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3D echo in assessment valvular regurgitation

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Faculty Disclosure

Alexandra Gonçalves

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MR Severity evaluation

 Table 3
 Grading the severity of organic mitral regurgitation

Parameters	Mild	Moderate	Severe	
Qualitative				
MV morphology	Normal/Abnormal	Normal/Abnormal	Flail lefleat/Ruptured PMs	
Colour flow MR jet	Small, central	Intermediate	Very large central jet or eccentric jet adhering, swirling and reaching the posterior wall of the l	
Flow convergence zone ^a	No or small	Intermediate	Large	
CW signal of MR jet	Faint/Parabolic	Dense/Parabolic	Dense/Triangular	
Semi-quantitative				
VC width (mm)	<3	Intermediate	\geq 7 (>8 for biplane) ^b	
Pulmonary vein flow	Systolic dominance	Systolic blunting	Systolic flow reversal ^c	
Mitral inflow	A wave dominant ^d	Variable	E wave dominant (>1.5 cm/s) ^e	
TVI mit /TVI Ao	<1	Intermediate	>1.4	
Quantitative				
EROA (mm ²)	<20	20-29; 30-39 ^f	≥40	
R Vol (mL)	< 30	30-44; 45-59 ^f	≥60	
LIV and LA size and the system	lic pulmonany processo			

European Association of Echocardiography recommendations for the assessment of valvular regurgitation. Part 2: mitral and tricuspid regurgitation (native valve disease)

+ LV and LA size and the systolic pulmonary pressure^g

AR Severity evaluation

Table 2 Grading the severity of AR

Parameters	Mild	Moderate	Severe
Qualitative			
Aortic valve morphology	Normal/Abnormal	Normal/Abnormal	Abnormal/flail/large coaptation defect
Colour flow AR jet width ^a	Small in central jets	Intermediate	Large in central jet, variable in eccentric jets
CW signal of AR jet	Incomplete/faint	Dense	Dense
Diastolic flow reversal in descending aorta	Brief, protodiastolic flow reversal	Intermediate	Holodiastolic flow reversal (end-diastolic velocity $>$ 20 cm/s)
Semi-quantitative			
VC width (mm)	<3	Intermediate	>6
Pressure half-time (ms) ^b	>500	Intermediate	<200
Quantitative			
EROA (mm ²)	<10	10–19; 20–29 ^c	≥30
R Vol (mL)	<30	30-44; 45-59 ^c	≥60
+LV size ^d			

European Association of Echocardiography recommendations for the assessment of valvular regurgitation. Part 1: aortic and pulmonary regurgitation (native valve disease) Table 4 Echocardiographic parameters used to quantify mitral regurgitation severity: recordings, advantages and limitations

Recordings Limitations Parameters Usefulness/advantages European Association of Echocardiography e or ruptured PMs are Other abnormalities are non-specific of for significant MR significant MR recommendations for the assessment of valvular Can be inaccurate for estimation of MR ise regurgitation. Part 2: mitral and tricuspid s the spatial severity on of MR jet Influenced by technical and regurgitation (native valve disease) reening test for mild haemodynamic factors vs. severe MR Underestimates eccentric jet adhering the LA wall (Coanda effect) VC width Two orthogonal planes (PT-LAX, AP-4CV) Relatively guick and easy Not valid for multiple jets · Small values; small measurement errors Optimize colour gain/scale · Relatively independent of Identify the three components of the haemodynamic and leads to large % error regurgitant jet (VC, PISA, Jet into LA) instrumentation factors Intermediate values need confirmation Reduce the colour sector size and imaging Not affected by other valve · Affected by systolic changes in depth to maximize frame rate leak regurgitant flow Expand the selected zone (Zoom) Good for extremes MR: mild Use the cine-loop to find the best frame for vs. severe · Can be used in eccentric jet measurement Measure the smallest VC (immediately distal to the regurgitant orifice, perpendicular to the direction of the jet) PISA method Apical four-chamber Can be used in eccentric jet PISA shape affected · Optimize colour flow imaging of MR Not affected by the aetiology by the aliasing velocity -· Zoom the image of the regurgitant mitral of MR or other valve leak in case of non-circular orifice valve Quantitative: estimate lesion by systolic changes in regurgitant severity (EROA) and volume Decrease the Nyquist limit (colour flow zero) flow baseline) overload (R Vol) by adjacent structures (flow With the cine mode select the best PISA Flow convergence at 50 cm/s constrainment) Display the colour off and on to visualize the alerts to significant MR PISA is more a hemi-ellipse MR orifice Errors in PISA radius measurement are Measure the PISA radius at mid-systole using squared the first aliasing and along the direction of the

