The New ASE Guidelines for Native Valvular Regurgitation

William A. Zoghbi MD, FASE, MACC
Professor and Chairman, Department of Cardiology
Elkins Family Distinguished Chair in Cardiac Health

(With caveats and comments from R. Hahn)

HOUSTON Methodist DEBAKEY HEART & VASCULAR CENTER

Disclosures

Rebecca T. Hahn, MD, FASE

- Core Lab Director for multiple tricuspid device trials for which I receive no direct compensation:
  - SCOUT Trial
  - Triluminate Trial
  - Tri-Repair Trial
- Speaker: Abbott Structural, GE, Philips, Boston Scientific
- Consultant: Gore&Associates, NaviGATE, Abbott Structural, GE, Philips

ASE GUIDELINES AND STANDARDS

Recommendations for Noninvasive Evaluation of Native Valvular Regurgitation

A Report from the American Society of Echocardiography Developed in Collaboration with the Society for Cardiovascular Magnetic Resonance

William A. Zoghbi, MD, FASE (Chair), David Adams, RCS, RDCS, FASE, Robert O. Bonow, MD, Maurice Enriquez-Sarano, MD, Elyse Foster, MD, FASE, Paul A. Grayburn, MD, FASE, Rebecca T. Hahn, MD, FASE, Yuchi Han, MD, MMSc,* Judy Hung, MD, FASE, Roberto M. Lang, MD, FASE, Stephen H. Little, MD, FASE, Dipan J. Shah, MD, MMSc,* Stanton Shernan, MD, FASE, Paaladinesh Thavendiranathan, MD, MSc, FASE,* James D. Thomas, MD, FASE, and Neil J. Weissman, MD, FASE, *Houston and Dallas, Texas; Durham, North Carolina; Chicago, Illinois; Rochester, Minnesota; San Francisco, California; New York, New York; Philadelphia, Pennsylvania; Boston Massachusetts; Toronto, Ontario, Canada; and Washington, DC*

J Am Soc Echocardiogr. 2017 Apr;30(4):303-371

New ASE Valvular Regurgitation Guidelines- *Endorsed by SCMR*

What is New?

- Emphasis on identification of Etiology/Mechanism of regurgitation
- 2D/3D TTE--an integrative approach & algorithms to assess severity
- When is TEE needed
- Important role of CMR & CMR methodology
- The challenge of co-existing valvular lesions
- A clinical perspective…
- Library of case studies on the web

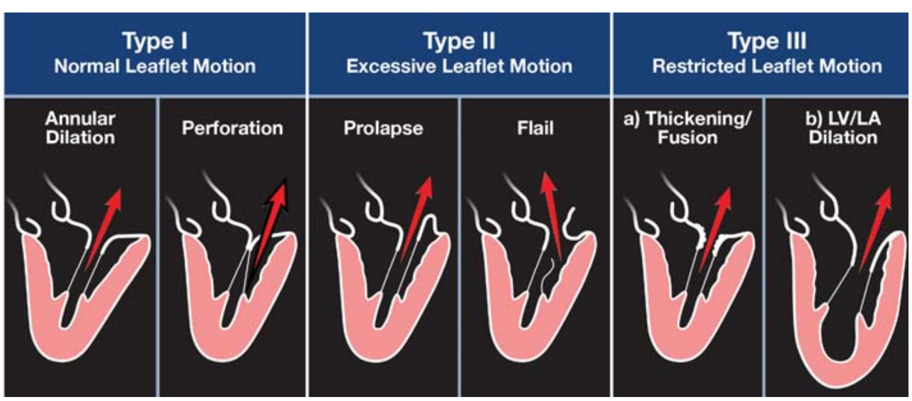
Mitral Regurgitation

Indicators of Severity

- Mitral valve pathology
- LV/ LA size
- Color Doppler:
  Vena contracta, Jet Area, Flow convergence
- Mitral E; Pulmonary vein pattern
- Regurgitant flow/fraction
- CW density and contour

Anatomy → Color Flow → Pulsed Doppler → CW Doppler

Carpentier Classification of Mechanisms of MV Regurgitation



Zoghbi W et al JASE March 2017

3D Echocardiography- MV

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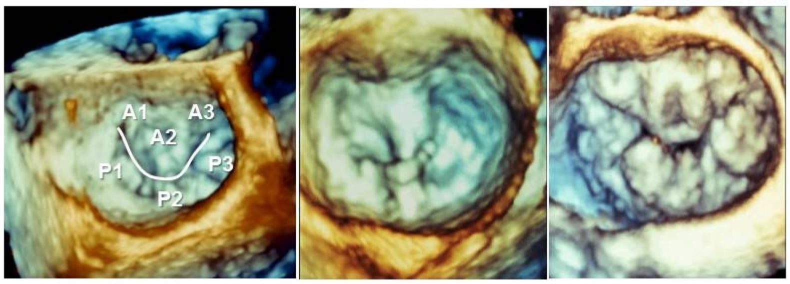
Normal | Fibroelastic Deficiency | Barlow's Disease



Zoghbi W et al JASE March 2017

Grading of Mitral Regurgitation

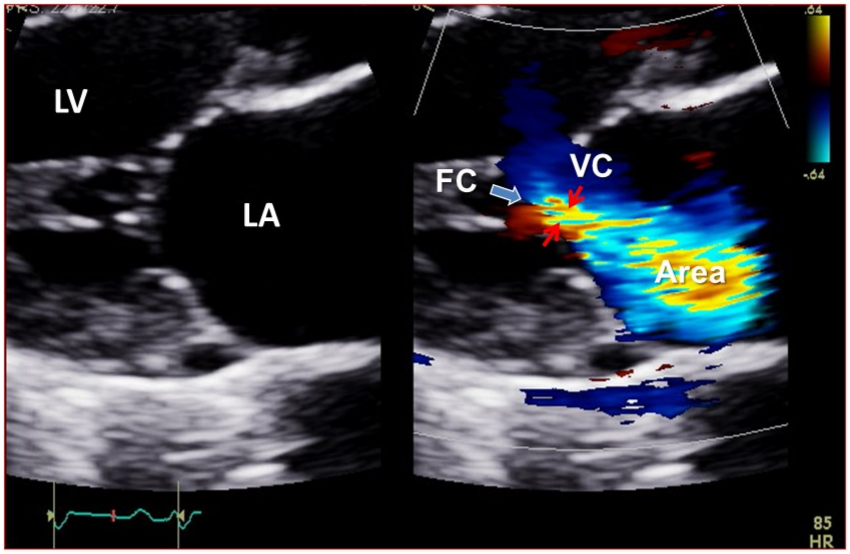
Grading the Severity of Chronic MR by Echocardiography[1]

Parameters	Mild	Moderate		Severe
Structural				
MV Morphology	**None or mild leaflet abnormality** (e.g., mild thickening, calcifications or prolapse, mild tenting)	Moderate leaflet abnormality or moderate tenting		**Severe valve lesions** (primary: flail leaflet, ruptured papillary muscle, severe retraction, large perforation; secondary: severe tenting, poor leaf coaptation)
LV and LA size[2]	Usually normal	Normal or mildly dilated		Dilated[3]
Qualitative Doppler				
Color flow jet area[4]	**Small, central, narrow, often brief**	Variable		Large central jet (>50% of LA) or eccentric wall-impinging jet of variable size
Flow convergence[5]	**Not visible, transient or small**	Intermediate in size and duration		**Large throughout systole**
CWD jet	Faint/partial/parabolic	Dense but partial or parabolic		Holosystolic/dense/triangular
Semiquantitative				
VCW (cm)	<0.3	Intermediate		≥0.7 (>0.8 for biplane)[6]
Pulmonary vein flow[7]	**Systolic dominance** (may be blunted in LV dysfunction or AF)	Normal or systolic blunting[8]		Minimal to no systolic flow/ **systolic flow reversal**
Mitral inflow[9]	**A-wave dominant**	Variable		E-wave dominant (>1.2m/sec)
Quantitative[10,11]				
EROA, 2D PISA (cm^2)	<0.20	0.20-0.29	0.30-0.39	≥0.40 (may be lower in secondary MR with elliptical regurgitant orifice area)
RVol (mL)	<30	30-44	45-59[10]	≥60 (may be lower in low flow conditions)
RF	<30%	30-39%	40-49%	≥50%

1. Bolded signs are considered specific for their MR grade. All parameters have limitations, and an integrated approach must be used that weighs the strength of each echocardiographic measurement. All signs and measures should be interpreted in an individualized manner that accounts for body size, sex, and all other patient characteristics.
2. This pertains mostly to patients with primary MR.
3. LV and LA can be within the "normal" range for patients with acute severe MR or with chronic severe MR who have a small body size, particularly women, or with small LV size preceding the occurence of MR.
4. With Nyquist limit of 50-70 cm/sec.
5. Small flow convergence is usually <0.3 cm, and large is ≥ 1 cm at a Nyquist limit of 30-40 cm/s.
6. For average between apical two- and four- chamber views.
7. Not valid with jets directed into the pulmonary vein.
8. Systolic blunting is non-specific for mitral regurgitation.
9. Most valid in patients >50 years old and is influenced by other causes of elevated LA pressure.
10. Discrepancies among EROA, RF, and RVol may arise in the setting of low or high flow states.
11. Quantitative parameters can help subclassify the moderate regurgitation group.

