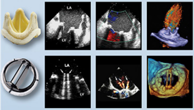
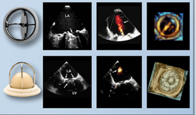
ASE American Society of Echocardiography
Heart & Circulation Ultrasound Specialists

Recommendations for
Evaluation of Prosthetic Valves with Echocardiography and Doppler Ultrasound

Normal Flow Patterns and Essential Parameters in the Evaluation of Prosthetic Valves

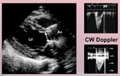


	Parameters
Clinical information	Date, type, and size of replacement valve Height, weight, and body surface area Symptoms and related clinical findings Blood pressure and heart rate
Imaging of the valve	Motion of leaflets or occluder Structure and integrity of valve and sewing ring
Doppler echocardiography of the valve	Contour of the jet velocity signal Peak velocity and mean gradient Velocity-time integral (VTI) of the jet Doppler velocity index (DVI) Pressure half-time (PHT) in mitral and tricuspid valves Effective orifice area (EOA) Presence, location, and severity of regurgitation
Comparison with previous post-operative study, when available	Comparison of above parameters helpful in suspected valvular dysfunction

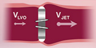


Prosthetic Aortic Valves

PW Doppler LVO



CW Doppler



$$\text{Effective Orifice Area} = \frac{CSA_{LVO} \times VTI_{LVO}}{VTI_{JET}}$$

$$\text{Doppler Velocity Index} = \frac{Velocity_{LVO}}{Velocity_{JET}}$$

Doppler Parameters of Prosthetic Aortic Valve Function in Mechanical and Stented Biological Valves*

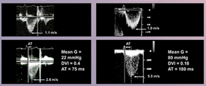
	Normal	Possible Stenosis	Suggests Significant Stenosis
Peak velocity Ψ	< 3 m/s	3 - 4 m/s	> 4 m/s
Mean gradient Ψ	< 20 mmHg	20 - 35 mmHg	>35 mmHg
Doppler velocity index	≥ 0.30	0.29 - 0.25	< 0.25
Effective orifice area	> 1.2 cm²	1.2 - 0.8 cm²	< 0.8 cm²
Contour of the jet velocity	Triangular, Early peaking	Triangular to Intermediate	Rounded, symmetrical contour
Acceleration time	< 80 ms	80 - 100 ms	> 100 ms

* In conditions of normal or near normal stroke volume (50 - 70 ml).
Ψ These parameters are more affected by flow, including concomitant aortic regurgitation.

Normal | Obstructed

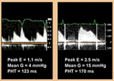
Pulsed Doppler LVO

CW Doppler Prosthetic AV



Prosthetic Mitral Valves

Normal | Obstructed



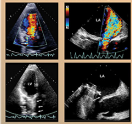
Doppler Parameters of Prosthetic Mitral Valve Function

	Normal*	Possible Stenosis	Suggests Significant Stenosis*
Peak velocity Ψ	< 1.9 m/s	1.9 – 2.5 m/s	≥ 2.5 m/s
Mean gradient Ψ	≤ 5 mmHg	6 – 10 mmHg	> 10 mmHg
VTI_{PrMV}/VTI_{LVO} Ψ	< 2.2	2.2 – 2.5	> 2.5
EOA	≥ 2.0 cm²	1 – 2 cm²	< 1 cm²
Pressure half-time	< 130 ms	130 – 200 ms	> 200 ms

* Best specificity for normality or abnormality is seen if the majority of the parameters listed are normal or abnormal, respectively.
Ψ Slightly higher cut-offs are seen in some bioprosthetic valves; these parameters are also abnormal in the presence of significant prosthetic mitral regurgitation.

Flow masking in mechanical valves from the transthoracic approach can hinder assessment of prosthetic mitral regurgitation

Transthoracic | Transesophageal



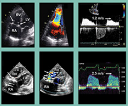
Findings Suggestive of Significant Prosthetic Mitral Regurgitation by TTE in Mechanical Valves with Normal Pressure Half-time

- Peak mitral velocity ≥1.9m/s
- VTI_{PrMV}/VTI_{LVO} ≥ 2.5
- Mean gradient ≥ 5mmHg
- LV stroke volume derived by 2D or 3D is > 30 % higher than systemic stroke volume by Doppler
- Systolic flow convergence seen in the LV towards the prosthesis
- Tricuspid regurgitation jet velocity > 3 m/s

Prosthetic Tricuspid Valves

Normal

Obstructed



Findings Suspecting Prosthetic Tricuspid Stenosis

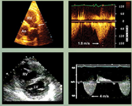
Prosthetic Valve	Consider Valve Stenosis*
Peak velocity Φ	> 1.7 m/s
Mean gradient Φ	≥ 6 mmHg
Pressure half-time	≥ 230 ms

* Because of respiratory variation, average at least 5 cycles
Φ May be increased also with concomitant valvular regurgitation

Prosthetic Pulmonic Valves

Normal

Obstructed



Findings Suspecting Prosthetic Pulmonic Stenosis

- Cusp or leaflet thickening or immobility
- Narrowing of forward color map
- Peak velocity through the prosthesis > 3 m/s, or > 2 m/s through a homograft
- Increase in peak velocity on serial studies
- Impaired RV function or elevated RV systolic pressure

Adapted from: Zoghbi WA, Chambers JB, Dumesnil JG, Foster E, Gottdiener JS, Grayburn PA, Khandheria BK, Levine RA, Marx GR, Miller FA, Nakatani S, Quiñones MA, Rakowski H, Rodriguez LL, Swaminathan M, Waggoner AD, Weissman NJ, Zabalgoitia M, Recommendations for Evaluation of Prosthetic Valves with Echocardiography and Doppler Ultrasound, J Am Soc Echocardiogr 2009 Sept; 22(9): 975-1014.

This ASE guideline document was endorsed by the American College of Cardiology Foundation, American Heart Association, European Association of Echocardiography, a registered branch of European Society of Cardiology, Canadian Society of Echocardiography, and Japanese Society of Echocardiography.

Poster ordering information and full text of ASE guideline documents available at: www.asecho.org

Design and illustration by **medmovie.com**

ASE American Society of Echocardiography
Heart & Circulation Ultrasound Specialists

Recommendations for Quantification Methods During the Performance of a Pediatric Echocardiogram

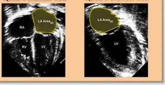
Left Atrium

- LA volume calculations using either the area-length or the summation of disks methods involve LA areas obtained in apical 4-chamber and 2-chamber views.
- Area-length method: (The shorter LA length l from either the A4C or A2C is used in the equation.)

$$V = \frac{8 \times A_{4C} \times A_{2C}}{3 \times \pi \times l}$$

- Summation of disks method: $V = \frac{\pi}{4} \times \sum_{i=1}^{N} d_{4Ci} \times d_{2Ci} \times \frac{L}{N}$

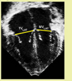
Apical 4-Chamber View — Apical 2-Chamber View



Atrioventricular Valves

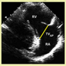
- The largest diameters should be measured at the valvar hingepoints during early diastole.