- Inter-observer variability
- Not valid for multiple jets

- Measure MR peak velocity and TVI (CW)
- Calculate flow rate, EROA, R Vol

ultrasound beam

Doppler Flow across the mitral valve

Measure the mitral inflave by placing the PM/
 Ouantitative: estimate lesion

Time consuming

 Table 3
 Echocardiographic parameters used to quantify aortic regurgitation severity: recordings, advantages, and
 limitations

	Parameters	Recordings	Usefulness/Advantages	Limitations
European Assoc	Aortic valve	Echocardiography	 Flail valve is specific for significant AR 	• Other abnormalities are non-specific of significant AR
recommendation regurgitation. P regurgitation (n	ons for the art 1: aor ative valve	e assessment of valvula tic and pulmonary e disease)	Ease of use Evaluates the spatial orientation of AR jet Quick screen for AR	 Influenced by technical and haemodynamic factors Inaccurate for eccentric jet Expands unpredictably below the orifice
	VC width	 PT-LAX is preferred (apical four-chamber if not available) Optimize colour gain/scale Identify the three components of the regurgitant jet (VC, PISA, Jet into LV) Reduce the colour sector size and imaging depth to maximize frame rate Expand the selected zone (Zoom) Use the cine loop to find the best frame for measurement Measure the smallest VC (immediately distal to the regurgitant orifice, perpendicular to the direction of the jet) 	 Relatively quick and easy Relatively independent of haemodynamic and instrumentation factors Not affected by other valve leak Good for extremes AR: mild vs. severe Can be used in eccentric jet 	 Not valid for multiple jets Small values; small measurement errors lead to large % error Intermediate values need confirmation Affected by systolic changes in regurgitant flow
	PISA method	 Apical five-chamber for central jets (PT-LAX for eccentric jets) Optimize colour flow imaging of AR Zoom the image of the regurgitant aortic valve Increase the Nyquist limit in apical views/decrease or increase in PT-LAX With the cine mode select the best PISA Display the colour off and on to visualize the AR orifice Measure the PISA radius at diastole using the first aliasing and along the direction of the ultrasound beam Measure AR peak velocity and TVI (CW) Calculate flow rate, EROA, R Vol 	 Can be used in eccentric jet Quantitative: estimate lesion severity (EROA) and volume overload (R Vol) 	 PISA shape affected by the aliasing velocity in the case of non-circular orifice by systolic changes in regurgitant flow by adjacent structures (flow constrainment) PISA radius is more a hemi-ellipse Errors in PISA measurement are squared Inter-observer variability Not valid for multiple jets Feasibility limited by aortic valve calcifications
	Doppler volumetric method (PW)	 Flow across the mitral valve Measure the mitral inflow by placing the PW sample volume at the mitral annulus (apical) 	 Quantitative: estimate lesion severity (ERO) and volume overload (R Vol) 	 Time-consuming Requires multiple measurements: source of

European Association of Echocardiography recommendations for the assessment of valvular regurgitation. Part 2: mitral and tricuspid regurgitation (native valve disease)





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GUIDELINES AND STANDARDS

EAE/ASE Recommendations for Image Acquisition and Display Using Three-Dimensional Echocardiography



3DE can be a valuable tool in mitral regurgitation assessment, particularly in those patients with mitral regurgitation that is felt to be underestimated by 2D imaging <u>methods or is anatomically complex.</u>

Eur Heart J Cardiovasc Imaging. 2012

J Am Soc Echocardiogr 2012;25:3-46





GUIDELINES AND STANDARDS

EAE/ASE Recommendations for Image Acquisition and Display Using Three-Dimensional Echocardiography



Using 3DE color Doppler, the exact perpendicular plane to the aortic regurgitation jet can be identified, from which the area of the <u>vena</u> <u>contracta can be planimetred</u>; Allows visualization and measurement of <u>multiple</u> jets

Eur Heart J Cardiovasc Imaging. 2012

J Am Soc Echocardiogr 2012;25:3-46



Problems



Multiple-beat full-volume acquisition Larger data volumes, but stitching artifacts.

Live 3D color Doppler acquisition
 Not affected by stitching artifacts, limited
 by smaller color Doppler volumes and
 lower frame rates.