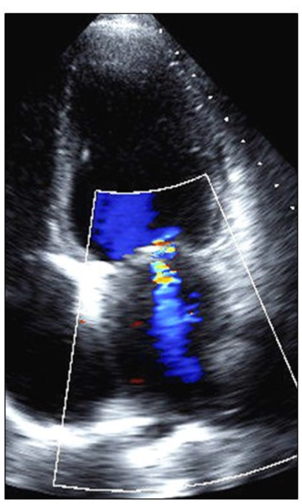
Zoghbi WA et al. J Am Soc Echocardiogr 2017; 30: 303-371.

Mitral Regurgitation- Color Doppler
3 Components of the Jet

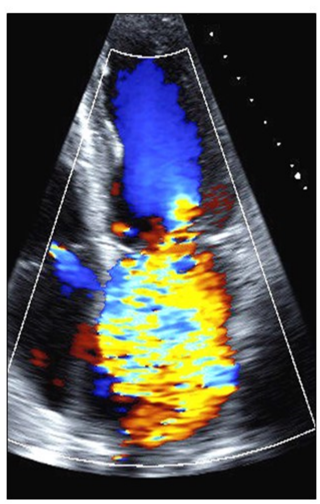


Mitral Regurgitation

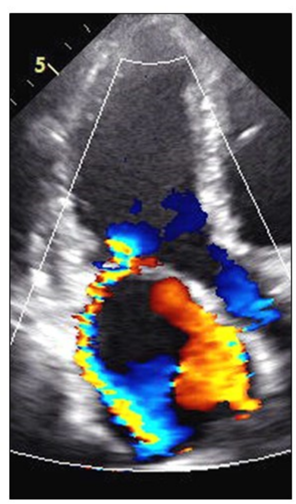
Mild Central



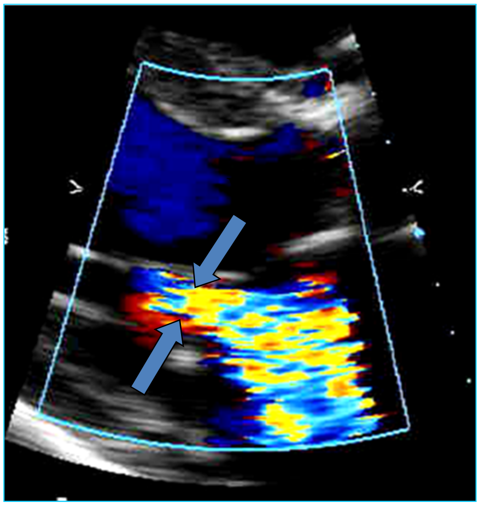
Severe Central



Severe Eccentric



Vena Contracta
Proximal Jet Width

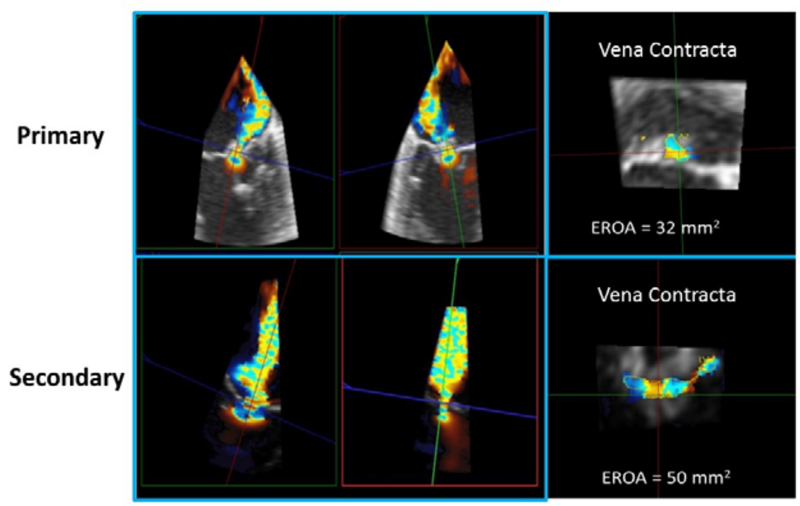


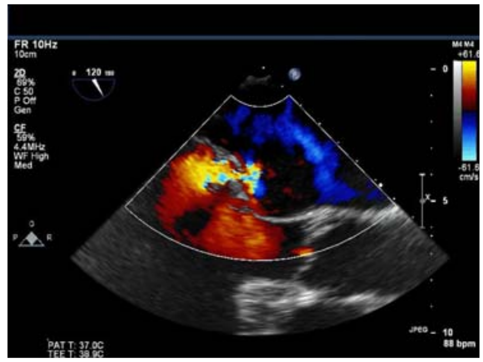
VC width (cm)

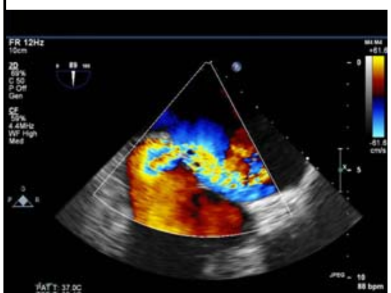
Mild	< 0.3
Moderate	0.3-0.7
Severe	> 0.7

3D Echocardiography in MR
Assessing VC Area

VC Area is often not circular in Secondary MR







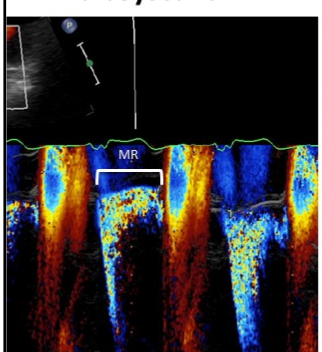
Flow Convergence

- Can be used semi-quantitatively
- Assumptions of hemispheric geometry
- Less accurate in eccentric jets
- Variability during the cardiac cycle and limitations in non-holosystolic MR