Apical 4-Chamber View



Parasternal Long Axis View

Parasternal Long Axis View w/ Posterior Angulation

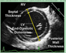


- The lateral diameters should be measured from inner edge to inner edge in an apical 4-chamber view.
- The antero-posterior diameters should be measured from inner edge to inner edge in a parasternal long-axis view.

Left Ventricle

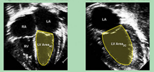
- End-diastole is defined as the maximum intraluminal area or the frame when the mitral valve closes.
- End-systole is defined as the minimum intraluminal area or the frame preceding mitral valve opening.
- Linear measurements of LV size include wall thickness and short-axis diameters measured from inner edge to inner edge in a parasternal short-axis view.
- Volumetric measurements of LV size can use either the Simpson biplane method or the area-length method.

Parasternal Short Axis View



Simpson Biplane Method

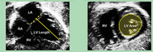
Apical 4-Chamber View — Apical 2-Chamber View



$$V = \frac{\pi}{4} \times \sum_{i=1}^{N} d_{4Ci} \times d_{2Ci} \times \frac{L}{N}$$

Area-Length Method

Subxiphoid Long Axis View* — Subxiphoid Short Axis View*



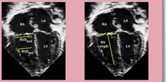
*or Apical 4-Chamber view — *or Parasternal Short Axis View

$$V = \frac{5}{6} \times CSA \times Length$$

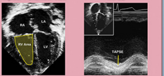
- LV mass can be calculated by subtracting end-diastolic endocardial volume from end-diastolic epicardial volume and multiplying the difference by 1.05 gm/ml.
- Linear and volumetric measurements of the LV during end-diastole and end-systole can be used to calculate LV function.
- Shortening fraction: $SF = \frac{EDD-ESD}{EDD}$
- Ejection fraction: $EF = \frac{EDV-ESV}{EDV}$

Right Ventricle

Apical 4-Chamber View — Apical 4-Chamber View

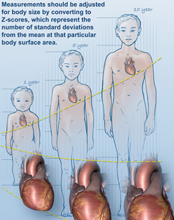


Apical 4-Chamber View — TAPSE



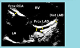
- Measurements of RV size include basal and mid-cavity diameters and lengths at end-diastole.
- Measurements of RV function include fractional area change and tricuspid annular plane systolic excursion (TAPSE).

Measurements should be adjusted for body size by converting to Z-scores, which represent the number of standard deviations from the mean at that particular body surface area.

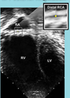


Coronary Arteries

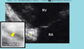
Parasternal Short Axis View



Apical 4-Chamber View w/ Posterior Angulation



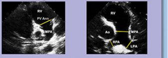
Parasternal Long Axis View w/ Posterior Angulation



- The left main, proximal and distal left anterior descending, circumflex, and proximal right coronary arteries (CAs) can be measured in a parasternal short-axis view.
- The posterior descending CA can be measured in a parasternal long-axis view with posterior angulation.
- The distal right CA can be measured in an apical 4-chamber view with posterior angulation.

Pulmonary Artery

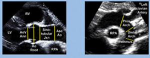
Parasternal Long Axis View w/ Anterior Angulation — Parasternal Short Axis View



- The largest diameters of the PV annulus and the main and branch PAs should be measured perpendicular to the long axis of the vessel during mid-systole.
- The PV annulus should be measured from inner edge to inner edge in a parasternal long-axis or short-axis view.
- The main and branch PAs should be measured from inner edge to inner edge in a parasternal, high left parasternal, or suprasternal short-axis view.

Aorta

Parasternal Long Axis View — Suprasternal Long Axis View



- The largest diameters of the Ao should be measured perpendicular to the long axis of the Ao during mid-systole.
- The Ao annulus, Ao root, sino-tubular junction, and ascending Ao should be measured from inner edge to inner edge in a parasternal long-axis view.
- The Ao arch should be measured from inner edge to inner edge in a suprasternal long-axis view.

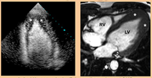
Adapted from: Lopez L, Colan SD, Frommelt PC, Ensing GJ, Kendall K, Younoszai AK, Lai WW, Geva T, Recommendations for Quantification Methods During the Performance of a Pediatric Echocardiogram: A Report from the Pediatric Measurements Writing Group of the ASE Pediatric and Congenital Heart Disease Council. J Am Soc Echocardiogr 2010 May; 23(5): 465-495

Poster ordering information and full text of ASE guideline documents available at: www.asecho.org/guidelines

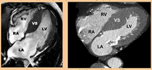
Multimodality Cardiovascular Imaging of Patients with Hypertrophic Cardiomyopathy

ASE American Society of Echocardiography
Heart & Circulation Ultrasound Specialists

Morphology



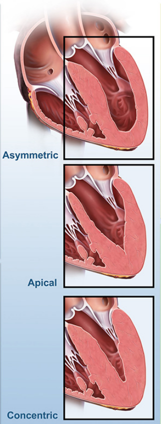
Apical Hypertrophy by Echocardiography and CMR



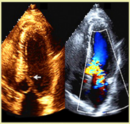
Septal Hypertrophy by CMR and Cardiac CT

- Echocardiography is the initial imaging modality.
- CMR should be used with patients with suboptimal echocardiographic images, and in situations with incomplete and/or unsatisfactory assessment of individual segmental wall thickness by echocardiography. CMR may be considered in selected patients with high index of suspicion for HCM.
- Cardiac CT is recommended when echocardiographic images are inadequate, and when CMR is contraindicated as in patients with ICD/pacemakers.
- Echocardiographic reports should include measurements of LV dimensions, wall thickness (including maximum wall thickness), pattern of hypertrophy and its severity and distribution.

★: site of apical hypertrophy
Top left image acquired after intravenous contrast injection.



LVOT Obstruction

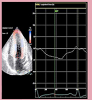


Systolic Anterior Motion (SAM) on 2D (arrow). In the same panel, color Doppler shows the high velocities across the LV outflow tract in mosaic color and the eccentric mitral regurgitation jet that is directed posterolaterally.

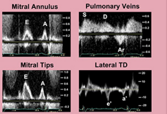
- Echocardiography is the recommended test. PW Doppler is used to localize site of obstruction and CW Doppler is needed to determine peak gradient.
- In patients with LVOT gradient <30 mmHg at rest, gradients can be provoked by Valsalva, amyl nitrite (when available), and if the patient is symptomatic with treadmill exercise.
- CMR may be considered in more challenging clinical scenarios as in patients with suspected subvalvular pathology or those with previous intervention.

Systolic & Diastolic Function

- Echocardiography is the initial imaging modality of choice for evaluation of LV EF, which should be included in the report.
- CMR is recommended when suboptimal echocardiographic images are present.
- Cardiac CT or radionuclide angiography can be considered for EF assessment when echocardiographic images are inadequate and CMR is contraindicated.
- Echocardiography is the only modality recommended for evaluation of LV diastolic function and a comprehensive approach should be followed per the recent ASE/EAE diastolic function guidelines.



