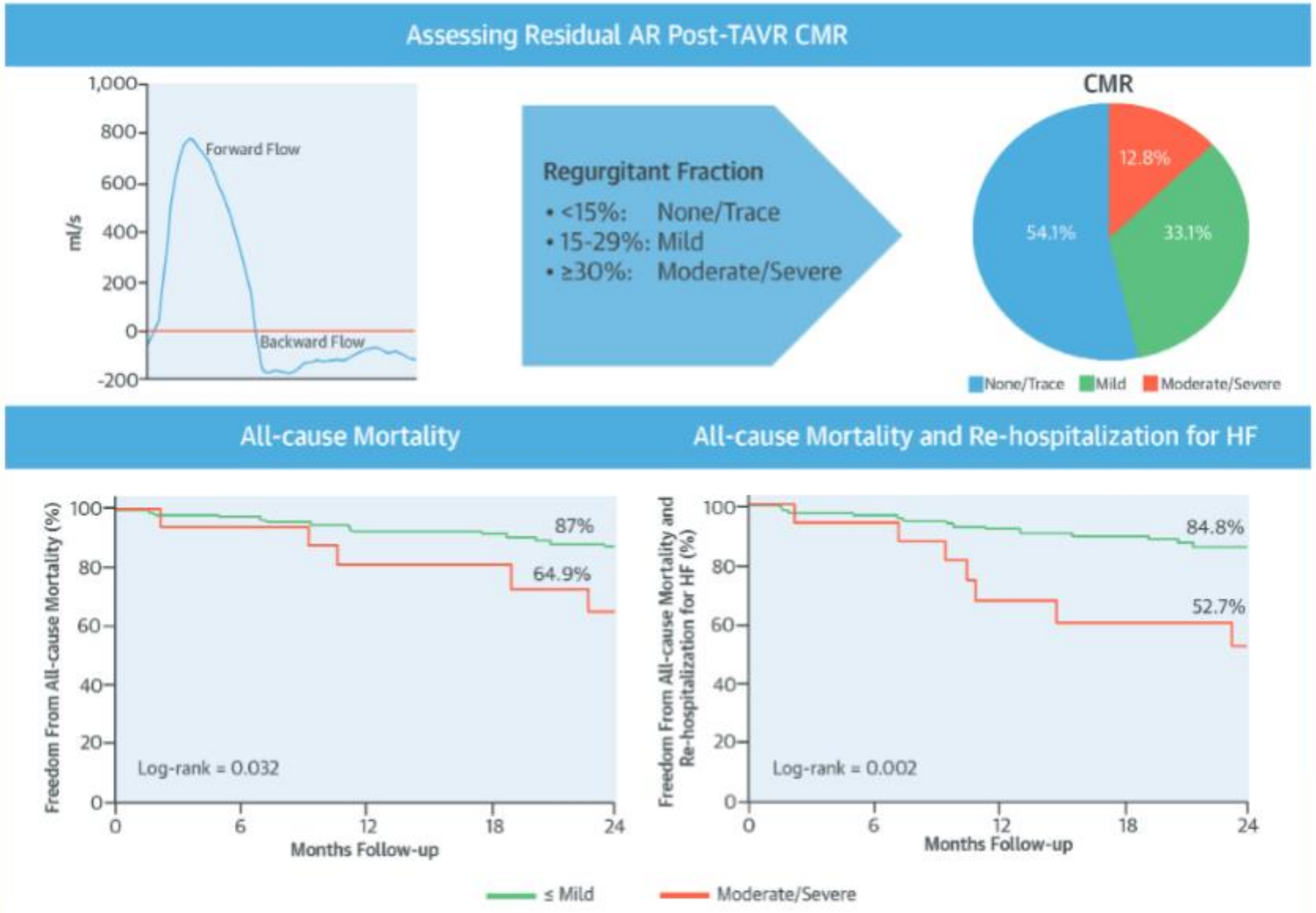


Primary composite outcome Kaplan-Meier survival analysis for patients with greater than mild paravalvular leak (PVL) by imaging method. QE = qualitative echocardiography, SQE = semi-quantitative echocardiography, CMR = cardiovascular magnetic resonance. CE = circumferential extent. Primary composite outcome = repeat invasive therapy, heart failure hospitalization, and all-cause death.

Hartlage GR et al JCMR 2014

AORTIC STENOSIS
TAVI FOLLOW UP: The emerging role of CMR in grading AR

CENTRAL ILLUSTRATION AR, CMR, and TAVR: Assessing Residual AR Post-TAVR



Ribeiro, H.B. et al. J Am Coll Cardiol. 2016;68(6):577-85.

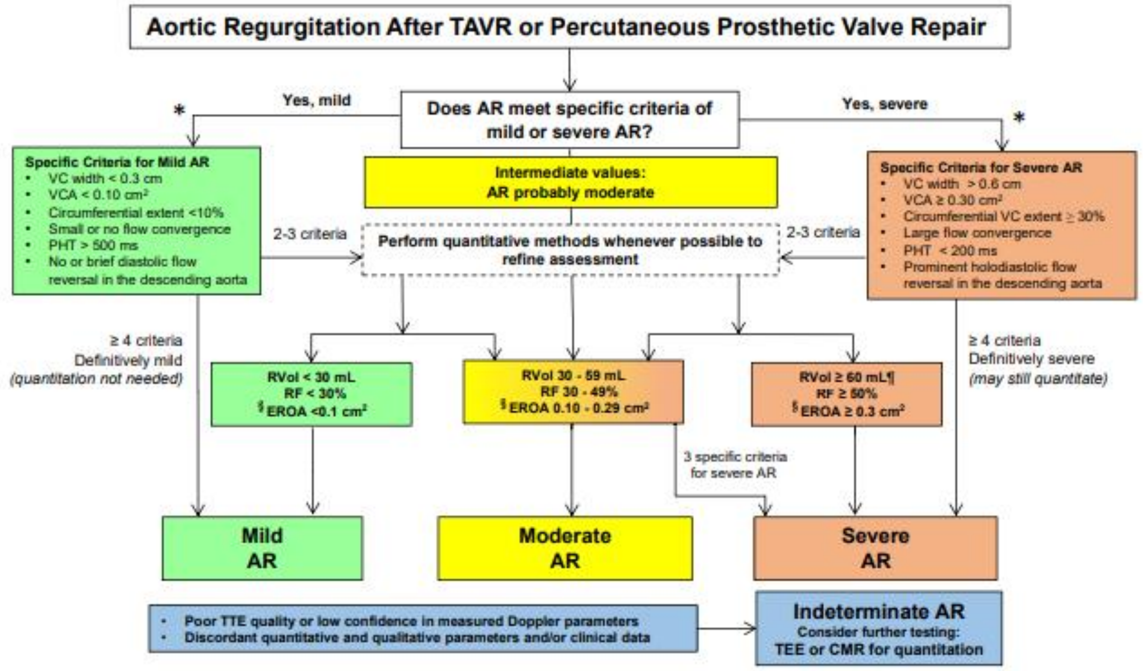
Assessment of AR severity post-TAVR by CMR **(top)**; clinical impact of moderate/severe AR post-TAVR as evaluated by CMR **(bottom)**. AR = aortic regurgitation; CMR = cardiovascular magnetic resonance; HF = heart failure; TAVR = transcatheter aortic valve replacement.

Ribeiro JACC 2016

AORTIC STENOSIS
TAVI FOLLOW UP: The emerging role of CMR in grading AR

GUIDELINES AND STANDARDS

Guidelines for the Evaluation of Valvular Regurgitation After Percutaneous Valve Repair or Replacement
A Report from the American Society of Echocardiography Developed in Collaboration with the Society for Cardiovascular Angiography and Interventions, Japanese Society of Echocardiography, and Society for Cardiovascular Magnetic Resonance



*	AR after TAVR is frequently eccentric, involving more than one jet; an integrative approach is essential
¶	Regurgitant volume for severe AR may be lower in low flow conditions.
§	EROA is infrequently used in AR. It is derived using the volumetric approach, not PISA.

Figure 9 Suggested algorithm to guide implementation of integration of multiple parameters of AR severity after TAVR or prosthetic aortic valve repair. Good-quality echocardiographic imaging and complete data acquisition are assumed. If imaging is technically difficult, consider TEE or CMR. AR severity may be indeterminate due to poor image quality, technical issues with data, internal inconsistency among echo findings, or discordance with clinical findings.

"When more than mild AR is suspected but the data are equivocal, **CMR should be performed** (at centers with appropriate expertise) to quantitate aortic regurgitant volume and fraction, as well as LV chamber volumes".