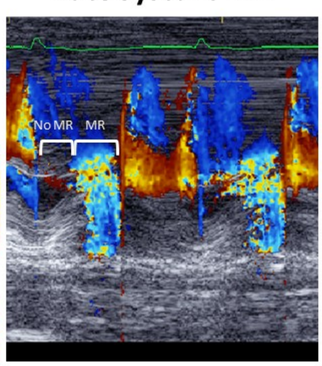
MR is not always Holosystolic

MR Duration Needs to be Accounted for

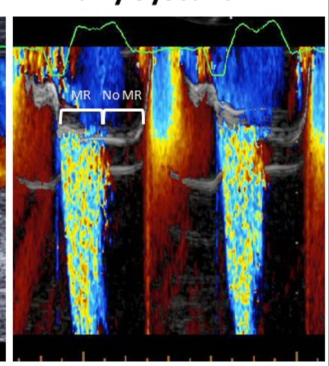
Holosystolic MR



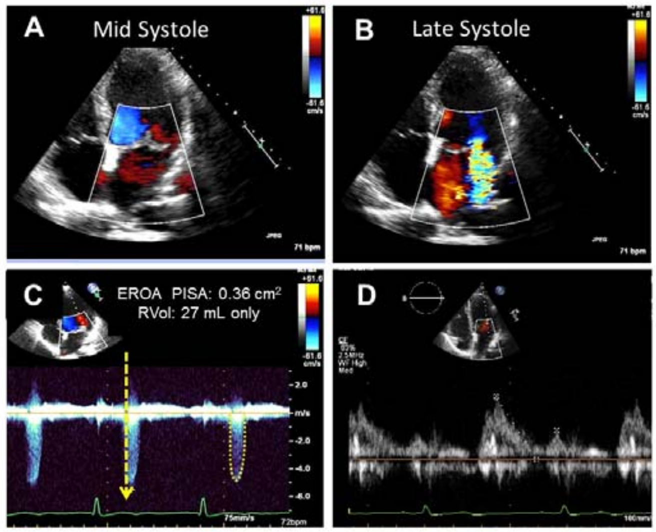
Late Systolic MR



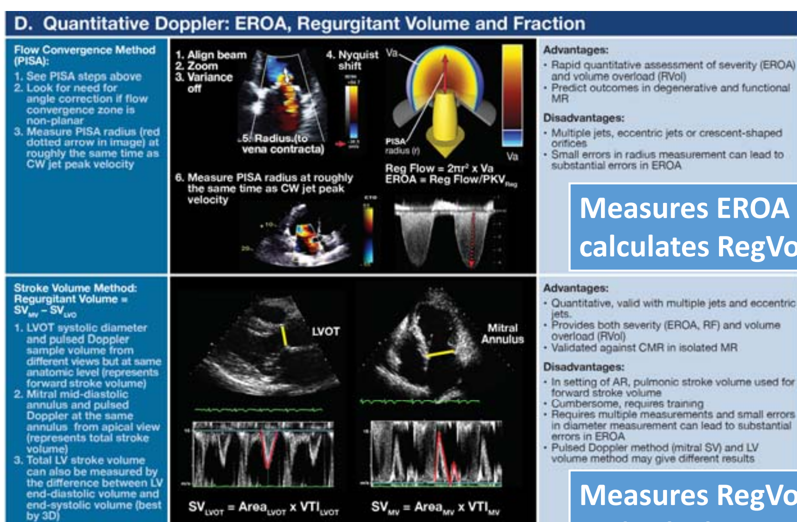
Early Systolic MR



Late Systolic MR



Quantitation of MR



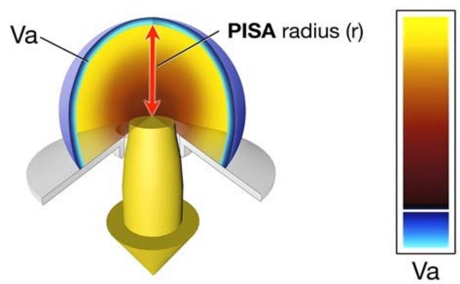
Measures EROA and calculates RegVol

Measures RegVol and calculates EROA

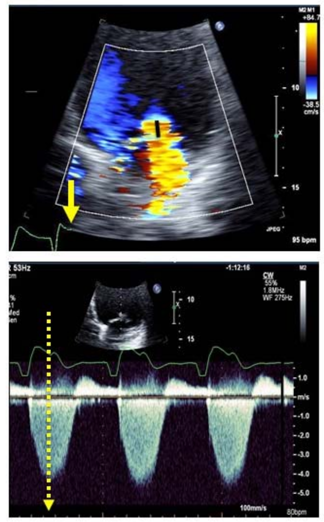
Zoghbi WA et al. J Am Soc Echocardiogr 2017; 30: 303-371.

Flow Convergence (PISA)

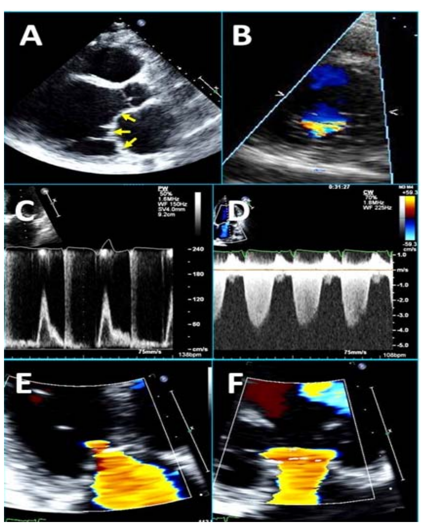
Flow Convergence Method



$$\text{Reg Flow} = 2\pi r^2 \times Va$$
$$\text{EROA} = \text{Reg Flow}/PKV_{Reg}$$
$$\text{R Vol} = \text{EROA} \times VTI_{Reg}$$



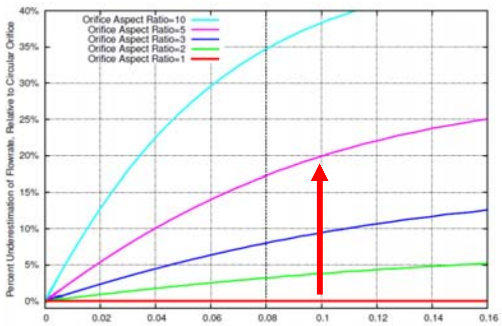
Secondary Mitral Regurgitation



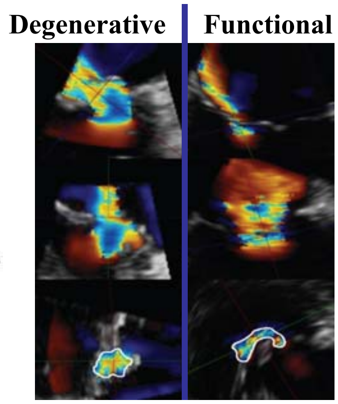
Assumptions of PISA

1. Flat Surface
2. Round Hole
3. No temporal variability
4. Hemispheric Flow Convergence

Secondary MR: Crescent-shaped Orifices

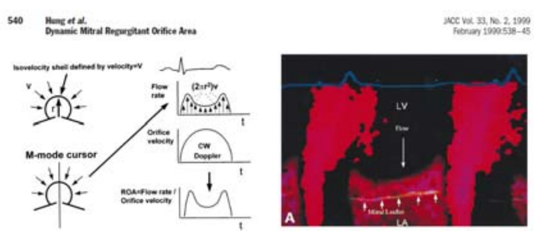


Courtesy of James Thomas, MD



Functional MR is particularly difficult to quantify!

Dynamic Nature of FMR

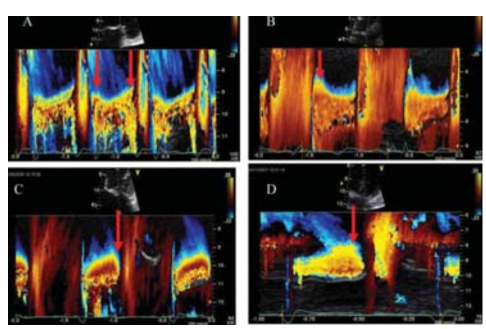


Early and Late systolic peak in flow and orifice area

Hung J et al. JACC 1999;33(2);538-45

<u>Dynamic PISA</u>

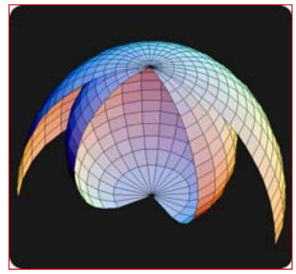
A. FMR: early and Late peaks
B. FMR: early peak
C. Rheumatic: Late peak
D. Organic: late peak

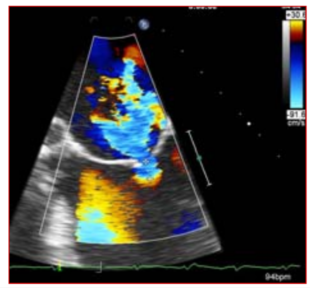


Lancellotti et al. Eur J Echocardiogr 2010;11:307-332

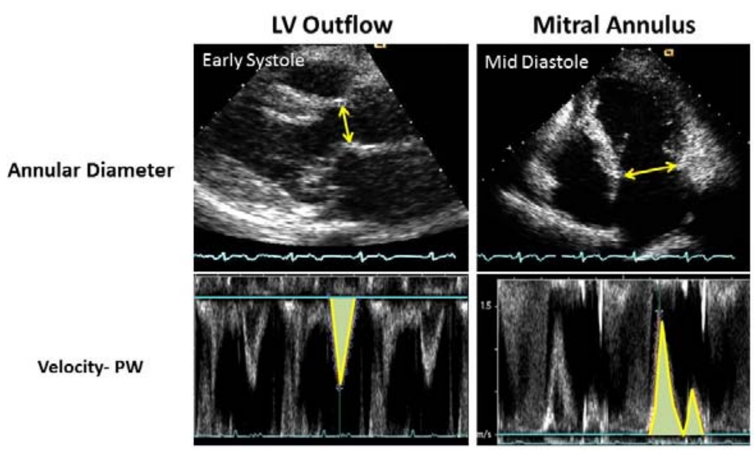
PISA Assumes a hemispheric flow convergence

- Assumptions
  - The regurgitant orifice is a “pinhole”
  - Flow approaches a flat surface
  - The regurgitant orifice is circular
  - The isovelocity shells are hemispheres
- Other theoretical pitfalls:
  - Doppler echocardiography measures not speed but velocity which is dependent on the cosine of the angle between the probe and the direction of flow.





Pulsed Doppler Volumetric Quantitation



$SV_{LVOT} = CSA_{LVOT} * VTI_{LVOT}$
$= 0.785 * d^2_{LVOT} * VTI_{LVOT}$

$SV_{MV} = CSA_{MV} * VTI_{MV}$
$= 0.785 * d^2_{MV} * VTI_{MV}$

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Effective Orifice Regurgitant Area & Regurgitant Volume

	Mild	Moderate		Severe
EROA (cm^2)	< 0.2	0.20-0.29	0.30-0.39	≥ 0.4
RVol (mL/beat)	< 30	30-44	45-59	≥ 60
RFraction	<30	30-39	40-49	≥ 50%

EROA cut-offs in 1ary and 2nd MR are similar
RVol may be lower in 2nd MR

Mitral Regurgitation
Indicators of Severity

- Mitral valve pathology
- LV/ LA size
- Color Doppler:
  Vena contracta, Jet Area, Flow convergence
- Mitral E; Pulmonary vein pattern
- Regurgitant flow/fraction
- CW density and contour