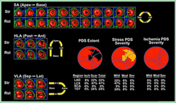
LV global longitudinal strain by speckle tracking echocardiography (STE), should be used in patients with HCM and hyperdynamic LV. LV global strain is markedly reduced at 7%. AVC (aortic valve closure).



Assessment of LV diastolic function in a patient with HCM who has an elevated LV end diastolic pressure (EDP), but a normal left atrial (LA) pressure. Mitral inflow shows a short mitral A duration at the level of the mitral annulus, whereas the Ar velocity in pulmonary venous flow is increased in amplitude and duration. Lateral annulus e' velocity is normal and the ratio of peak E velocity (at the level of mitral tips) to e' velocity is <8, consistent with a normal LA pressure. E: peak mitral early diastolic velocity, A: peak mitral late diastolic velocity, S: systolic velocity in pulmonary veins, D: diastolic velocity in pulmonary veins, and Ar: atrial reversal signal in pulmonary veins, e': early diastolic TD velocity, a': late diastolic TD velocity

CAD Diagnosis

- In HCM patients with chest pain and low probability of CAD, stress SPECT imaging can be considered.
- Coronary angiography, including CT angiography is recommended in patients with chest pain and intermediate or high pre-test probability of CAD.

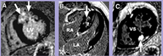


SPECT perfusion imaging from an HCM patient. Septal thickness is increased as is the count activity (hot spot) in the septum relative to the lateral wall. The computer analysis software registered a spurious fixed perfusion defect (scar) in the lateral and apical regions upon normalization to the septum (SA: short axis, HLA: horizontal long axis, VLA: vertical long axis).

Imaging Risk Factors of SCD

As part of a comprehensive SCD risk assessment that also includes medical history and family/genetic history, the following imaging specific variables may be considered on an individual patient basis.

Risk Factor	Imaging Modality
Maximum wall thickness ≥3 cm	Echocardiography, CMR, cardiac CT
End stage HCM: EF <50%	Echocardiography, radionuclide angiography, CMR, cardiac CT
Apical aneurysms	Contrast echocardiography, CMR, and cardiac CT
LVOT gradient ≥ 30mmHg	Doppler echocardiography
Perfusion defects	SPECT (though no association in some studies)
Reduced coronary flow reserve	PET (observations limited to very few patients)
LGE (presence and extent)	CMR (evidence not conclusive)



Contrast-enhanced CMR with late gadolinium enhancement (arrows) in HCM.

A. Asymptomatic 58-year-old woman with a large transmural area of late gadolinium enhancement in the basal anterior septum and anterior wall;

B. Diffuse and patchy area of late gadolinium enhancement in the mid-myocardial area of ventricular septum in a 21-year-old man;

C. Late gadolinium enhancement confined to the area of RV free wall insertion into the anterior and posterior ventricular septum.

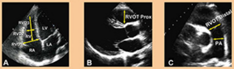
Adapted from: Nagueh SF, Bierig SM, Budoff MJ, Desai M, Dilsizian V, Eidem B, Goldstein SA, Hung J, Maron MS, Ommen SR, Woo A, American Society of Echocardiography Clinical Recommendations for Multimodality Cardiovascular Imaging of Patients with Hypertrophic Cardiomyopathy, J Am Soc Echocardiogr 2011; 24:473-98.
Endorsed by the American Society of Nuclear Cardiology, Society for Cardiovascular Magnetic Resonance, and Society of Cardiovascular Computed Tomography.

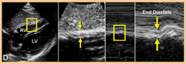
Poster ordering information and full text of ASE guideline documents available at: www.asecho.org/guidelines

ASE American Society of Echocardiography
Heart & Circulation Ultrasound Specialists

Guidelines for the Echocardiographic Assessment of the Right Heart in Adults

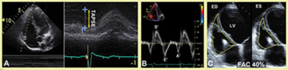
Chamber Quantification

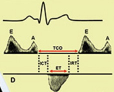


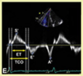


Variable	Abnormal
A. RV Basal (RVD1)	> 4.2 cm
RV Mid (RVD2)	> 3.5 cm
RV Longitudinal (RVD3)	> 8.6 cm
B. RVOT PLAX proximal	> 3.3 cm
C. RVOT PSAX distal	> 2.7 cm
D. RV Wall Thickness	> 0.5 cm

Systolic Function





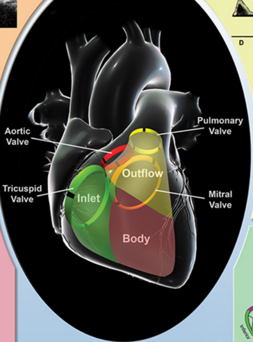


$$RVMPI = \frac{(ICT + IRT)}{ET} = \frac{(TCO - ET)}{ET}$$

TCO = Time from closure to opening of tricuspid valve
ET = Ejection time
ICT = Isovolumetric contraction time
IRT = Isovolumetric relaxation time
ED = End-diastole
ES = End-systole
RVMPI = Right ventricular myocardial performance index

Variable	Abnormal
A. TAPSE	<1.6 cm
B. Pulsed Doppler peak velocity at the annulus (S')	<10 cm/s
C. FAC (%)	<35%
D. Pulsed Doppler MPI	>0.40
E. Tissue Doppler MPI	>0.55

Figure D adapted from Assessment of the Right Ventricle by Echocardiography: A Primer for Cardiac Sonographers, J AM Soc Echocardiogr. 2009; 22:776-792.



Right Atrium

Tracing of the right atrium (RA) is performed from the plane of the tricuspid annulus (TA), along the interatrial septum (IAS), superior and antero-lateral walls of the RA. The RA major dimension is measured from the TA center to the superior RA wall, and the RA minor dimension is measured from the anterolateral wall to the IAS, as indicated by the yellow arrows.

Inferior vena cava (IVC) view. Measurement of the IVC. The diameter (solid line) is measured perpendicular to the long axis of the IVC at end expiration, just proximal to the junction of the hepatic veins that lie approximately 0.5-3.0 cm proximal to the ostium of the right atrium (RA).

Variable	Abnormal
RA Major Dimension	>5.3 cm
RA Minor Dimension	>4.4 cm
RA End-Systolic Area	>18 cm²

Right Atrial Pressure

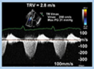
Estimation of RA pressure on the basis of IVC diameter and collapse

Variable	Normal (0-5 (3) mmHg)	Intermediate (5-10 (8) mmHg)		High (15 mmHg)
IVC diameter	≤2.1 cm	≤ 2.1 cm	>2.1 cm	> 2.1 cm
Collapse with sniff	>50%	<50%	>50%	< 50%
Secondary indices of elevated RA pressure				- Restrictive filling - Tricuspid E/E' >6 - Diastolic flow predominance in HV

* Ranges are provided for low and intermediate categories; however, for simplicity, a mid-range value of 3 mmHg for "normal" and 8 mmHg for "intermediate" are suggested. Intermediate (8 mmHg) RA pressures may be downgraded to normal (3 mmHg) if no secondary indices of elevated RA pressure are present, upgraded to high if minimal collapse with sniff (<35%) and secondary indices of elevated RA pressure are present, or left as 8 mmHg if uncertain.