Zoghbi JASE 2019

MITRAL REGURGITATION

grading mitral regurgitation

ESC European Society of Cardiology
European Heart Journal (2017) 38, 2739–2786
doi:10.1093/eurheartj/ehx391
ESC/EACTS GUIDELINES

2017 ESC/EACTS Guidelines for the management of valvular heart disease

The Task Force for the Management of Valvular Heart Disease of the European Society of Cardiology (ESC) and the European Association for Cardio-Thoracic Surgery (EACTS)

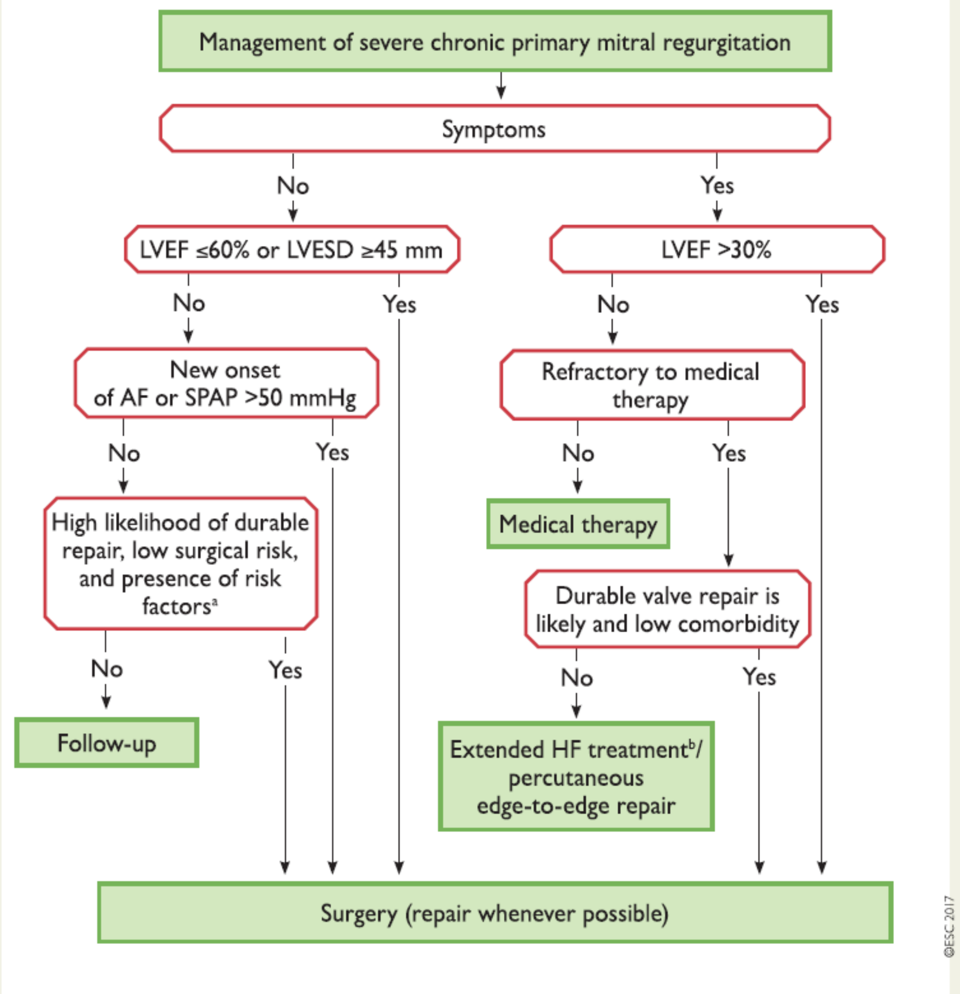


Figure 4 Management of severe chronic primary mitral regurgitation. AF = atrial fibrillation; BSA = body surface area; CRT = cardiac resynchronization therapy; HF = heart failure; LA = left atrial; LVEF = left ventricular ejection fraction; LVESD = left ventricular end-systolic diameter; SPAP = systolic pulmonary arterial pressure.
[a]When there is a high likelihood of durable valve repair at a low-risk, valve repair should be considered (IIa C) in patients with LVESD ≥40 mm and one of the following is present: flail leaflet or LA volume ≥60 mL/m^2 BSA at sinus rhythm.
[b]Extended HF management includes the following: CRT; ventricular assist devices; cardiac restraint devices; heart transplantation.

MITRAL REGURGITATION
Grading mitral regurgitation CMR vs echo

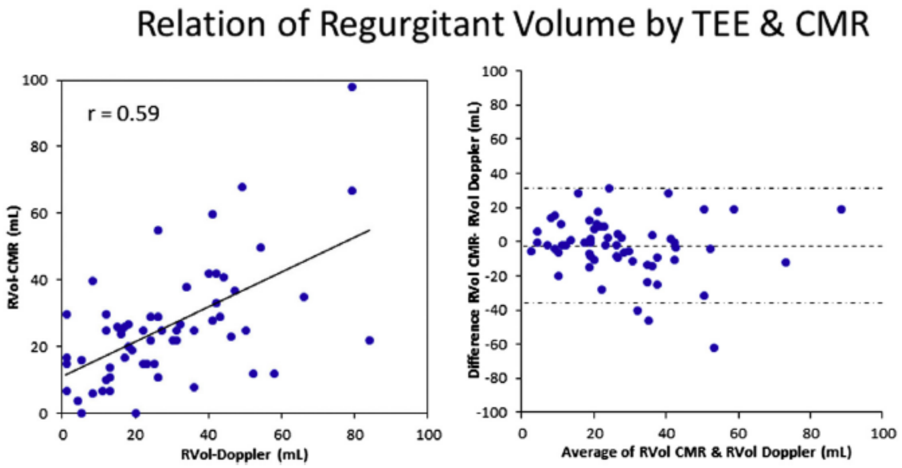


Figure 2. Correlation of R Vol by TTE and CMR along with Bland−Altman plots.

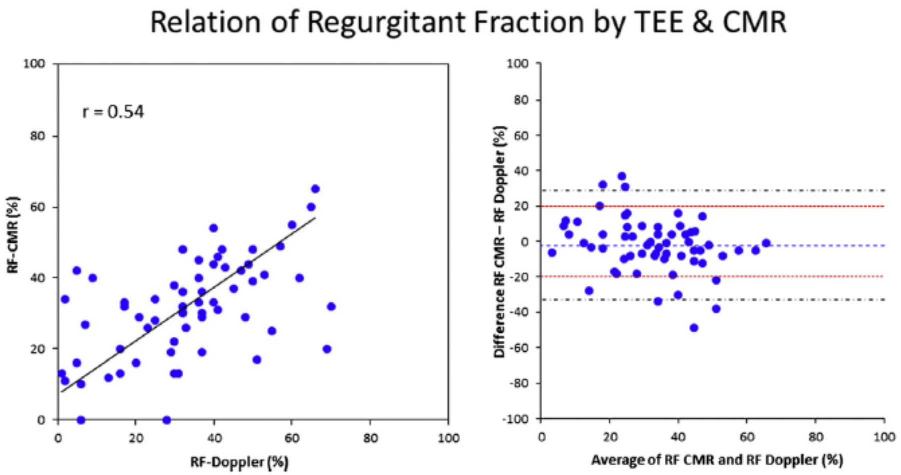


Figure 3. Correlation of RF by TTE and CMR, along with Bland−Altman plots. The ± 20% CI of reproducibility is shown in *red*.