Anatomy → Color Flow → Pulsed Doppler → CW Doppler

Regurgitant Volume & Fraction

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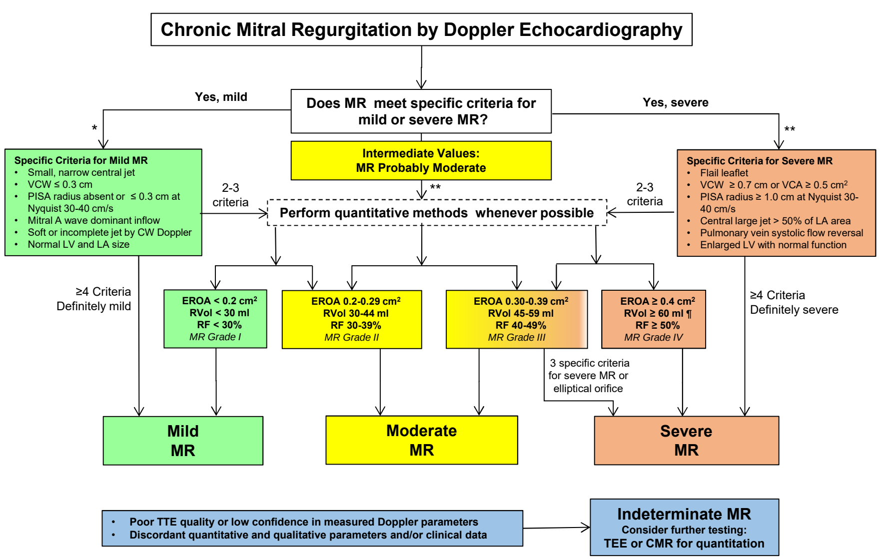
Advantages

- Quantitative, valid in multiple jets and eccentric jets
- Provides both lesion severity and volume overload

Limitations

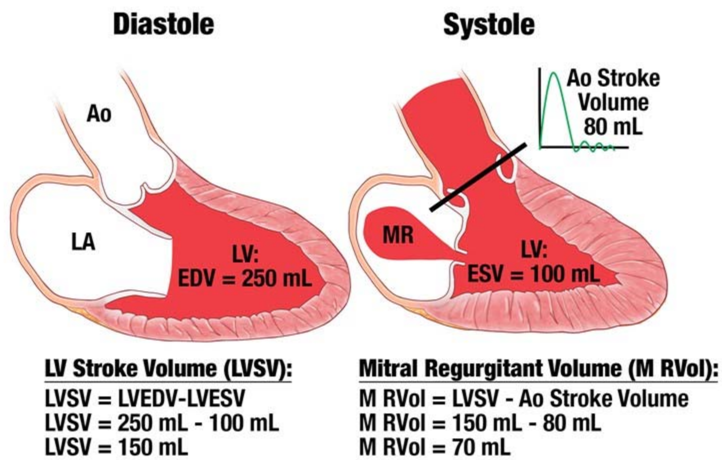
- Needs training; Cumbersome; wide (20%) confidence limits

- Measurement of flow at MV annulus is less reliable in calcific MV and/or annulus



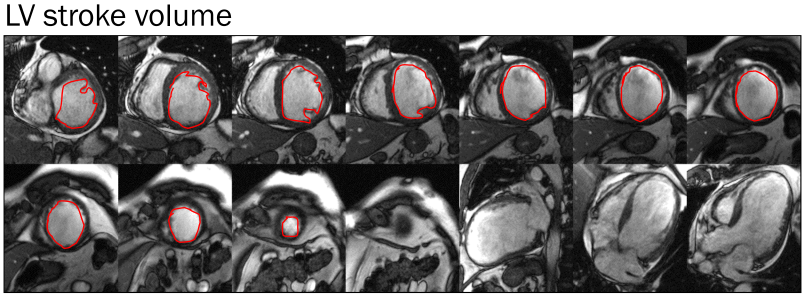
*	Beware of underestimation of MR severity in eccentric, wall impinging jets; quantitation is advised
**	All values for EROA by PISA assume holosystolic MR; single frame EROA by PISA, VCW, and VCA overestimate non-holosystolic MR
¶	Regurgitant volume for severe MR may be lower in low flow conditions.

Quantitation of MR with CMR

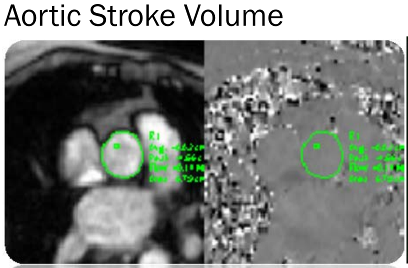


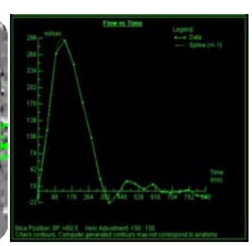
Quantification of MR with CMR

LV stroke volume



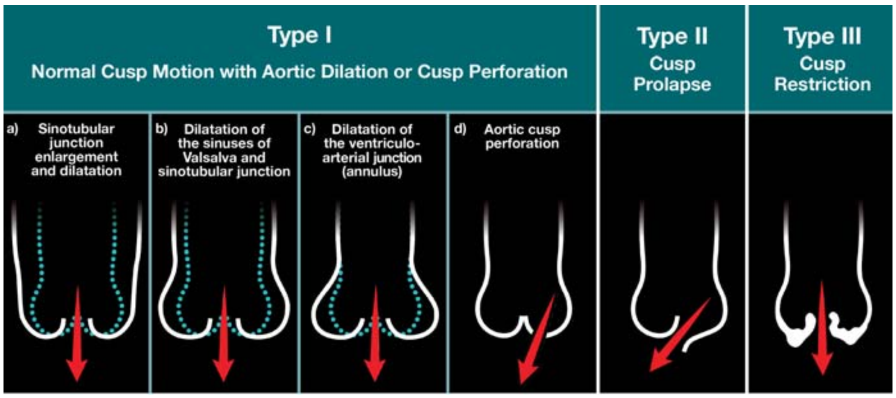
Aortic Stroke Volume



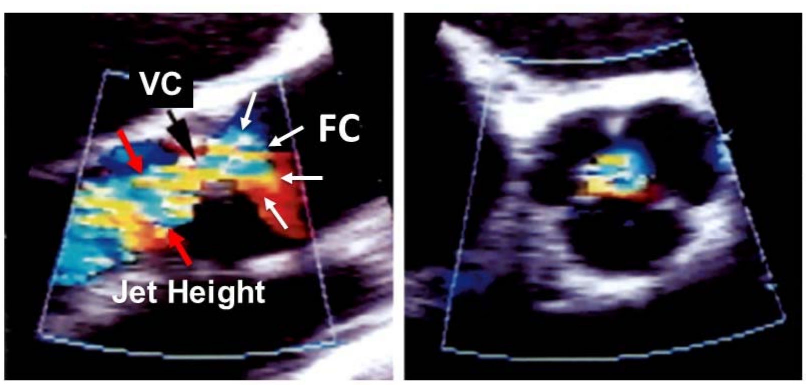


Reg Volume =
LV SV- Ao SV

Aortic Regurgitation



Aortic Regurgitation- Color Doppler



Integrative Approach to AR

- Integrative approach should be used
  - Supportive data
    - LV/LA size
    - PHT >500
  - Specific Data (>90% Sp)
    - Reversal of flow in the aorta (EDVel >20 cm/s)
    - Vena contracta > 0.6 cm
    - % LVOT ≥ 65%
  - Quantitative Data: 2D **and 3D**
    - Regurgitant Volume
    - Regurgitant Fraction
    - EROA

Attempt to understand discrepant measurements!

Aortic Regurgitation

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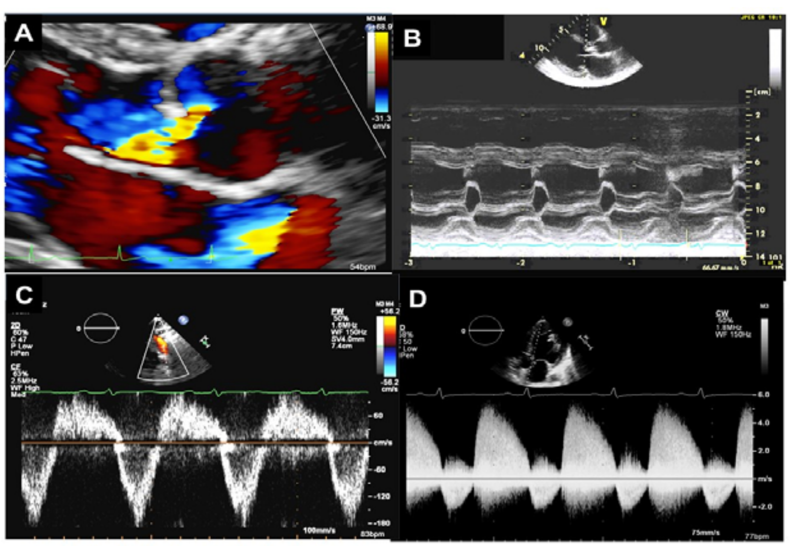