IVC = Inferior vena cava; RA=Right atrium; HV=Hepatic veins

Pulmonary Hemodynamics



$sPAP = 4(TRV_{max})^2 + RAP$

Abnormal >35-40mm Hg

mPAP = 4(Early PI velocity)2 + RAP

mPAP = 1/3 sPAP + 2/3 dPAP

mPAP = 79 – 0.45 x Acceleration Time

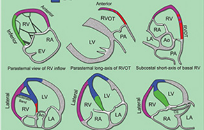
Abnormal ≥ 25mm Hg

dPAP = 4(End PI velocity)2 + RAP

sPAP = Systolic pulmonary artery pressure
mPAP = Mean pulmonary artery pressure
dPAP = Diastolic pulmonary artery pressure
RAP = Right atrial pressure

Segmental Analysis and Perfusion

RCA: Posterior Descending Artery
RCA: Acute Marginal Branch
RCA: Conus Branch
LAD



Parasternal view of RV inflow | Parasternal long-axis of RVOT | Subcostal short-axis of basal RV

RV apical 5-chamber view | RV apical 4-chamber | RV apical coronary sinus view

Diastolic Function

	E:A	E:E'	Deceleration Time	Additional Findings
Normal	0.8-2.1	<6	>120ms	-
Impaired Relaxation	<0.8	<6	>120ms	-
Pseudonormal	0.8-2.1	>6	>120ms	Diastolic flow predominance in HV
Restrictive	>2.1	>6	<120ms	Late diastolic antegrade flow in PA

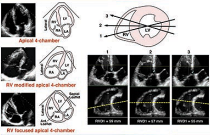
Adapted from: Rudski LG, Lai WW, Afilalo J, Hua L, Handschumacher MD, Chandrasekaran K, Solomon SD, Louie EK, Schiller NB, Guidelines for the Echocardiographic Assessment of the Right Heart in Adults: A Report from the American Society of Echocardiography, J Am Soc Echocardiogr 2010;23:685-713.

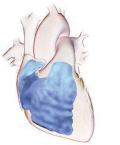
Poster ordering information and full text of ASE guideline documents available at: www.asecho.org/guidelines

ASE American Society of Echocardiography

Guidelines for Chamber Quantification of the Right Heart

RV Views





RV Linear Dimensions

Inflow

Basal RV linear diameter (RVD1) = maximal transversal dimension in the basal one third of RV inflow at end-diastole in the RV-focused view.

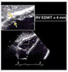
Mid-cavity RV linear diameter (RVD2) = transversal RV dimension in the middle third of RV inflow, approximately halfway between the maximal basal diameter and the apex, at the level of papillary muscles at end-diastole.

Outflow

Proximal RV outflow diameter (RVOT Prox) = linear dimension measured from the anterior RV wall to the inter-ventricular septal-aortic junction (in parasternal long-axis view) or to the aortic valve (in parasternal short-axis) at end-diastole.

Distal RV outflow diameter (RVOT Distal) = linear transversal dimension measured just proximal to the pulmonary valve at end-diastole.

RV Wall Thickness



Linear measurement of RV free wall thickness (either by M-mode or 2D echocardiography) performed at end-diastole (EDWT), below the tricuspid annulus at a distance approximating the length of anterior tricuspid leaflet, when it is fully open and parallel to the RV free wall.

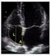
Trabeculae, papillary muscles and epicardial fat should be excluded.

Zoomed imaging with focus on the RV mid-wall and respiratory maneuvers may improve endocardial border definition.

RA Size

RA linear dimensions

The minor axis of the right atrium should be measured in the apical 4-chamber view as the distance between the lateral right atrial wall and inter-atrial septum, at the mid-atrial level defined by half of right atrial long axis.



RA volume

2D volume measurements are usually based on tracings of the blood-tissue interface in the apical 4-chamber view. At the tricuspid valve level, the contour is closed by connecting the two opposite sections of the tricuspid annulus with a straight line. Volumes can be computed by using either the single plane area-length or the disk summation technique.

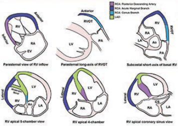
	Women	Men
RA minor axis dimension (cm/m²)	1.9 ± 0.3	1.9 ± 0.3
RA major axis dimension (cm/m²)	2.5 ± 0.3	2.4 ± 0.3
2D right atrial volume (mL/m²)	21 ± 6	25 ± 7

RV Size

Parameter	Mean ± SD	Normal range
RV basal diameter (mm)	33 ± 4	25 - 41
RV mid-cavity diameter (mm)	27 ± 4	19 - 35
RVOT PLAX proximal diameter (mm)	25 ± 2.5	20 - 30
RVOT SAX proximal diameter (mm)	28 ± 3.5	21 - 35
RVOT SAX distal diameter (mm)	22 ± 2.5	17 - 27
RV wall thickness (mm)	3 ± 1	1 - 5
RV EDA (cm²)		
Men	17 ± 3.5	10 - 24
Women	14 ± 3	8 - 20
RV EDA indexed to BSA (cm²/m²)		
Men	8.8 ± 1.9	5 - 12.6
Women	8.0 ± 1.75	4.5 - 11.5
RV ESA (cm²)		
Men	9 ± 3	3 - 15
Women	7 ± 2	3 - 11
RV ESA indexed to BSA (mL/m²)		
Men	4.7 ± 1.35	2.0 - 7.4
Women	4.0 ± 1.2	1.6 - 6.4
RV EDV indexed to BSA (mL/m²)		
Men	61 ± 13	35 - 87
Women	53 ± 10.5	32 - 74
RV ESV indexed to BSA (mL/m²)		
Men	27 ± 8.5	10 - 44
Women	22 ± 7	8 - 36

Abbreviations: BSA, body surface area; EDA, end-diastolic area; EDV, end-diastolic volume; ESA, end-systolic area; ESV, end-systolic volume; PLAX, parasternal long-axis view; RV, right ventricle; RVOT, right ventricular outflow tract.

RV Segmentation and Perfusion



Abbreviations: Ao, aorta; CS, coronary sinus; LA, left atrium; LAD, left anterior descending artery; LV, left ventricle; PA, pulmonary artery; RA, right atrium; RCA, right coronary artery; RV, right ventricle; RVOT, right ventricular outflow tract.

RV Area

Manual tracing of RV endocardial border from the lateral tricuspid annulus along the free wall to the apex and back to medial tricuspid annulus, along the interventricular septum at end-diastole and at end-systole.

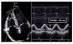
Trabeculations, papillary muscles and moderator band are included in the cavity area.

RV Longitudinal Systolic Function

TAPSE

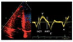
Tricuspid annular peak systolic excursion by M-mode (mm), measured between end-diastole and peak systole.

Proper alignment of M-mode cursor with the direction of RV longitudinal excursion should be achieved from the apical approach.



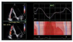
Pulsed tissue Doppler S wave

Peak systolic velocity of the tricuspid annulus (cm/s), obtained from the apical approach, in the view that achieves parallel alignment of Doppler beam with RV free-wall longitudinal excursion.