Eur Heart J Cardiovasc Imaging. 2012

J Am Soc Echocardiogr 2012;25:3-46



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Problems

- Limited spatial resolution of the reconstructed image problem with small regurgitant orifice area
- The choice of the systolic frame affects VCA measurement
- The multiplanar 3D-VCA is easily affected by reformatting process used to obtain the cross-sectional plane for planimetry
- The measurement can be affected by color bleeding into the grayscale image resulting in overestimation of VCA.
- Requieres expertise









Direct Assessment of Size and Shape of Noncircular Vena Contracta Area in Functional Versus Organic Mitral Regurgitation Using Real-Time Three-Dimensional Echocardiography

Philipp Kahlert, MD, Björn Plicht, MD, Ingmar M. Schenk, MD, Rolf-Alexander Janosi, MD, Raimund Erbel, MD, FACC, FESC, and Thomas Buck, MD, FACC, FESC, Essen, Germany



J Am Soc Echocardiogr 21:913-921, 2008



Full-volume Color Flow Quantification in Mitral Regurgitation

Alexandra Gonçalves, MD,^{1,2} Carla Sousa, MD,² José Alberto de Agustín, MD, PhD,¹ Pedro Marcos-Alberca, MD, PhD, FESC,¹ Covadonga Fernández-Golfín, MD¹ and José Luis Zamorano, MD, PhD, FESC¹



 $ERO = \frac{6.28 \text{ x } r^2 \text{ x aliasing velocity}}{MR \text{ peak velocity}}$

The flow convergence is not always hemispheric but rather an ellipsoid shell .

US Cardiology 2011. 8(2):94-7



-----Distance(s)------<u>Vena Contracta = 0.84</u> <u>cm</u> I ×





Gonçalves A, Zamorano JL. Update on Three Dimensional Echocardiography Current Cardiovascular Imaging Reports 2012





Quantification of Functional Mitral Regurgitation by Real-Time 3D Echocardiography





Quantification of EROA and Rvol of functional MR with 3D echocardiography is feasible and accurate as compared with VE-CMR; the currently recommended 2D echocardiographic approach significantly underestimates both EROA and Rvol.

Marsan N A et al., J Am Coll Cardiol Img 2009;2:1245–52



MR Severity

Xin Zeng et al. Circ Cardiovasc Imaging. 2011;4:506-513





Ertunc Altiok, MD^a, Sandra Hamada, MD^a, Silke van Hall^a, Mehtap Hanenberg, MD^a, Guido Dohmen, MD^b, Mohammed Almalla, MD^a, Eva Grabskaya, MD^a, Michael Becker, MD^a, Nikolaus Marx, MD^a, and Rainer Hoffmann, MD^{a,*}





Direct measurement of MR AROA correlates well with EROA by proximal convergence method and VCA. Agreement between methods is better for patients with a circular regurgitation orifice area than in patients with a noncircular regurgitation orifice area.















07/06/2011 11:38 AM

-4D-----2.8 MHz 0 dB / DR: 65 dB ----Color----CDV / 2.5 MHz 1 dB 9 / 24 100 %

4Z1c





0dB / MI: 0.64 TIS: 0.5 / TIB: 0.5

0.73 m/s

0.36 m/s





Direct Measurement of Proximal Isovelocity Surface Area by Single-Beat Three-Dimensional Color Doppler Echocardiography in Mitral Regurgitation: A Validation Study

Jose Alberto de Agustín, MD, PhD, Pedro Marcos-Alberca, MD, PhD, FESC, Covadonga Fernandez-Golfin, MD, Alexandra Gonçalves, MD, Gisela Feltes, MD, Ivan Javier Nuñez-Gil, MD, PhD, Carlos Almeria, MD, PhD, Jose Luis Rodrigo, MD, PhD, Leopoldo Perez de Isla, MD, PhD, Carlos Macaya, MD, PhD, FESC, and Jose Zamorano, MD, PhD, FESC, *Madrid, Spain*



Better correlation between 3D PISA and EROA (either when estimated by TEE planimetry or by quantitative Doppler method)



J Am Soc Echocardiogr 2012



man man



3 / MI: 0.6 0.5 / TIB: 0.5 3 m/s

7 m/s

Lingen A

4

Mitral Regurgitation

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Measurement	Current	Peak	
VolumePISA	17.89	17.89	cm2
ERO	0.99	0.99	cm2
Aliasing Velocity	0.37	0.37	m/s
Inst. Flow Rate	656.08	656.08	ml/s
Peak Regurg Vol	98.45	98.45	ml
Peak RF			%
VTI	0.99	0.99	m

20 vps 170 Cardiac Gen F

-7 dB / DR: 64 ---Colo

CDV / 2.5M

94 b ----41

2

5 /





4. 17 vps 180 Cardiac Gen F 90 b ---4 2.8M 4 dB / DR: 65 ---Colo CDV / 2.5M 1 11 / 100





Automated Quantification of Mitral Inflow and Aortic Outflow Stroke Volumes by Three-Dimensional Real-Time Volume Color-Flow Doppler Transthoracic Echocardiography: Comparison with Pulsed-Wave Doppler and Cardiac Magnetic Resonance Imaging



RT-VCFD imaging with an automated quantification algorithm is feasible, accurate, and reproducible for the measurement of mitral inflow and aortic SVs and is superior to manual 2D TTE– based measurements.