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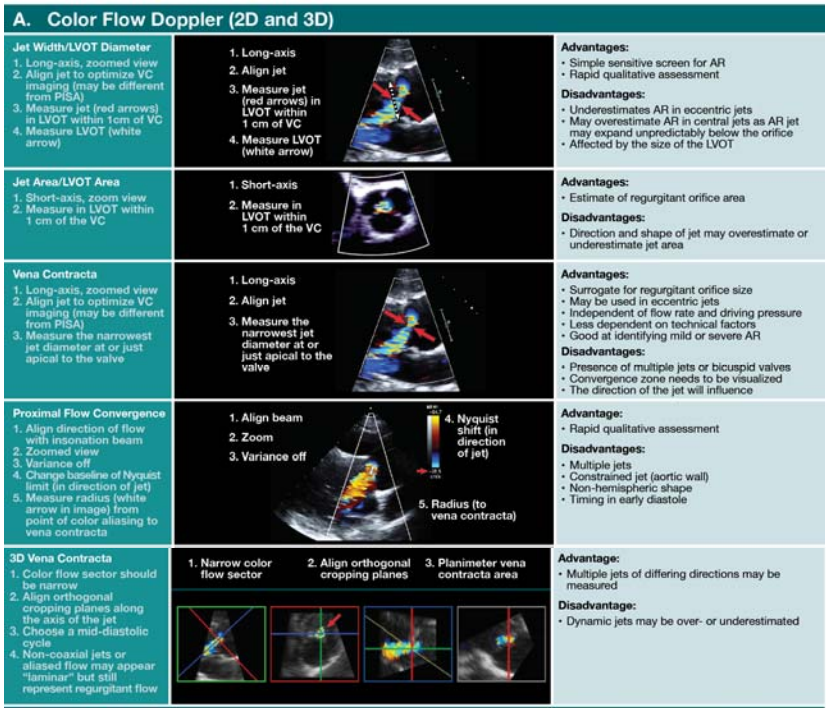
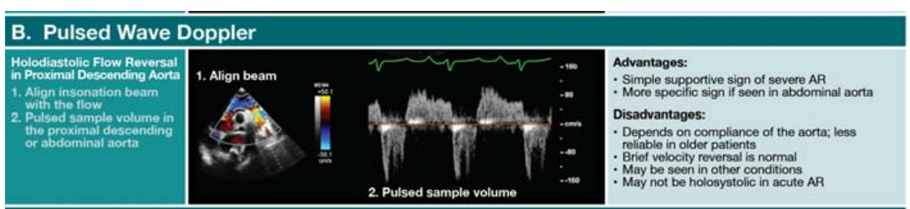




- Aortic compliance
  - The aortic reverse/forward flow ratio (35±10%) was positively associated with parameters of aortic stiffness

Holodiastolic and rapid flow reversal can occur in elderly patients with stiff aorta, even in the absence of significant AR

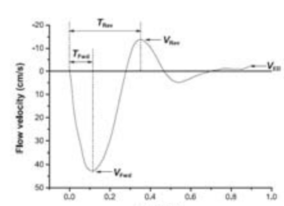
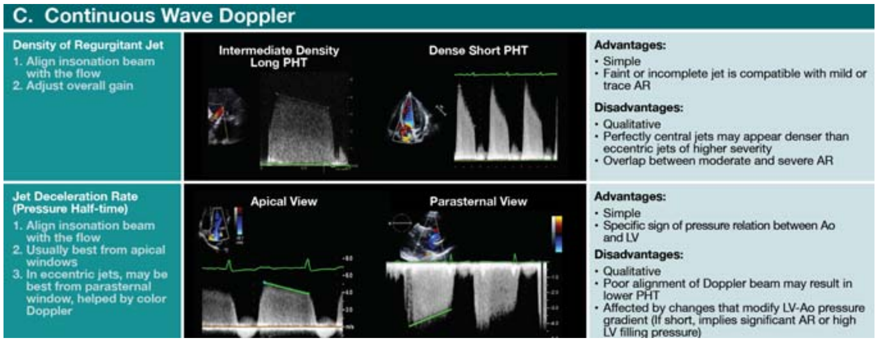
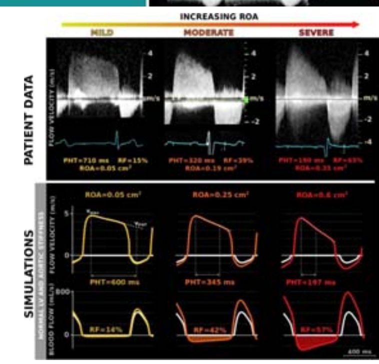


Figure 1. Representative example of ensemble-averaged descending aortic flow velocity pulse waveform. Reverse/forward flow ratio (R/F ratio) was calculated as follows: R/F ratio = $|V_{Rev}|/|V_{Fwd}| \times 100$ (%). T_{Fwd} indicates forward (downward) peak time; T_{Rev}, reverse (upward) peak time; V_{Fwd}, systolic forward peak velocity; V_{Rev}, reverse peak velocity; and V_{ED}, end-diastolic velocity.