Global longitudinal free-wall strain

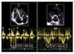
Peak value of 2D longitudinal speckle tracking derived strain (%), averaged over the 3 segments of the RV free wall in RV-focused apical 4-chamber view.



RV Global Function

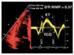
Pulsed Doppler RIMP

Right ventricular index of myocardial performance (Tei index):
RIMP = (TCO-ET)/ET



Tissue Doppler RIMP

Right ventricular index of myocardial performance by tissue Doppler:
RIMP=(IVRT+IVCT)/ET=(TCO-ET)/ET



RV Function

Parameter	Mean ± SD	Abnormality threshold
TAPSE (mm)	24 ± 3.5	<17
Pulsed DTI S wave (cm/s)	14.1 ± 2.3	<9.5
Color DTI S wave (cm/s)	9.7 ± 1.85	<6.0
RV fractional area change (%)	49 ± 7	<35
RV free wall 2D strain* (%)	-29 ± 4.5	>-20
RV 3D ejection fraction (%)	58 ± 6.5	<45
Pulsed Doppler RIMP	0.26 ± 0.085	>0.43
Tissue Doppler RIMP	0.38 ± 0.08	>0.54
E wave deceleration time (ms)	180 ± 31	<119 or >242
E/A	1.4 ± 0.3	<0.8 or >2.0
e'/a'	1.18 ± 0.33	<0.52
e'	14.0 ± 3.1	<7.8
E/e'	4.0 ± 1.0	>6.0

Abbreviations: E, early transtricuspid filling velocity; A, transtricuspid atrial contraction velocity; e' and a', early and late diastolic myocardial velocities by tissue Doppler; MPI, myocardial performance index; RV, right ventricle; S, systolic myocardial velocity by tissue Doppler; TAPSE, tricuspid annular plane systolic excursion. † Limited data; values may vary depending on vendor and software version.

Lang RM, Badano LP, Mor-Avi V, Afilalo J, Armstrong A, Ernande L, Flachskampf FA, Foster E, Goldstein SA, Kuznetsova T, Lancellotti P, Muraru D, Picard MH, Rietzschel ER, Rudski L, Spencer KT, Tsang W, and Voigt JU; Recommendations for Cardiac Chamber Quantification by Echocardiography in Adults: An Update from the American Society of Echocardiography and the European Association of Cardiovascular Imaging. J Am Soc Echocardiogr 2015; 28:1-39.

Poster ordering information and full text of ASE guideline documents available at: www.asecho.org

Recommendations for Image Acquisition and Display Using 3D Echocardiography

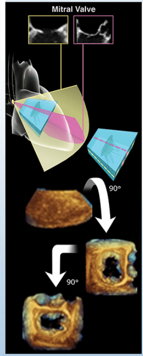
ASE American Society of Echocardiography
Heart & Circulation Ultrasound Specialists

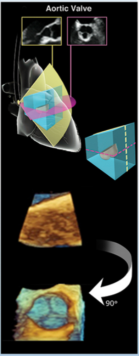
European Association of Echocardiography — European Society of Cardiology

Transthoracic Acquisition

Structure	Position	Acquisition
Left ventricle	Apical four chamber view	narrow-/ wide-angle
Right ventricle	Apical four chamber view, with RV in center	narrow-/ wide-angle
Interatrial septum	Apical four chamber view	narrow angle/ zoomed
Aortic Valve	Parasternal long-axis view	with/ without color, narrow angle/ zoomed
Mitral Valve	Parasternal long-axis view Apical 4-chamber view	with/ without color, narrow angle/ zoomed
Tricuspid Valve	Apical 4-chamber view Parasternal RV inflow tract view	with/ without color, narrow angle/ zoomed
Pulmonic Valve	Parasternal RV outflow tract view	with/ without color, narrow angle/ zoomed

Acquisition (TEE)





Transesophageal Acquisition

Structure	Position	Acquisition
Left ventricle	0°-120° ME	wide-angle
Right ventricle	0°-120° ME, centered on RV	wide-angle
Interatrial septum	0° ME	zoomed/ wide-angle
Aortic valve	60° ME, short-axis view 120°, long-axis view	with/without color, zoomed/ wide-angle
Mitral valve	0° -120° ME	with/without color, zoomed
Tricuspid valve	0°-30°, 4C ME 40° transgastric view with anteflexion	with/without color, zoomed
Pulmonic valve	90° high-esophageal view 120° ME, 3C view	with/without color, zoomed

ME= mid esophageal

Recommended For Clinical Practice

- Guidance of transcatheter procedures
- Left ventricular ejection fraction
- Left ventricular volume
- Mitral valve anatomy
- Mitral stenosis severity

Promising Clinical Studies

- Aortic valve and root anatomy
- Aortic stenosis severity
- Left ventricular mass
- Right ventricular volume
- Right ventricular ejection fraction
- Tricuspid valve anatomy

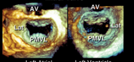
Display of Cardiac Structures

Left Atrial Appendage

En-face — Transverse

The left atrial appendage should be presented en-face from the left atrial perspective (left) with the pulmonary veins located superiorly or longitudinally (right). Image from TEE.
LAA=left atrial appendage, Pul Veins=pulmonary veins

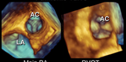
Mitral Valve



Left Atrial — Left Ventricle

Display with the AV placed in the 12 o'clock position regardless if the valve is viewed from the left atrium or the left ventricle perspective. Image from TEE. AV=aortic valve, Lat=lateral left ventricle, PMVL=posterior mitral valve leaflet

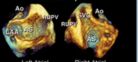
Pulmonic Valve



Main PA — RVOT

Display with the AC located at the 12 o'clock position, regardless if presented as viewed from the main PA or the RVOT.
Image from TEE.
AC=anterior cusp, LA=left atrium, PA=pulmonary artery

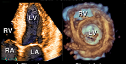
Interatrial Septum



Left Atrial — Right Atrial

Display with the RUPV at the one o'clock position when viewed from the left atrial perspective. Display with the SVC at the 11 o'clock position when viewed from the right atrial perspective. Image from TEE. AS=atrial septum, Ao=aorta, LAA=left atrial appendage, RUPV=right upper pulmonary vein, SVC=superior vena cava

Left Ventricle



4-Chamber — Short Axis

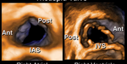
Display from either the apical four-chamber view or the short axis view. Image from TTE. LA=left atrium, LV=left ventricle, RV=right ventricle

Aortic Valve

Aorta — LVOT

Display with the RCC located in the 6 o'clock position regardless if the valve is viewed from the aorta or the LVOT. Image from TTE.
RCC=right coronary cusp

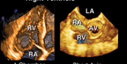
Tricuspid Valve



Right Atrial — Right Ventricle

Display with the IAS or IVS at the 6 o'clock position regardless if viewed from the right atrial or right ventricular perspective. Image from TTE.
Ant=anterior, IAS=interatrial septum, Post=posterior, IVS=interventricular septum

Right Ventricle



4-Chamber — Short Axis

Display from either the apical four-chamber view or the short-axis view. Image from TTE (left), image from TEE (right).
AV=aortic valve, LA=left atrium, RV=right ventricle, RA=right atrium

Adapted from: Lang RM, Badano LP, Tsang W, Adams DH, Agricola E, Buck T, Faletra FF, Franke A, Hung J, Perez de Isla L, Kamp O, Kasprzak JD, Lancellotti P, Marwick TH, McCulloch ML, Monaghan MJ, Nihoyannopoulos P, Pandian NG, Pellikka PA, Pepi M, Roberson DA, Shernan SK, Shirali GS, Sugeng L, ten Cate FJ, Vannan MA, Zamorano JL, Zoghbi WA, EAE/ASE Recommendations for Image Acquisition and Display Using Three-Dimensional Echocardiography, J Am Soc Echocardiogr 2012;25:3-46.