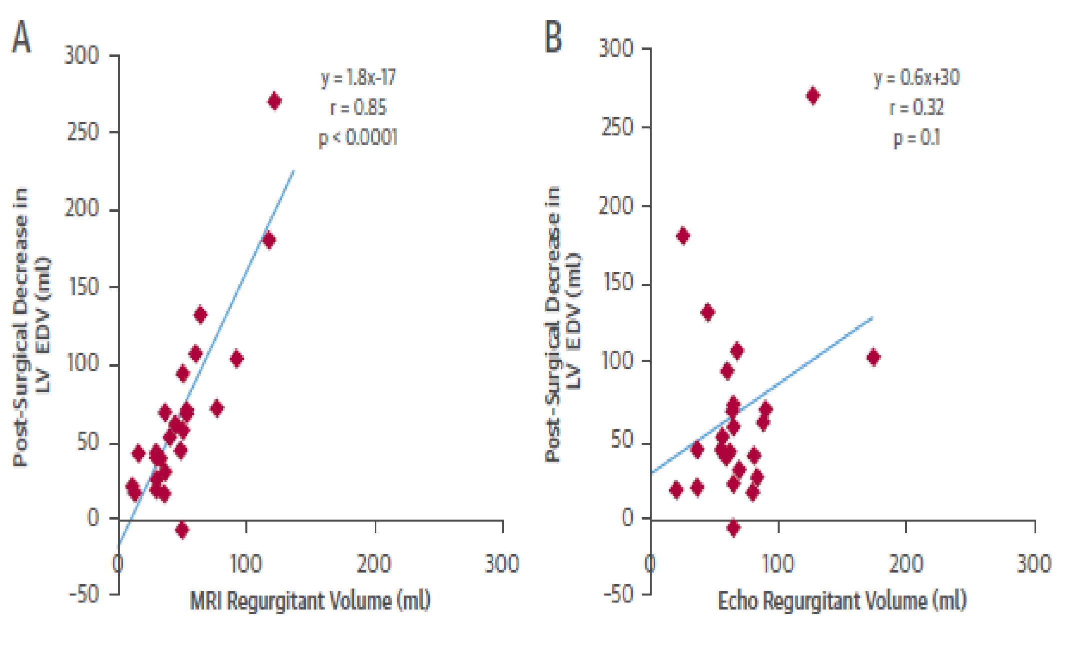
Interobserver variability in RF was higher with TTE compared with CMR (L5.5 – 15% vs 0.1 – 7.3%)

Centro Cardiologico Monzino

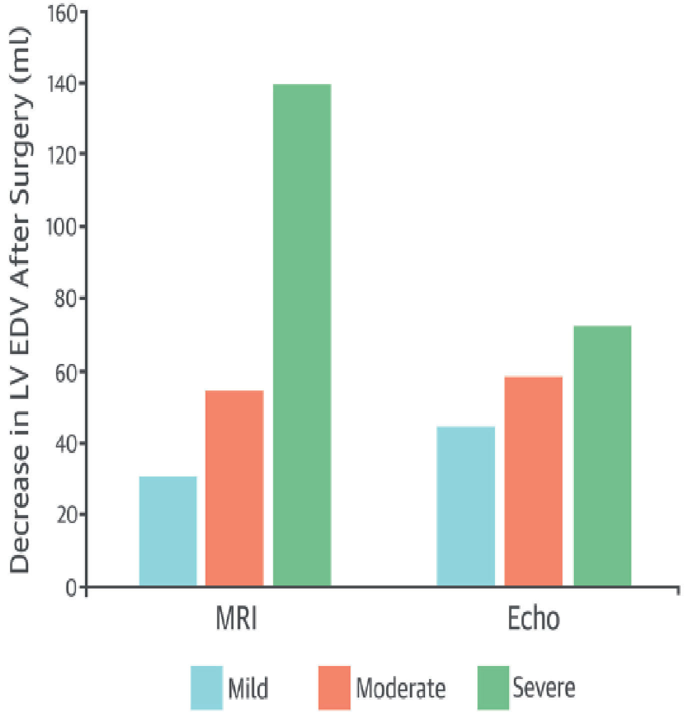
Lopez-Mattei 2016, AJC 2016

MITRAL REGURGITATION
Grading regurgitant lesions

FIGURE 4 Post-Surgical Decrease in LV EDV Versus Pre-Surgical Regurgitant Volume



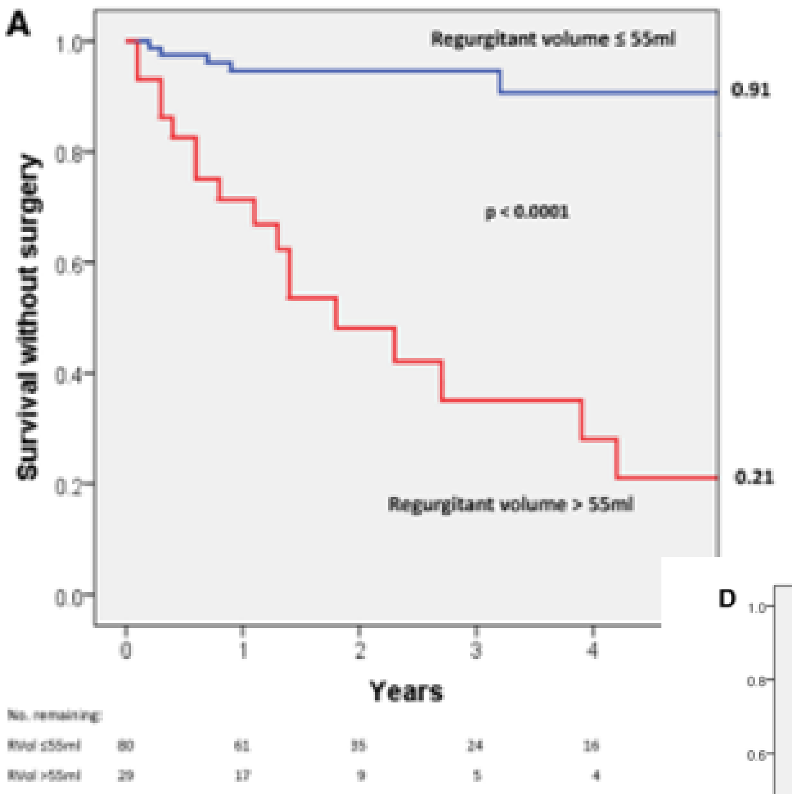
(A) MRI. (B) Echocardiography. LV EDV = left ventricular end-diastolic volume; other abbreviations as in Figures 1 and 2.

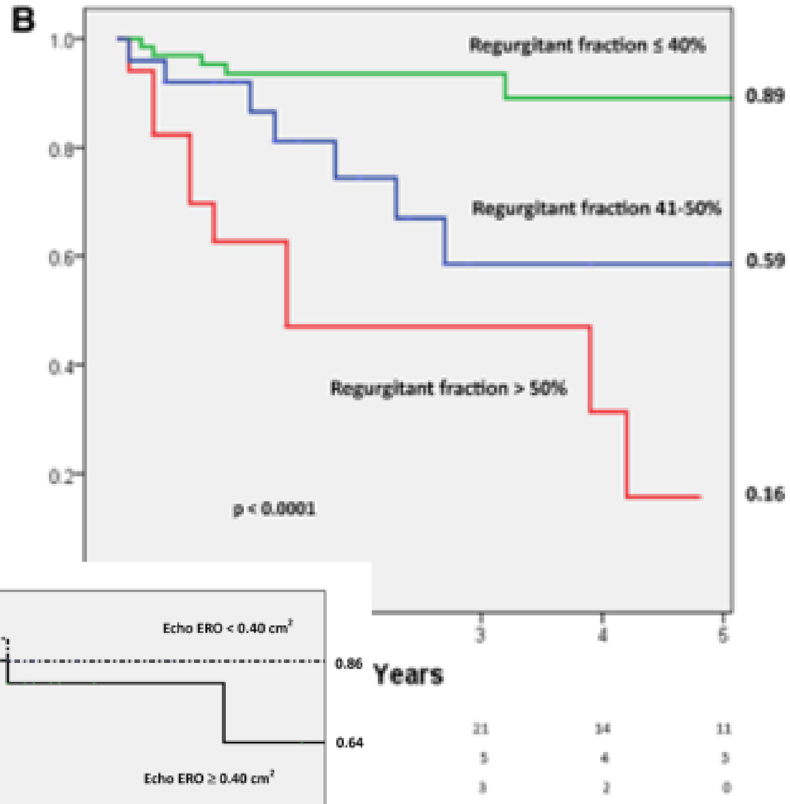


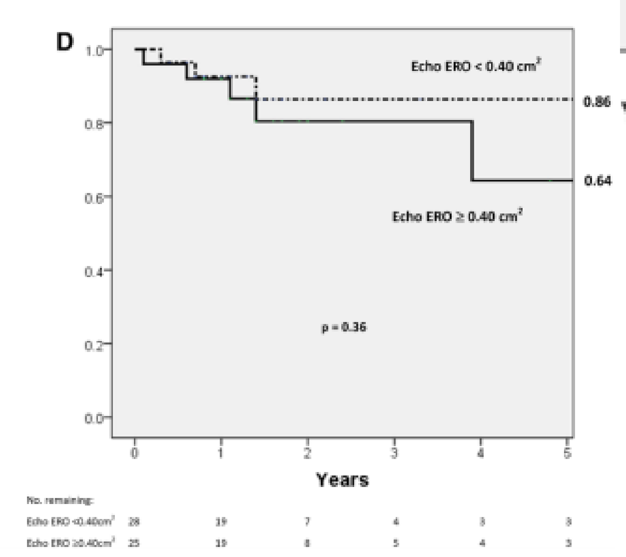
Centro Cardiologico Monzino

Uretsky S, JACC 2015

MITRAL REGURGITATION
Grading regurgitant lesions: outcome







109 asymptomatic pts, with at le
Mean FU 2,5 ± 1,9 years. Outcor
(symptoms or guideline criteria)

Centro Cardiologico Monzino

Myerson, Circulation 2016

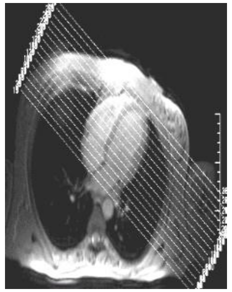
ViosWorks to have 3D cardiac anatomy in 1 free-breathing in less than 10 min scan

What is it?