Hashimoto,H and Ito, S. ***Hypertension*. 2013;62:542-549**





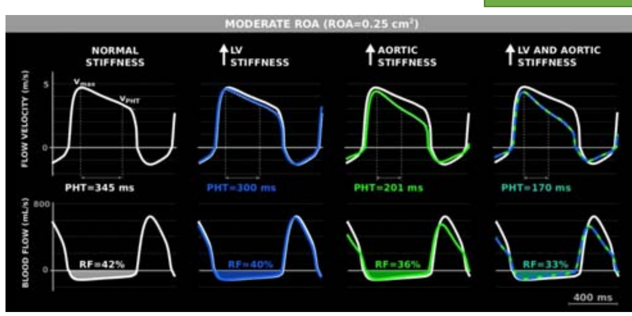
RF ↑ as PHT ↓

CircAdapt computational model of the human cardiovascular system

Palau-Caballero G et al. J Am Soc Echocardiogr 2016 Nov;29(11):1122-1130

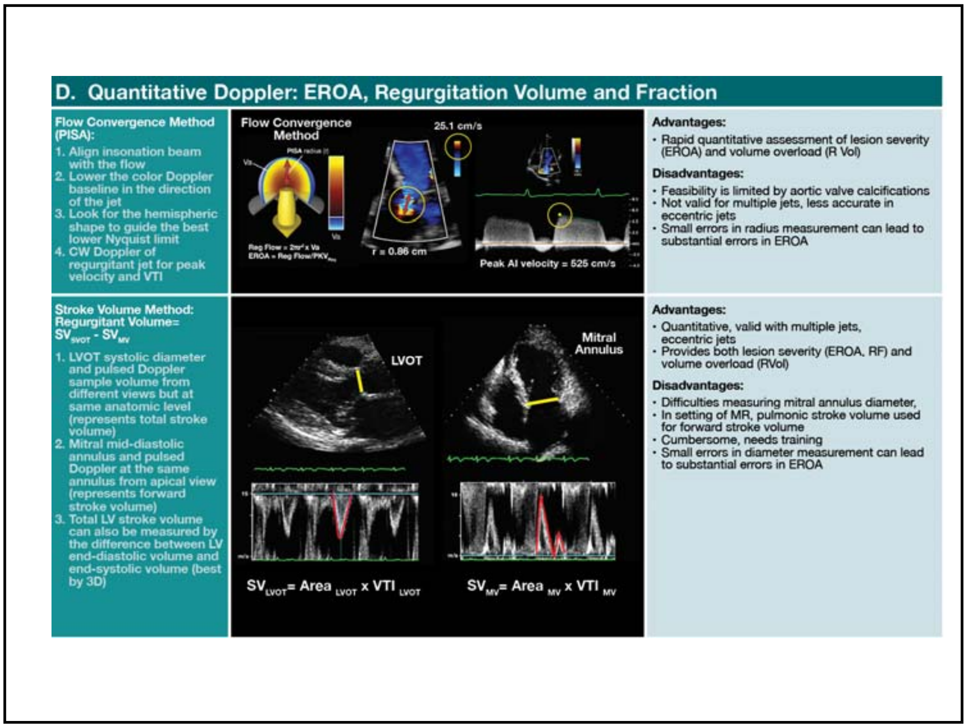
LV Stiffness and PHT

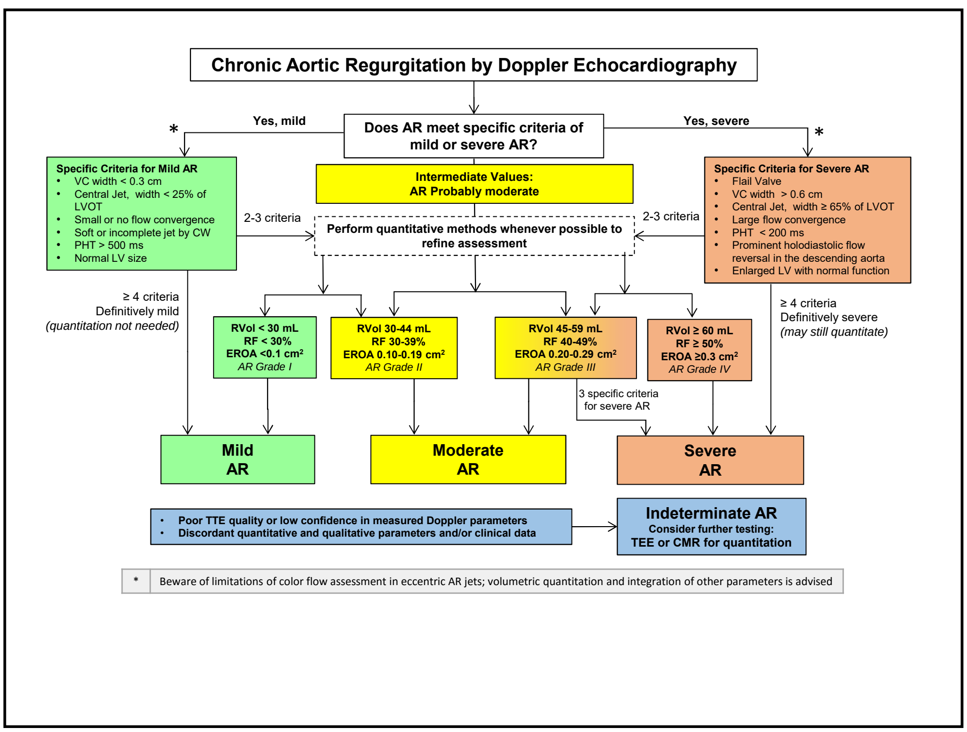
RF ↓ as PHT ↓



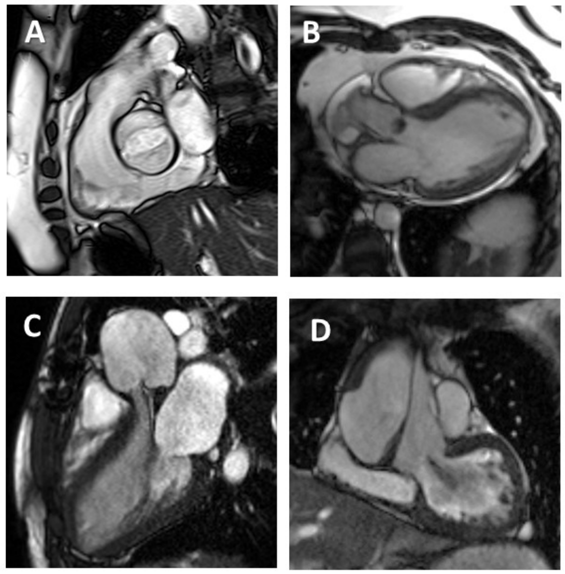
- Inconsistent AR severity scores can result from variations in ventricular and aortic stiffness.
  - A more **rapid decay** in the diastolic transvalvular pressure gradient **due to ventricular or aortic stiffening** can lead to overestimation of AR severity by PHT.

Palau-Caballero G et al. J Am Soc Echocardiogr 2016 Nov;29(11):1122-1130

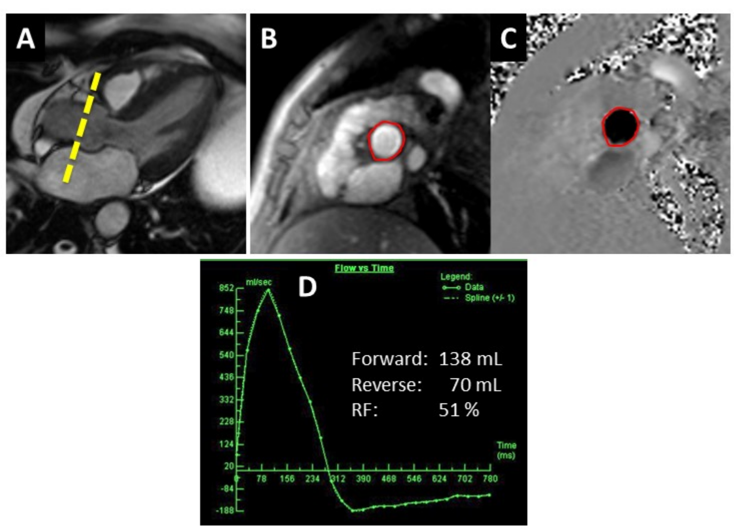

D. Quantitative Doppler: EROA, Regurgitation Volume and Fraction
Flow Convergence Method (PISA):
1. Align insonation beam with the flow
2. Lower the color Doppler baseline in the direction of the jet
3. Look for the hemispheric shape to guide the best lower Nyquist limit
4. CW Doppler of regurgitant jet for peak velocity and VTI
Flow Convergence Method
25.1 cm/s
r = 0.86 cm
Peak AI velocity = 525 cm/s
Advantages:
• Rapid quantitative assessment of lesion severity (EROA) and volume overload (R Vol)
Disadvantages:
• Feasibility is limited by aortic valve calcifications
• Not valid for multiple jets, less accurate in eccentric jets
• Small errors in radius measurement can lead to substantial errors in EROA
Stroke Volume Method: Regurgitant Volume= SVLVOT - SVMV
1. LVOT systolic diameter and pulsed Doppler sample volume from different views but at same anatomic level (represents total stroke volume)
2. Mitral mid-diastolic annulus and pulsed Doppler at the same annulus from apical view (represents forward stroke volume)
3. Total LV stroke volume can also be measured by the difference between LV end-diastolic volume and end-systolic volume (best by 3D)
LVOT
Mitral Annulus
SVLVOT= Area LVOT x VTI LVOT
SVMV= Area MV x VTI MV
Advantages:
• Quantitative, valid with multiple jets, eccentric jets
• Provides both lesion severity (EROA, RF) and volume overload (RVol)
Disadvantages:
• Difficulties measuring mitral annulus diameter,
• In setting of MR, pulmonic stroke volume used for forward stroke volume
• Cumbersome, needs training
• Small errors in diameter measurement can lead to substantial errors in EROA


Chronic Aortic Regurgitation by Doppler Echocardiography
Does AR meet specific criteria of mild or severe AR?
Yes, mild
Yes, severe
*
*
Specific Criteria for Mild AR
• VC width < 0.3 cm
• Central Jet, width < 25% of LVOT
• Small or no flow convergence
• Soft or incomplete jet by CW
• PHT > 500 ms
• Normal LV size
Intermediate Values: AR Probably moderate
Specific Criteria for Severe AR
• Flail Valve
• VC width > 0.6 cm
• Central Jet, width ≥ 65% of LVOT
• Large flow convergence
• PHT < 200 ms
• Prominent holodiastolic flow reversal in the descending aorta
• Enlarged LV with normal function
2-3 criteria
2-3 criteria
Perform quantitative methods whenever possible to refine assessment
≥ 4 criteria
Definitively mild
(quantitation not needed)
RVol < 30 mL
RF < 30%
EROA <0.1 cm²
AR Grade I
RVol 30-44 mL
RF 30-39%
EROA 0.10-0.19 cm²
AR Grade II
RVol 45-59 mL
RF 40-49%
EROA 0.20-0.29 cm²
AR Grade III
RVol ≥ 60 mL
RF ≥ 50%
EROA ≥0.3 cm²
AR Grade IV
≥ 4 criteria
Definitively severe
(may still quantitate)
3 specific criteria for severe AR
Mild AR
Moderate AR
Severe AR
• Poor TTE quality or low confidence in measured Doppler parameters
• Discordant quantitative and qualitative parameters and/or clinical data
Indeterminate AR
Consider further testing:
TEE or CMR for quantitation
* Beware of limitations of color flow assessment in eccentric AR jets; volumetric quantitation and integration of other parameters is advised