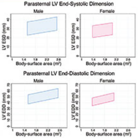
Poster ordering information and full text of ASE guideline documents available at: www.asecho.org/guidelines

ASE American Society of Echocardiography

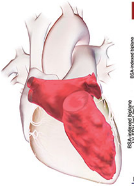
Guidelines for Chamber Quantification of the Left Heart

LV Dimensions

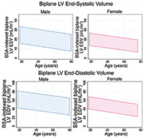
2D-guided linear measurements

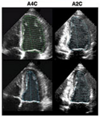


LV internal dimension	Male Mean ± SD	Male 2-SD Range	Female Mean ± SD	Female 2-SD Range
Diastolic dimension (mm)	50.2 ± 4.1	42.0 - 58.4	45.0 ± 3.6	37.8 - 52.2
Systolic dimension (mm)	32.4 ± 3.7	25.0 - 39.8	28.2 ± 3.3	21.6 - 34.8



LV Volumes by 2D





Biplane method of disks

LV volumes normalized by BSA	Male Mean ± SD	Male 2-SD Range	Female Mean ± SD	Female 2-SD Range
LV end-diastolic volume (mL/m²)	54 ± 10	34 - 74	45 ± 8	29 - 61
LV end-systolic volume (mL/m²)	21 ± 5	11 - 31	16 ± 4	8 - 24

LV Volumes by 3D

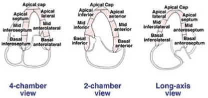
Volumetric measurements

Upper limits of normal

End-diastolic volume:
79 mL/m² for men
71 mL/m² for women

End-systolic volume:
32 mL/m² for men
28 mL/m² for women

LV Segmentation



LV Function

Ejection fraction

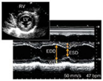
	Normal range	Mildly abnormal	Moderately abnormal	Severly abnormal
Male	52 - 72	41 - 51	30 - 40	< 30
Female	54 - 74	41 - 53	30 - 40	< 30

Global longitudinal strain

Peak GLS in the range of -20% can be expected in a healthy person, and the lower the absolute value of strain is, the more likely it is to be abnormal.

LV Mass

Linear method

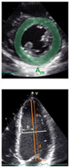


Cube formula
LV mass = 0.8 × 1.04 × [(IVS+LVID+PWT)³-LVID³] + 0.6 g

	Women	Men
LV mass/BSA (g/m²)	*43-95*	*49-115*
Relative wall thickness (cm)	0.22-0.42	0.24-0.42
Septal thickness (cm)	*0.6-0.9*	*0.6-1.0*
Posterior wall thickness (cm)	*0.6-0.9*	*0.6-1.0*

Bold italic values: recommended and best validated.

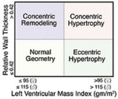
2D Methods



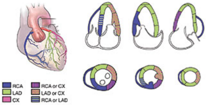
Two methods for estimating LV mass based on area-length formula and the truncated ellipsoid formula, from short axis (top) and apical four-chamber (bottom) 2D echo views.

	Women	Men
LV mass/BSA (g/m²)	*44-88*	*50-102*

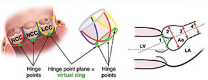
Bold italic values: recommended and best validated.

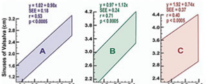


Perfusion Territories



Aortic Root

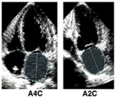




LA Volume

Biplane method of disks

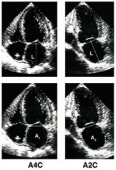
Biplane method of disks, using the apical four-chamber (A4C) and apical two-chamber (A2C) views at ventricular end-systole (maximum LA size).



Area-length technique

$$\frac{8}{3\pi}\left[\frac{(A_1 \times A_2)}{L}\right]$$

Area-length method using the apical four-chamber and apical two-chamber views at ventricular end-systole (maximum LA size). The length (L) is measured from the back wall to the line across the hinge points of the mitral valve. The shorter L from either the A4C or the A2C is used in the equation.



	Normal range	Mildly abnormal	Moderately abnormal	Severly abnormal
Maximum LA volume / BSA (mL/m²)	16 - 34	35 - 41	42 - 48	> 48

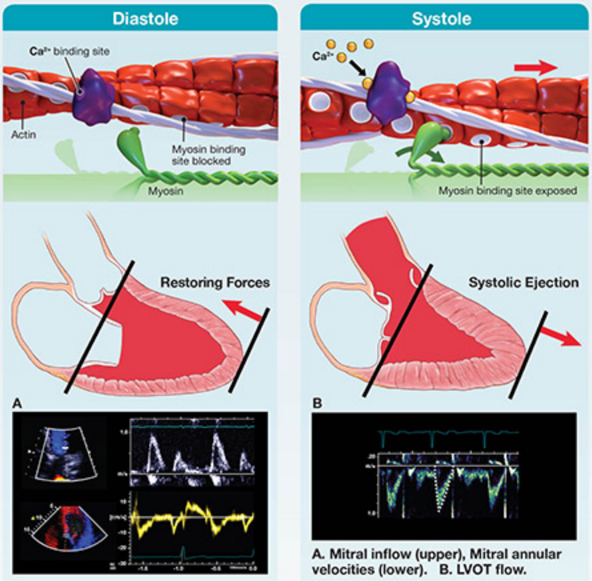
Lang RM, Badano LP, Mor-Avi V, Afilalo J, Armstrong A, Ernande L, Flachskampf FA, Foster E, Goldstein SA, Kuznetsova T, Lancellotti P, Muraru D, Picard MH, Rietzschel ER, Rudski L, Spencer KT, Tsang W, and Voigt JU; Recommendations for Cardiac Chamber Quantification by Echocardiography in Adults: An Update from the American Society of Echocardiography and the European Association of Cardiovascular Imaging. J Am Soc Echocardiogr 2015; 28:1-39

Poster ordering information and full text of ASE guideline documents available at: www.asecho.org