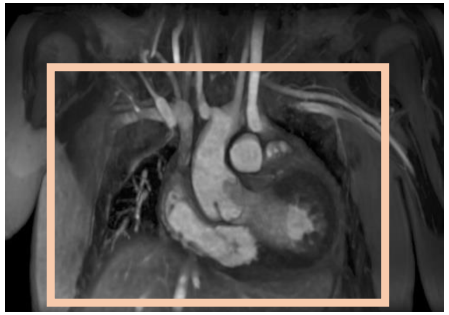
- 3D Cine (EFGRE)
- Capture data in 7 dimensions
  - 3 in space, 1 in time, and 3 in velocity direction

Benefits

- Free-breathing, non-invasive
- Unsupervised cardiac imaging – no expertise or clinician guidance needed
- Faster cardiac exams help to shorten backlog scheduling times
- Cloud-based visualization and reporting attracts new referrals



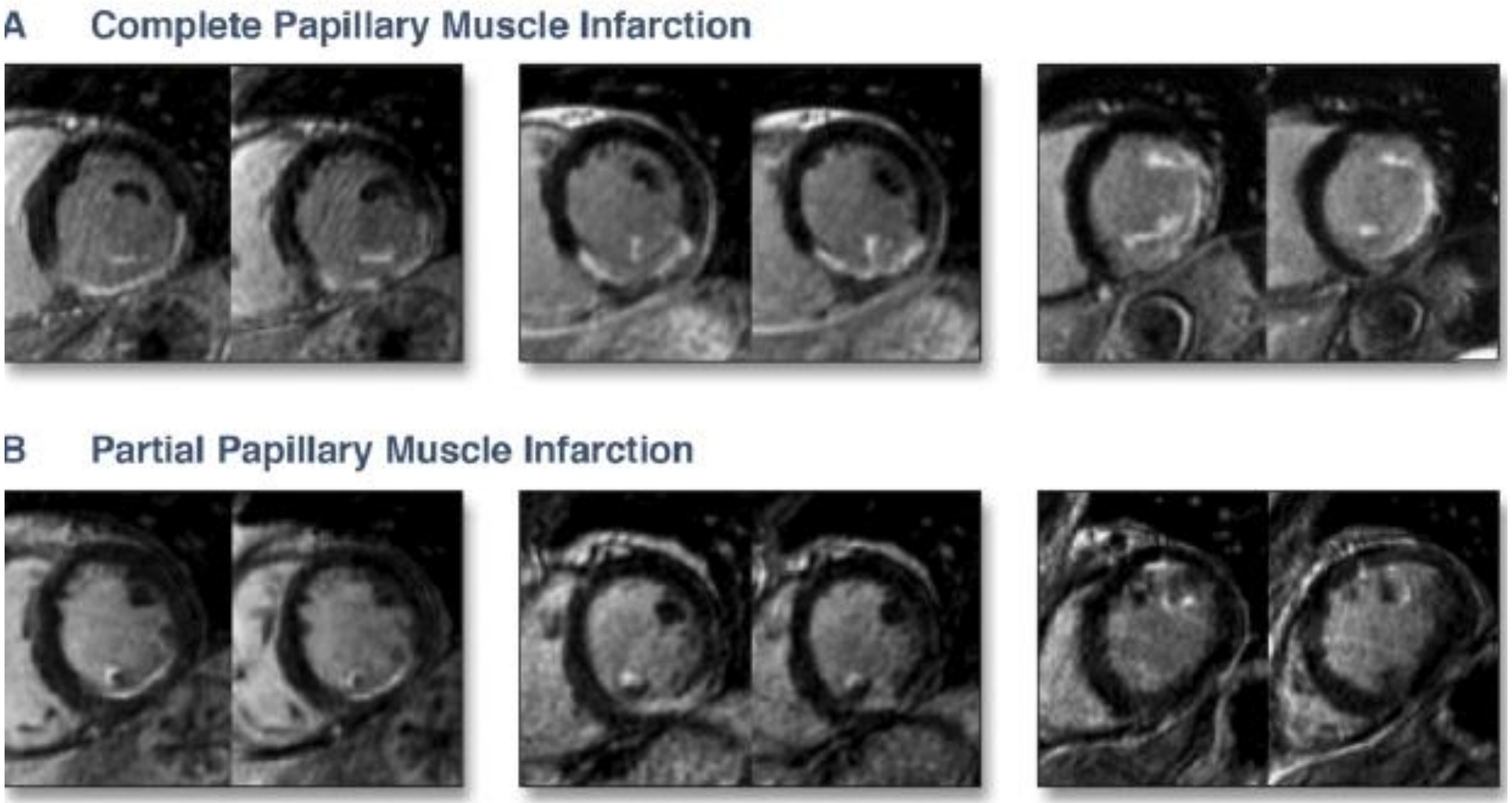
- 60-90 min exam
- 20-50+ breath-holds
- Many imaging slices and sequences
- Dedicated, cardiac technologist and Clinician needed to perform exam and post-processing



- 8-30 min exam (clinical indication dependent)
- Free breathing
- 1, 3D volume placed over chest
- No dedicated, cardiac technologist or clinician needed to perform exam.

MITRAL REGURGITATION

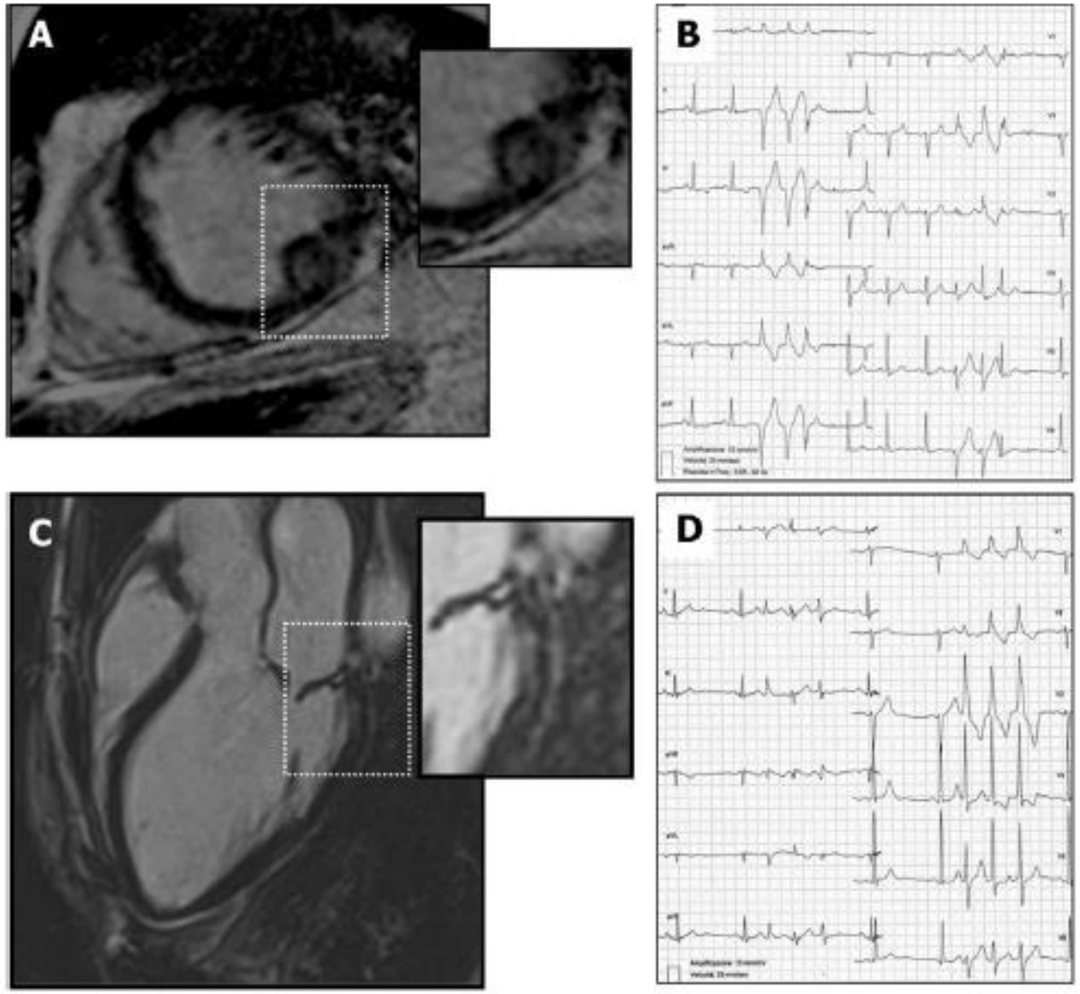
Cardiac magnetic resonance – evaluating etiology of VHD