CMR in Aortic Regurgitation



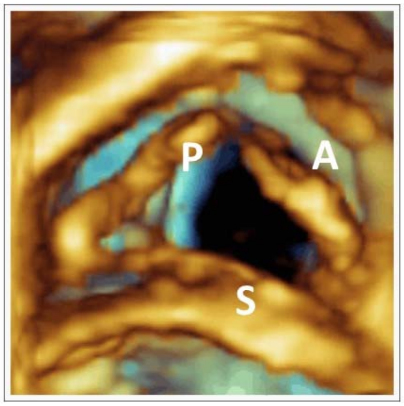
Quantitation of AR with CMR

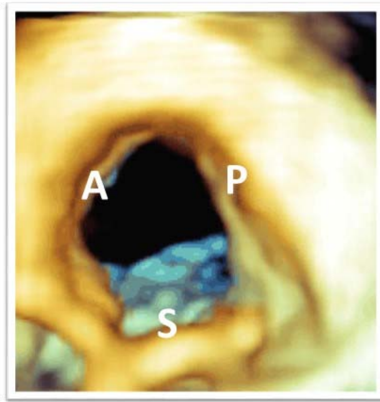


Tricuspid Valve Regurgitation

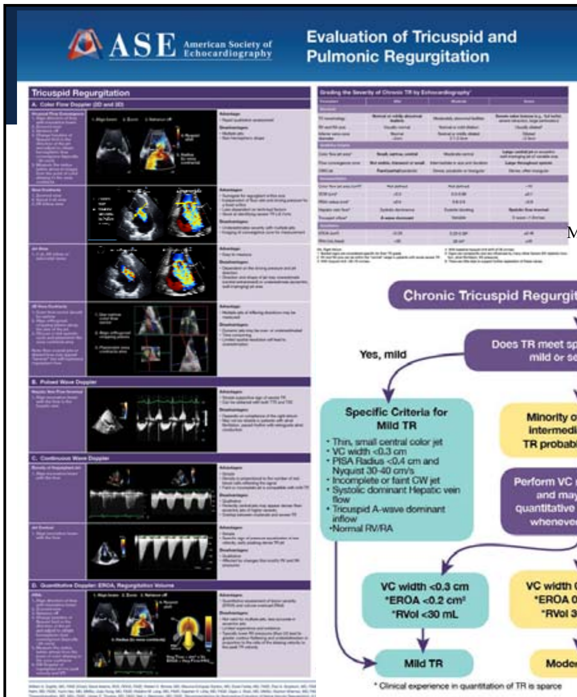
Tricuspid Valve

Ventricular perspective **Atrial perspective**

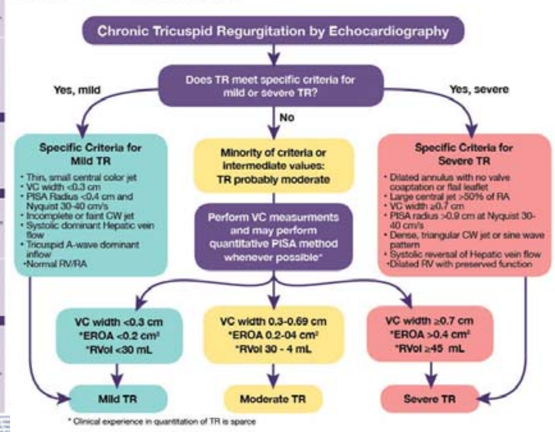




Tricuspid Valve Regurgitation

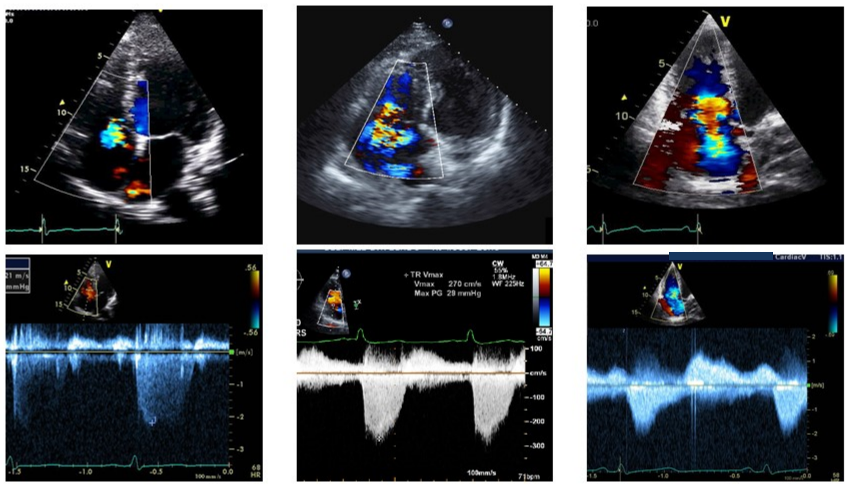


Zoghbi et al J Am Soc Echocardiogr April 2017 http://dx.doi.org/10.1016/j.echo.2017.01.007

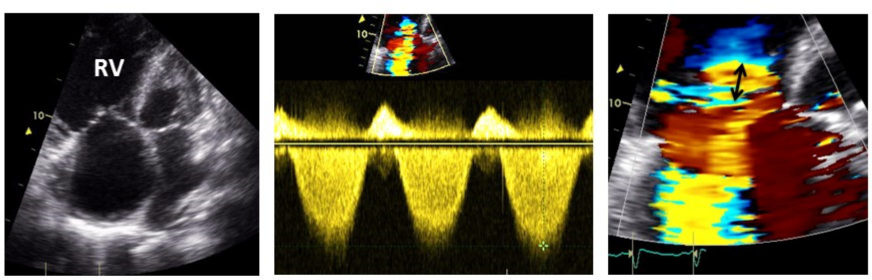


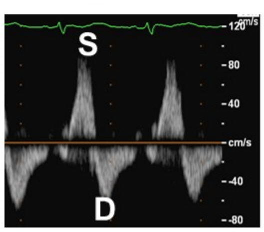
The Spectrum of Tricuspid Regurgitation

Mild TR | **Severe Eccentric TR** | **Severe Central TR**



PISA in Tricuspid Regurgitation



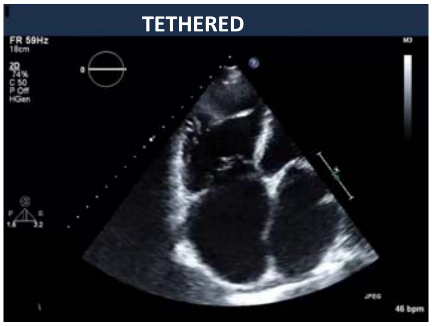


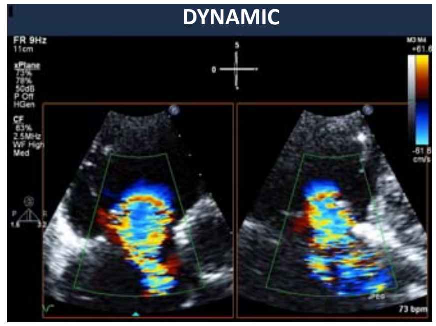
TR Peak Velocity = 386 cm/s
VTI of jet= 109 cm

Alias Velocity = 32 cm/s
Radius = 0.9 cm

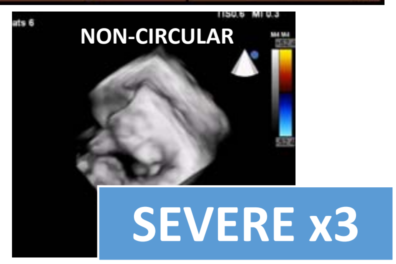
EROA = 6.28 * 0.9^2 * 32 / 386 = 0.4 cm^2
RVol = 0.4 * 109 = 44 mL

PISA LIMITED FOR FUNCTIONAL TR!



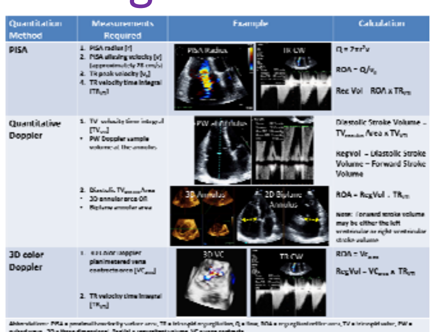


- Volume overload is well-tolerated for years
  - No reduction in RV function
  - Few symptoms of insidious onset
- Poor understanding about grading the severity of TR on Echo
  - Patients present LATE!!



3D vena contracta area = 1.5 cm2

TR Grading: Work in Progress



Hahn RT. *Circ Cardiovasc Imaging*. 2016 Dec;9(12)

SCOUT 1 is the first tricuspid valve device trial to use Doppler quantitative measures of disease severity

Table I **Proposed expansion of the 'Severe' grade**

Variable	Mild	Moderate	Severe	Massive	Torrential
VC (biplane)	<3 mm	3-6.9 mm	7–13 mm	14–20 mm	≥21 mm
EROA (PISA)	<20 mm^2	20–39 mm^2	40–59 mm^2	60–79 mm^2	≥80 mm^2
3D VCA or quantitative EROA[a]			75–94 mm^2	95–114 mm^2	≥115 mm^2

VC, vena contracta; EROA, effective regurgitant orifice area; 3D VCA, three-dimensional vena contracta area.
[a]3D VCA and quantitative Doppler EROA cut-offs may be larger than PISA EROA.

RT Hahn and JL Zamorano. European Heart Journal - Cardiovascular Imaging (2017) 00, 1–2 doi:10.1093/ehjci/jex139