Echocardiographic Evaluation of LV Diastolic Function

ASE American Society of Echocardiography

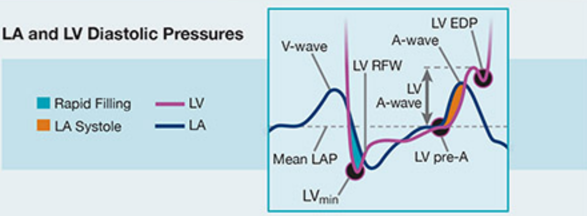
Myocardial Function and LV Filling

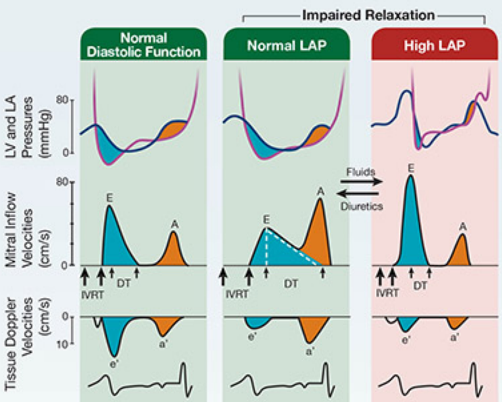


A. Mitral inflow (upper), Mitral annular velocities (lower). B. LVOT flow.

Relation of Mitral Inflow and TD Velocities with LV Filling Pressures

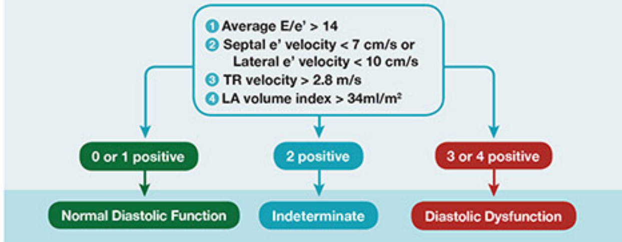
LA and LV Diastolic Pressures



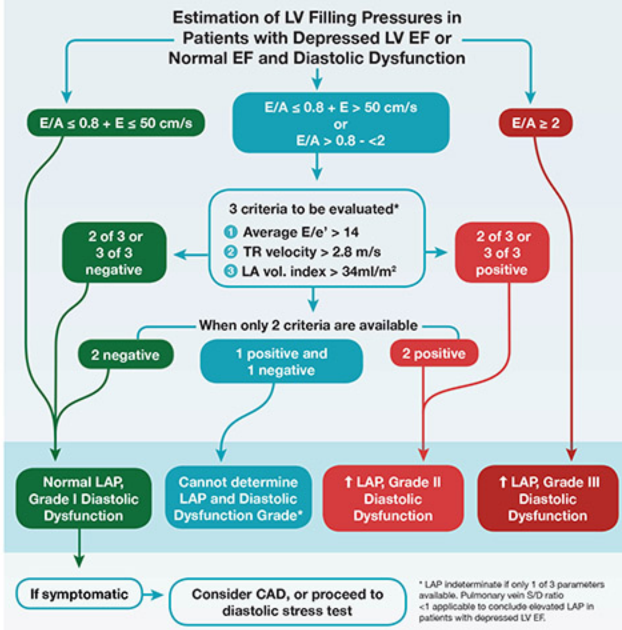


Criteria for Diagnosis of LV Diastolic Dysfunction

Diagnosis of Diastolic Dysfunction in Patients with Normal LV EF



Estimation of LV Filling Pressures in Patients with Depressed LV EF or Normal EF and Diastolic Dysfunction



* LAP indeterminate if only 1 of 3 parameters available. Pulmonary vein S/D ratio <1 applicable to conclude elevated LAP in patients with depressed LV EF.

LV Relaxation, Filling Pressures, and Usual 2D Doppler Findings According to Diastolic Dysfunction Grade

	Normal	Grade I	Grade II	Grade III
1) LV Relaxation	Normal	Impaired	Impaired	Impaired
2) LA Pressure	Normal	Low or Normal	Elevated	Elevated
3) Mitral E/A Ratio	≥ 0.8	≤ 0.8	> 0.8 to < 2	> 2
4) Average E/e' Ratio	< 10	< 10	10 - 14	> 14
5) Peak TR Velocity (m/s)	< 2.8	< 2.8	> 2.8	> 2.8
6) LA Volume Index	Normal	Normal or Increased	Increased	Increased

Sherif F. Nagueh, MD, FASE (Chair); Otto A. Smiseth, MD, PhD (Co-Chair); Christopher P. Appleton, MD; Benjamin F. Byrd III, MD, FASE; Hisham Dokainish, MD, FASE; Thor Edvardsen, MD, PhD; Frank A. Flachskampf, MD, PhD, FESC; Thierry C. Gillebert, MD, PhD, FESC; Allan L. Klein, MD, FASE; Patrizio Lancellotti, MD, PhD, FESC; Paolo Marino, MD, FESC; Jae K. Oh, MD; Bogdan Alexandru Popescu, MD, PhD, FESC, FASE; Alan D. Waggoner, MHS, RDCS. Recommendations for the Evaluation of Left Ventricular Diastolic Function by Echocardiography: An Update from the American Society of Echocardiography (ASE) and the European Association of Cardiovascular Imaging (EACVI). J Am Soc Echocardiogr 2016;29:277-314.

Poster ordering information and full text of ASE guideline documents available at: ASEcho.org

Design and illustration by medmovie.com

American Society of Echocardiography: Evaluation of Mitral Regurgitation

A. Color Flow Doppler (2D and 3D)

Proximal Isovelocity Surface Area

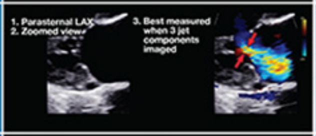
1. Align direction of flow with insonation beam
2. Zoomed view
3. Variance off
4. Change baseline of Nyquist limit (direction of the jet—typically to 30-40 cm/s)
5. Measure radius (white arrow in image) from point of color aliasing to vena contracta

Advantages:
- Rapid qualitative and quantitative assessment
- This is less likely to misclassify patients at very large (≥1.0 cm) or very small radii (≤0.3 cm)

Disadvantages:
- Multiple jets, eccentric jets
- Constrained jet (LV wall)
- Non-hemispheric shape
- Overestimation when MR not holosystolic

Vena Contracta

1. Parasternal long-axis view
2. Zoomed view
3. Best measured when proximal flow convergence, vena contracta and MR jet aligned in same plane



Advantages:
- Surrogate for regurgitant orifice size
- Independent of flow rate and driving pressure
- Can be applied in eccentric jets
- Good at separating mild (<0.3cm) from severe MR (≥0.7 cm)

Disadvantages:
- Multiple jets
- Overestimation when MR not holosystolic

Jet Area or Jet Area/ LA Area Ratio

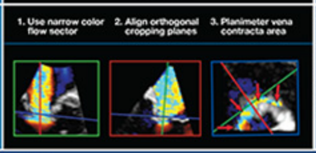
1. Apical view, zoom view
2. Measure largest jet alone or as ratio to LA area in same view

Advantage:
- Easy to measure

Disadvantages:
- Shown to be imprecise in eccentric jets
- Dependent on hemodynamic and technical variables
- Overestimation when MR not holosystolic

Color Flow Doppler 3D

1. Color flow sector should be as narrow as possible
2. Align orthogonal cropping planes along the axis of the jet
3. Planimeter the high velocity aliased signal of VC