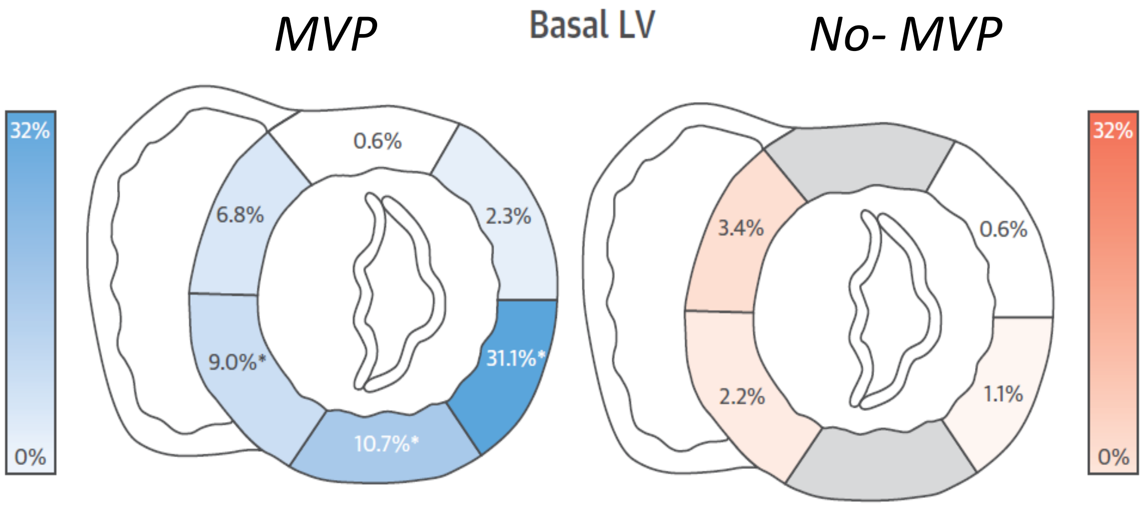
Representative Examples of Complete and Partial PMI Typical examples of (A) complete papillary muscle infarction (PMI) and (B) partial PMI detected by delayed-enhancement cardiac magnetic resonance. Each example is composed of 2 short-axis images within the affected papillary muscle. As shown, complete PMI was often associated with transmural infarction of the adjacent left ventricular wall, whereas partial PMI was associated with subendocardial infarction. Upper right shows bilateral, complete PMI with transmural infarction of the inferior and lateral walls.

Chinitz JS JACC CI 2013

MITRAL REGURGITATION
CMR for stratifying arrhythmic risk



Basso C et al, Circulation 2015



Kitkungvan D JACC 2018

T1-Mapping and Cardiac Magnetic Resonance Feature-Tracking in Mitral Valve Prolapse

Short title: T1-Mapping and CMR-FT in Mitral Valve Prolapse

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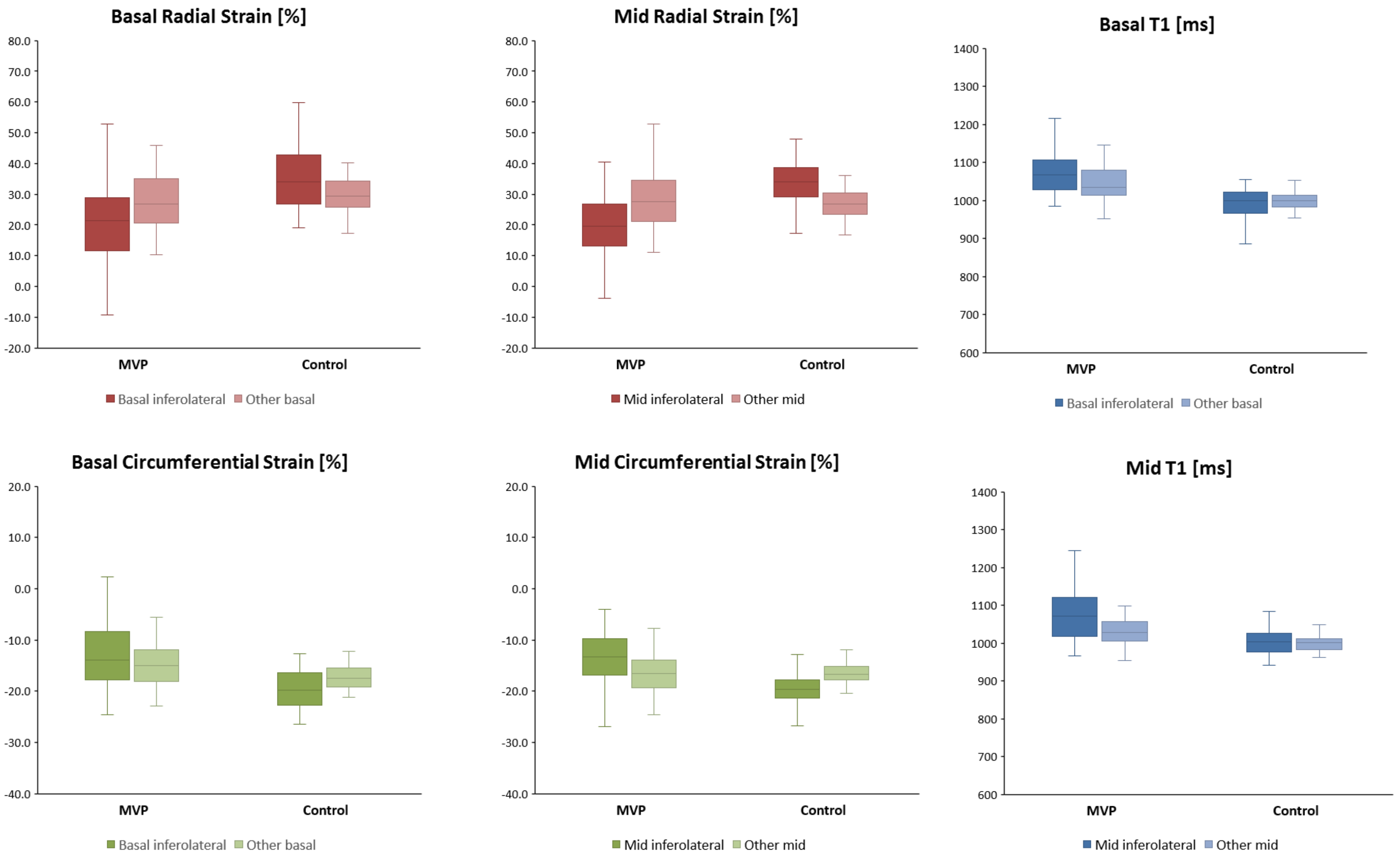
Guglielmo M, Pontone G, submitted