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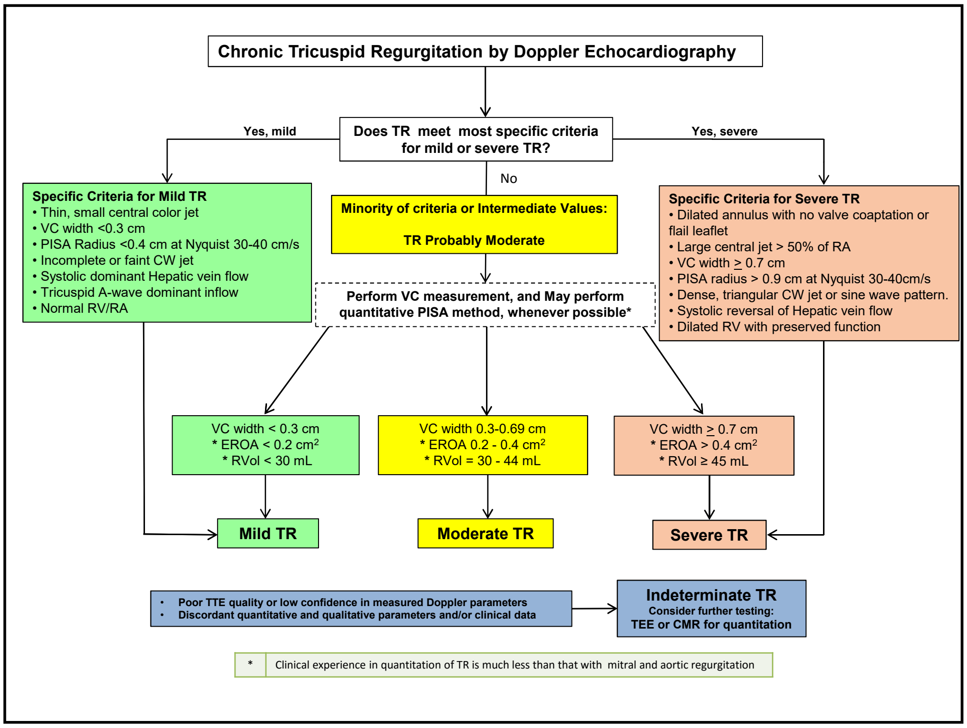
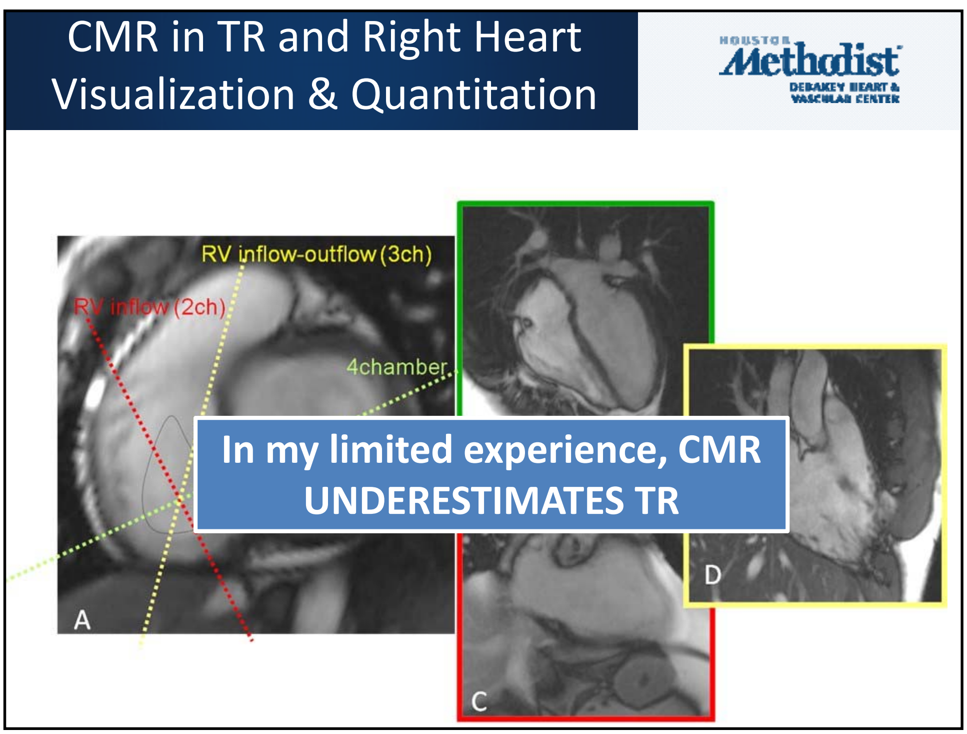
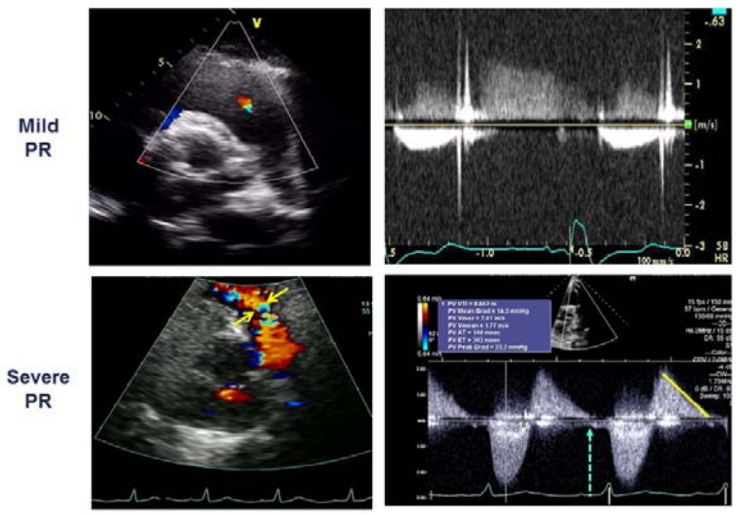
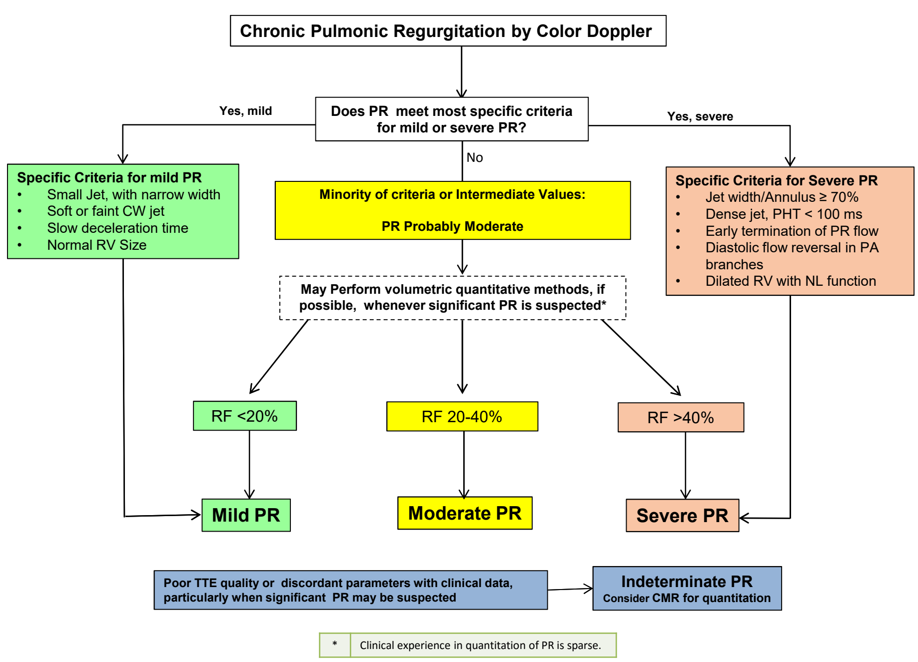

Chronic Tricuspid Regurgitation by Doppler Echocardiography
Does TR meet most specific criteria for mild or severe TR?
Yes, mild
Yes, severe
No
Specific Criteria for Mild TR
• Thin, small central color jet
• VC width <0.3 cm
• PISA Radius <0.4 cm at Nyquist 30-40 cm/s
• Incomplete or faint CW jet
• Systolic dominant Hepatic vein flow
• Tricuspid A-wave dominant inflow
• Normal RV/RA
Minority of criteria or Intermediate Values:
TR Probably Moderate
Specific Criteria for Severe TR
• Dilated annulus with no valve coaptation or flail leaflet
• Large central jet > 50% of RA
• VC width ≥ 0.7 cm
• PISA radius > 0.9 cm at Nyquist 30-40cm/s
• Dense, triangular CW jet or sine wave pattern.
• Systolic reversal of Hepatic vein flow
• Dilated RV with preserved function
Perform VC measurement, and May perform quantitative PISA method, whenever possible*
VC width < 0.3 cm
* EROA < 0.2 cm²
* RVol < 30 mL
VC width 0.3-0.69 cm
* EROA 0.2 - 0.4 cm²
* RVol = 30 - 44 mL
VC width ≥ 0.7 cm
* EROA > 0.4 cm²
* RVol ≥ 45 mL
Mild TR
Moderate TR
Severe TR
• Poor TTE quality or low confidence in measured Doppler parameters
• Discordant quantitative and qualitative parameters and/or clinical data
Indeterminate TR
Consider further testing:
TEE or CMR for quantitation
* Clinical experience in quantitation of TR is much less than that with mitral and aortic regurgitation


CMR in TR and Right Heart Visualization & Quantitation
HOUSTON Methodist DEBAKEY HEART & VASCULAR CENTER
RV inflow-outflow (3ch)
RV inflow (2ch)
4chamber
A
C
D
In my limited experience, CMR UNDERESTIMATES TR

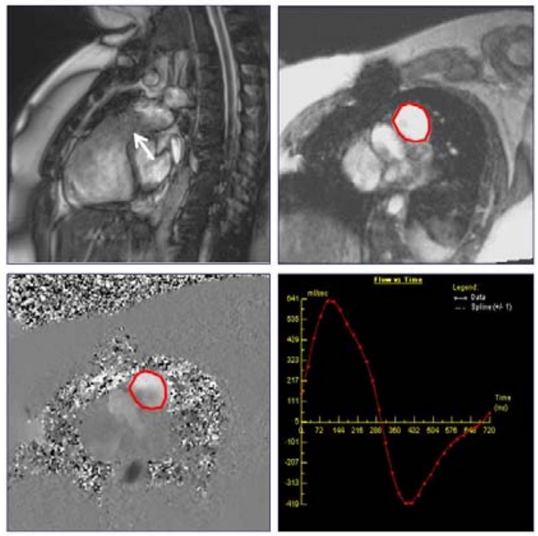
Pulmonic Regurgitation





CMR in Pulmonic Regurgitation

Quantitation of Rvol, RV Size & Function



New ASE Valvular Regurgitation Guidelines- *Endorsed by SCMR*

What is New?

- Emphasis on identification of Etiology/Mechanism of regurgitation
- 2D/3D TTE--an integrative approach & algorithms to assess severity
- When is TEE needed
- Important role of CMR & CMR methodology
- The challenge of co-existing valvular lesions
- A clinical perspective
- Library of case studies on the web: www.asecho.org/vrcases