Thavendiranathan PJ et al. Am Soc Echocardiogr 2012;25:56-65





Automated Quantification of Mitral Inflow and Aortic Outflow Stroke Volumes by Three-Dimensional Real-Time Volume Color-Flow Doppler Transthoracic Echocardiography: Comparison with Pulsed-Wave Doppler and Cardiac Magnetic Resonance Imaging



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TEMP. PCTE.: 37.0C TEMP. ETE: 40.1C







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Useful parameters

Antero-posterior diameter

Commissural diameter

Total circumference

Annulus saddle height

Total mitral orifice area

Mitral annulus to aortic valve angle



The 3D approach gives the advantage of direct calculation of the leaflets angles, tenting volume, and surface of the leaflets. Echocardiography 2011;28:1125-1132





<mark>Е 8 = 132.7 *</mark>

3D echocardiography for quantification of valvular heart disease. Heart. 2013











Circulation. 2012;126:2005-2017









Assessment of Aortic Regurgitation by Live Three-Dimensional Transthoracic Echocardiographic Measurements of Vena Contracta Area: Usefulness and Validation



Live 3D TTE color Doppler measurements of VCA can be used for accurate assessment of AR and are comparable to assessment by aortography.





4Z1c 12 vps / 160 mm Cardiac / Gen Flow 67 bpm

-----4D------2.8 MHz 4 dB / DR: 65 dB ---Color---CDV / 2.5 MHz 1 dB 8 / 11 100 %





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3D color-Doppler echocardiography and chronic aortic regurgitation: A novel approach for severity assessment $\overset{\triangleleft}{\sim}$

Leopoldo Perez de Isla *, Jose Zamorano, Covadonga Fernandez-Golfin, Sara Ciocarelli, Cecilia Corros, Tibisai Sanchez, Joaquín Ferreirós, Pedro Marcos-Alberca, Carlos Almeria, Jose Luis Rodrigo, Carlos Macaya



3DCDE has the best agreement with the CMR determined CAR severity.

International Journal of Cardiology 166 (2013) 640-645





Goncalves A, et al. EuroIntervention 2010











Goncalves A, et al. J Am Soc Echocardiogr 2012



AR volume - calculated as the difference between 3D derived total LV stroke volume and RV stroke volume estimated by 2D TTE.



Goncalves A, et al. J Am Soc Echocardiogr 2012





The area under the ROC curve:

0.96 for vena contracta planimetry; 0.35 for vena contracta width





Geometric changes after tricuspid annuloplasty and predictors of residual tricuspid regurgitation: a real-time three-dimensional echocardiography study



Pre-TAP tenting volume and antero-posterior annulus diameter measured using RT3DE are independent predictors of residual TR severity,

28/07/2010 10:15

4Z1c

18 vps / 140 mm HCSC* / Flujo general FC: 79 bpm

-----4D------2,8 MHz -5 dB / CD: 65 dB ---Color---VDC / 2,5 MHz 1 dB 14 / 30 100 %



0dB / IM: 0,6 ITT 0,5 / ITO: 0,5 0,65 m/s 0,46 m/s 4 4





Conclusion

- 3DE has been establishing its role in the quantification of valvular disease.
- It increases accuracy for the assessment of MV regurgitation and AR
- There is increasing applicability in daily clinical practice with reproducible results
- Rapid evolution and software improvements are foreseen in the close future



Alexandra Gonçalves





Regarding the 3D echocardiography (3DE) image acquisition for valvular heart disease evaluation select the correct sentence:

- 1-3DE quality is independent of the intrinsic quality of the ultrasound images;
- 2- Electrocardiographic gating has never been an issue;
- 3- Full volume mode is the most appropriate for individual analysis of each heart valve;
- 4- 3D Zoom mode allows the visualization of the mitral valve either from the atrium or from the left ventricle;
- 5-3D Colour Doppler can only be acquired using 7 individual gated volumes.





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Considering the evaluation of mitral regurgitation by 3DE select the incorrect sentence:

- Dedicated software for visualization and recognition of 3D PISA surface and effective regurgitant orifice area measurement has already been launched
 According to 3DE data the vena contracta in mitral regurgitation is circular
 The axial axes is the appropriate view for 3DE yong contracts planimetry
- 3- The axial axes is the appropriate view for 3DE vena contracta planimetry
- 4-3DE presents particular interest in functional mitral regurgitation evaluation
- 5- The direct measurement of the anatomic regurgitant orifice by 3DE planimetry may be performed in selected cases.





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