MITRAL REGURGITATION
CMR for stratifying arrhythmic risk



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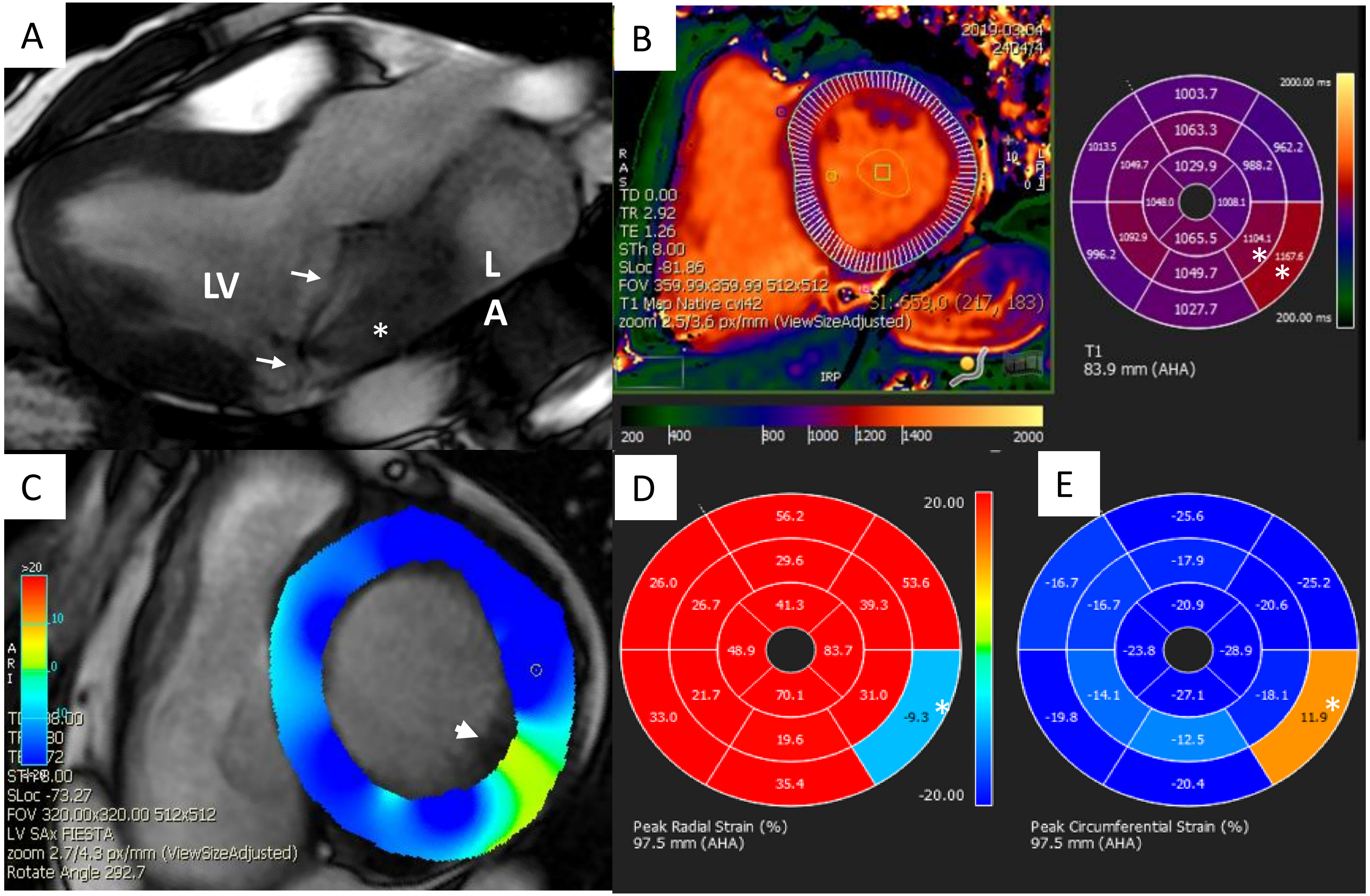
Guglielmo M, Pontone G, submitted

MITRAL REGURGITATION
CMR for stratifying arrhythmic risk



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Guglielmo M, Pontone G, submitted

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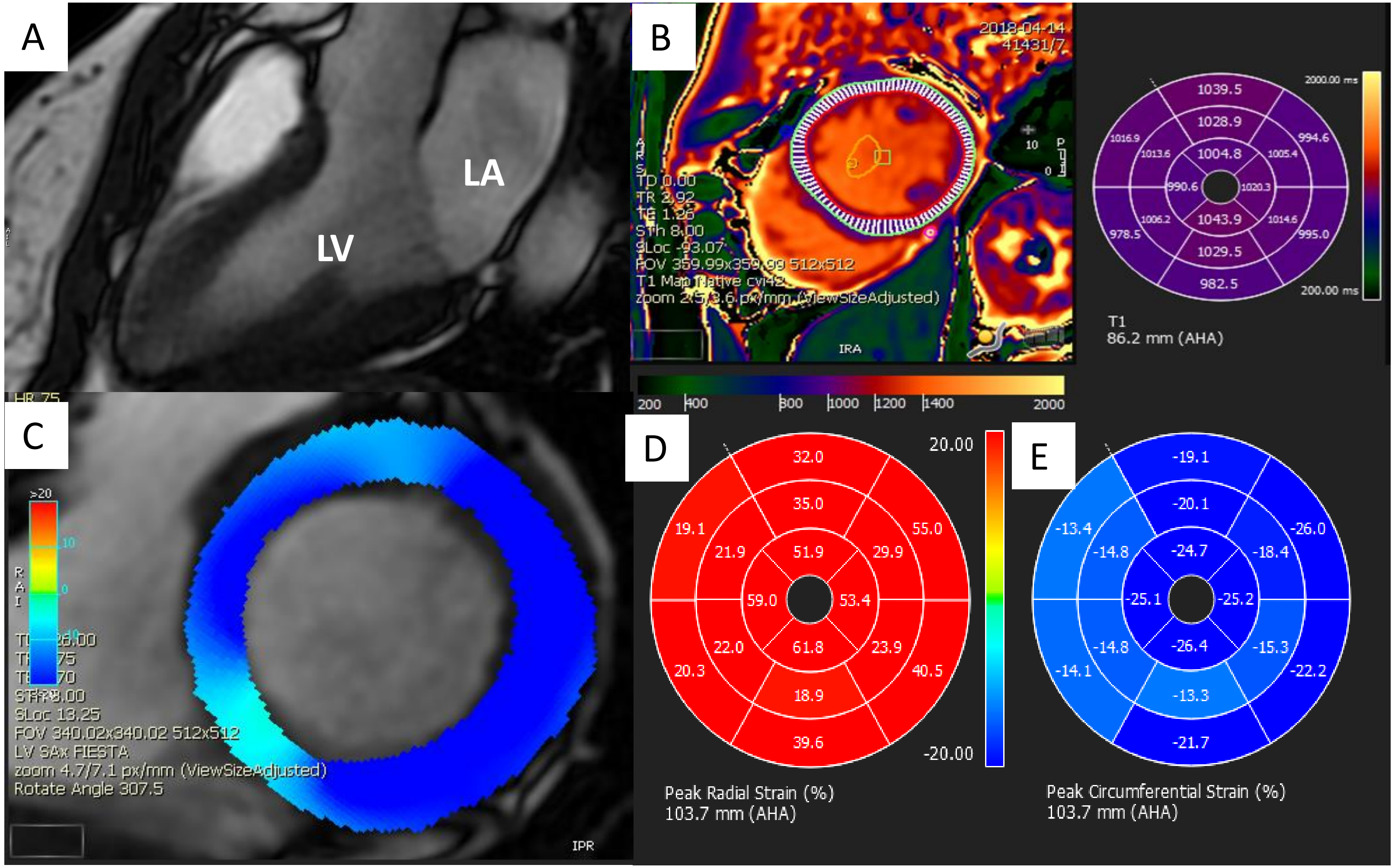
CMR for stratifying arrhythmic risk



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Guglielmo M, Pontone G, submitted

TAKE HOME MESSAGE

- **Structural heart disease** is an exciting and evolving field for CMR

- CMR could be a valid alternative to CT **pre-TAVI** in patients with severe renal insufficiency

- CMR is emerging as the gold standard technique **to quantify PAR** and to detect the **subclinical amyloidosis** with important implication in the clinical decision making workflow

- CMR can help **to grade MR in challenging cases** and it is emerging as a technique to **stratify the arrhythmic risk in MVP**

- Complementary role to angiography, echo, and CT – **multimodality imaging field**

Thank you

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Area of Cardiovascular Imaging
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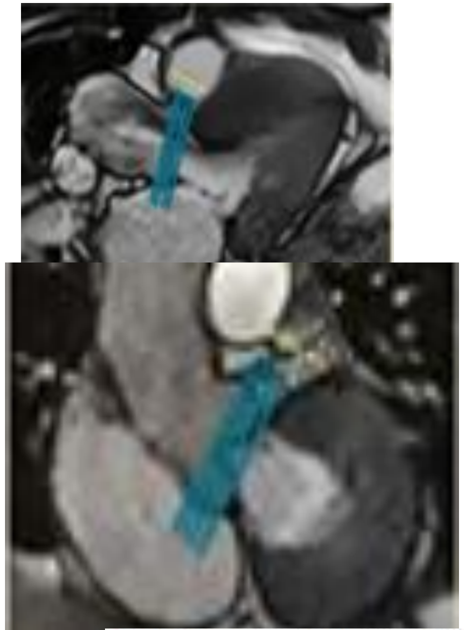
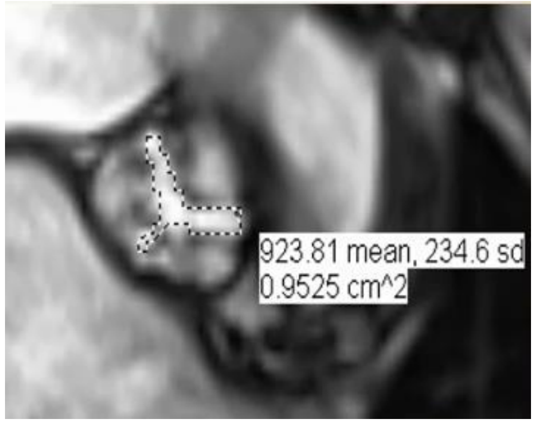
AORTIC STENOSIS
Grading aortic stenosis – valve planimetry





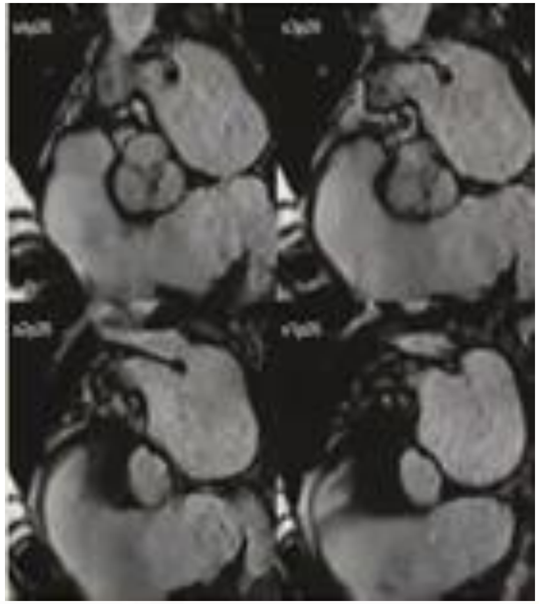


Table 2. Select Studies Validating Indices of Aortic Stenosis by CMR

First Author (Year)	Principle	Reference Standard	n	*r*	Mean Difference±1 SD (CMR−Echo)	CMR Reproducibility*: Mean Difference±1 SD
Anatomic valve area						
John[27] (2003)	planimetry‖	TEE	40	0.96	0.02±0.08 cm^2¶	0.07±0.06 cm^2‡ 0.05±0.04 cm^2#
Kupfahl[28] (2004)	planimetry	TEE	32	...	0.02±0.21 cm^2	0.03±0.05 cm^2‡ −0.02±0.06 cm^2#
Debl[29] (2005)	planimetry	TEE	25	0.86	0.13±0.16 cm^2¶	...
Reant[30] (2006)	planimetry	TEE	39	0.58	0.01±0.14 cm^2 (Echo−CMR)	0.03±0.14 cm^2‡ 0.02±0.07 cm^2#
Schlosser[31] (2007)	planimetry	TEE	32	0.82	0.15±0.13 cm^2	0.75**‡

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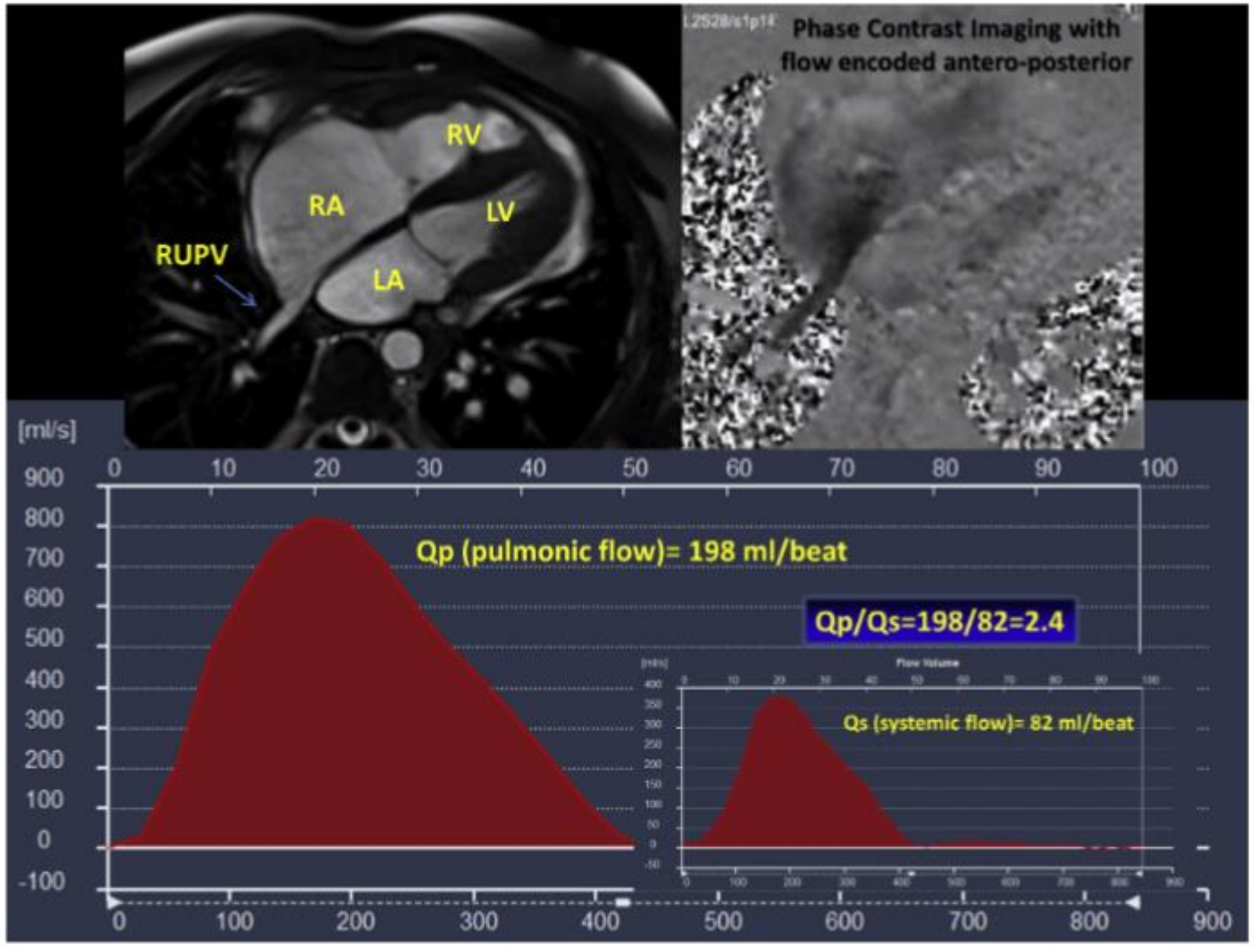
Cawley Circulation 2009

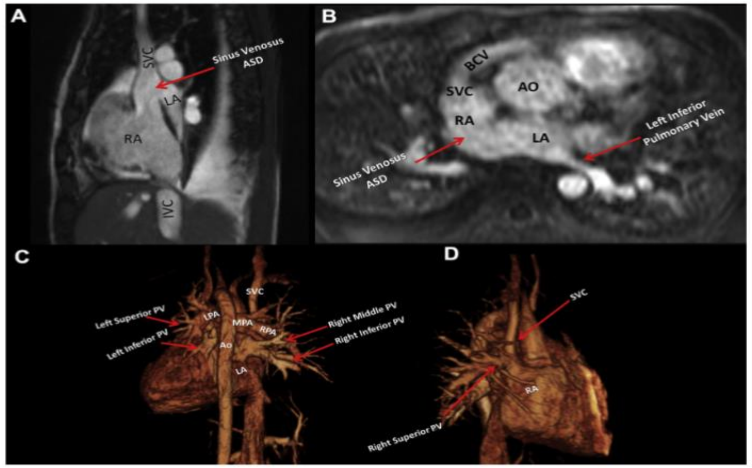
ASSESSMENT OF INTRACARDIAC SHUNTING

FIGURE 21 CMR Imaging of Patient With Remote Sinus Venosus ASD Repair Now Presenting With Right-Sided Chamber Dilation and Volume Overload



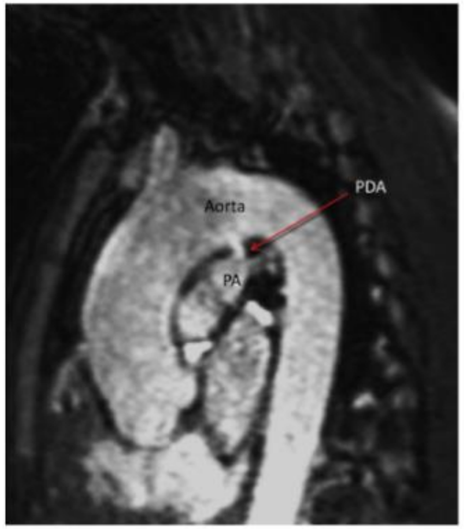
A 4-chamber in-plane breath-hold phase-contrast sequence showing anomalous right upper pulmonary vein (RUPV) drainage into the right atrium (RA) causing significant left-to-right shunting confirmed by right-sided chamber dilation as well as high pulmonic to systemic flow ratio (Qp/Qs = 2.4). LA = left atrium; LV = left ventricle; RV = right ventricle.

FIGURE 16 CMR Evaluation of a Patient With Sinus Venosus ASD



... Note the confluence of the SVC, right atrium (RA), and left
...t (ASD). **(B)** Magnetic resonance angiogram (MRA) image
...h the LA. The left inferior pulmonary vein enters the LA, but
...ormally be seen at this level. **(C)** Posterior projection of a
...n (LA). **(D)** Anterior projection of a volume rendered MRA
...is dilated at its junction with the RA (Online Video 4). AO =
... main pulmonary artery; PV = pulmonary vein; RPA = right

FIGURE 18 CMR Evaluation of a Patient With Patent Ductus Arteriosus



Sagittal reconstruction using noncontrast 3-dimensional magnetic resonance angiogram demonstrating patent ductus arteriosus (PDA) **(red arrow)** connecting the distal aortic arch (Aorta) with the left pulmonary artery (PA).

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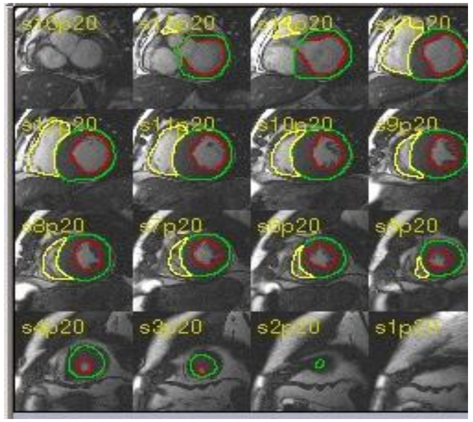
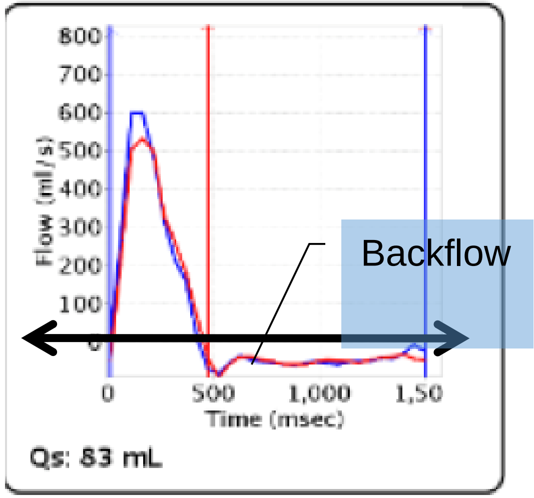
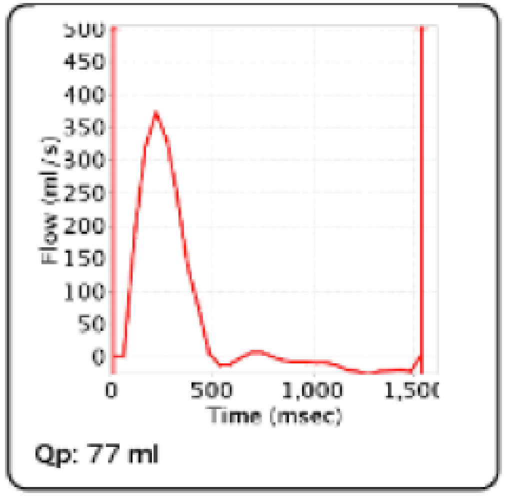
Cavalcante, JACC Card Int 2016

indirect method



STEP 1: Measurement of left stroke volume (LSV) and right stroke volume (RSV)





STEP 2: Measurement of Qs, Qp and Backflow

STEP 3: Semilunar Valve regurgitation = backflow
Atrio-ventricular Valve regurgitation = SV – Qx Backflow

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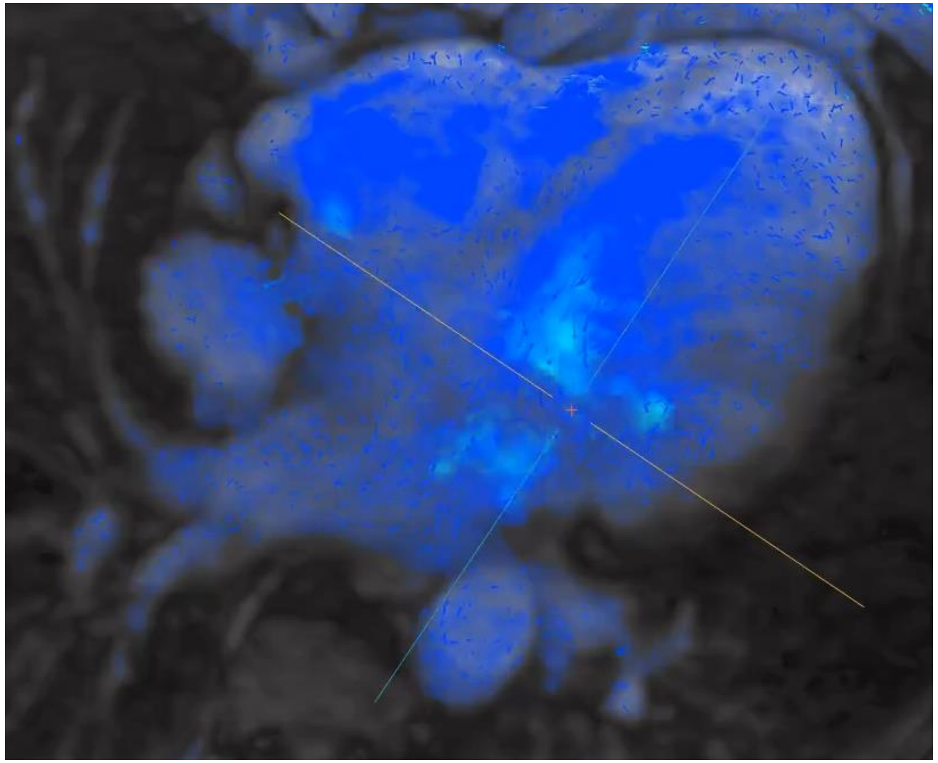
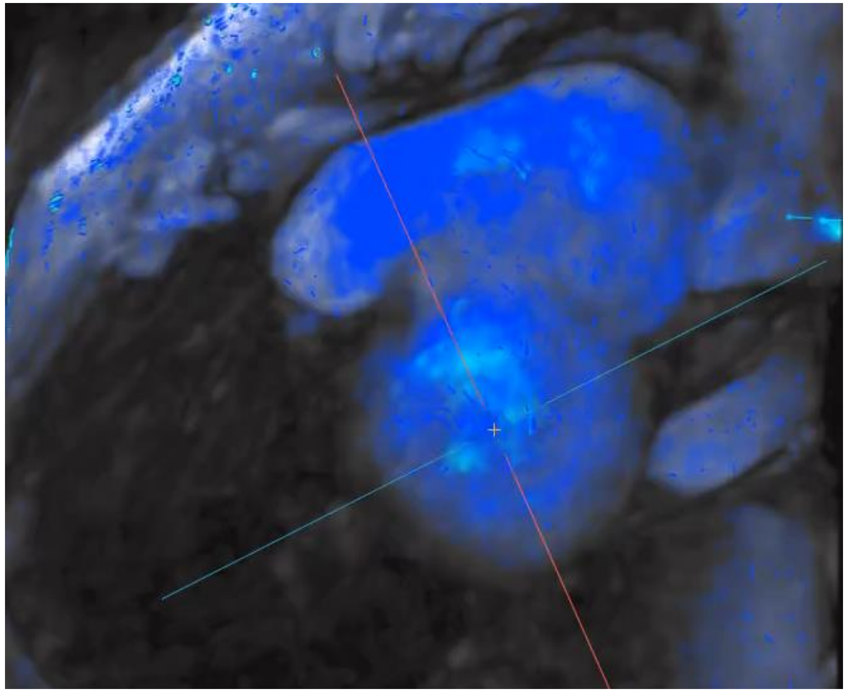
4D flow





MITRAL REGURGITATION

4D flow