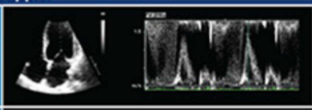
Advantages:
- Multiple jets of differing directions may be measured
- Can identify severe functional MR in some cases where PISA underestimates EROA

Disadvantages:
- Subject to color Doppler blooming
- Limited temporal and spatial resolution
- Overestimation when MR not holosystolic
- Multiple jets may be in different planes, must be analyzed separately and then added

B. Pulsed Wave Doppler

Mitral Inflow Velocity

1. Align insonation beam with the flow
2. Sample volume at leaflet tips

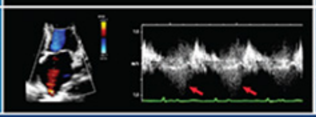


Advantages:
- E velocity ≥1.2 m/s a simple supportive sign of severe MR
- Dominant A-wave inflow pattern can exclude severe MR

Disadvantages:
- Depends on LV relaxation and filling pressures
- High E velocity not specific for severe MR

Pulmonary Vein Flow Pattern

1. Use small sample volume (3-5 mm) placed 1 cm into pulmonary vein



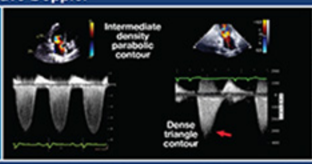
Advantages:
- Systolic flow reversal in >1 pulmonary vein is specific for severe MR
- Normal pulmonary vein pattern suggests low LA pressure and non-severe MR

Disadvantages:
- Eccentric MR directed into a pulmonary vein may not be severe
- Systolic blunting is not specific for significant MR

C. Continuous Wave Doppler

Density and Contour of Regurgitant Jet

1. Align insonation beam with the flow
2. Adjust overall gain



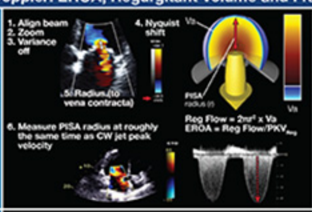
Advantages:
- Simple
- Density is roughly proportional to the number of red blood cells
- Faint/incomplete jet is compatible with mild MR
- A triangular contour denotes a large regurgitant pressure wave (red arrow) and hemodynamic significance

Disadvantages:
- Qualitative, gain dependent
- Perfectly aligned jets may appear denser than eccentric jets of higher severity
- Early peaking contour is not sensitive for severe MR

D. Quantitative Doppler: EROA, Regurgitant Volume and Fraction

Flow Convergence Method (PISA):

1. See PISA steps above
2. Look for need for angle correction if flow convergence zone is non-planar
3. Measure PISA radius (red solid arrow in image) at roughly the same time as CW jet peak velocity (red dotted arrow)

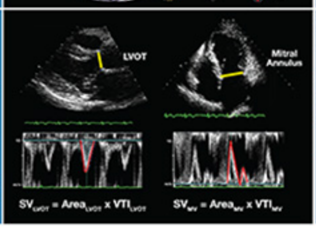


Advantages:
- Rapid quantitative assessment of severity (EROA) and volume overload (RVol)
- Predict outcomes in degenerative and functional MR

Disadvantages:
- Multiple jets, eccentric jets or crescent-shaped orifices
- Small errors in radius measurement can lead to substantial errors in EROA

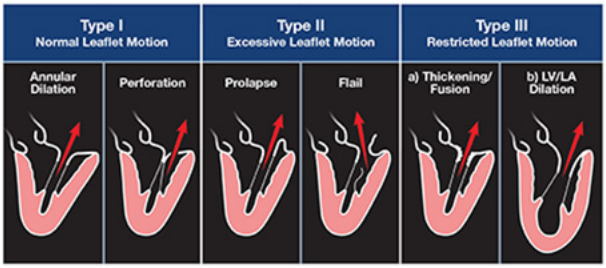
Stroke Volume Method: Regurgitant Volume = $SV_{MV} - SV_{LVOT}$

1. LVOT systolic diameter and pulsed Doppler sample volume from different views but at same anatomic level (represents forward stroke volume)
2. Mitral mid-diastolic annulus and pulsed Doppler at the same annulus from apical view (represents total 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)



Advantages:
- Quantitative, valid with multiple jets and eccentric jets.
- Provides both severity (EROA, RF) and volume overload (RVol)
- Validated against CMR in isolated MR

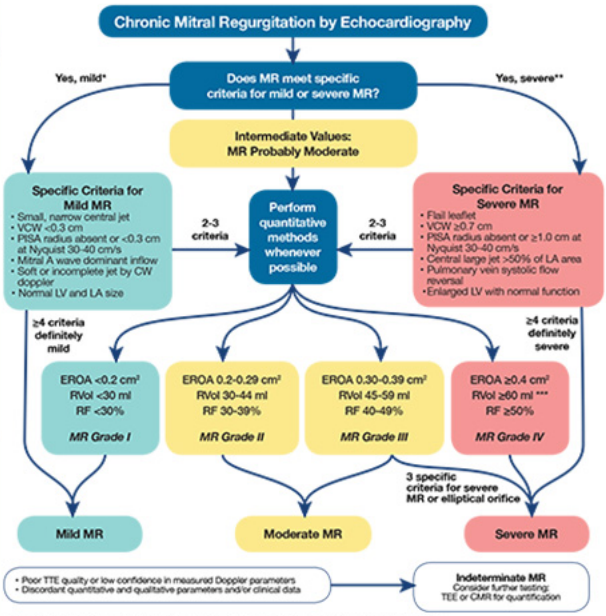
Disadvantages:
- In setting of AR, pulmonic stroke volume used for forward stroke volume
- Cumbersome, requires training
- Requires multiple measurements and small errors in diameter measurement can lead to substantial errors in EROA
- Pulsed Doppler method (mitral SV) and LV volume method may give different results



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 leaflet 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 occurrence 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.



* 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 and VCW overestimate non-holosystolic MR.
*** Regurgitant volume for severe MR may be lower in low flow conditions.

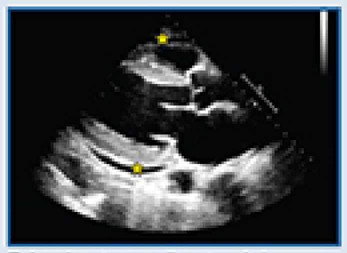
William A. Zoghbi, MD, FASE (Chair); David Adams, RCS, RDCS, FASE; Robert O. Bonow, MD; Maurice Enriquez-Sarano, MD; Elyse Foster, MD, FASE; Paul A. Grayburn, MD, FASE; Rebecca T. Hahn, MD, FASE; Yuchi Han, MD, MMSc; Judy Hung, MD, FASE; Roberto M. Lang, MD, FASE; Stephen H. Little, MD, FASE; Dipan J. Shah, MD, MMSc; Stanton Sherman, MD, FASE; Paaladinesh Thavendiranathan, MD, MSc, FASE; James D. Thomas, MD, FASE; Neil J. Weissman, MD, FASE. 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. J Am Soc Echocardiogr 2017; 30: 303-371.

Poster ordering information and full text of ASE guideline documents available at: ASEcho.org

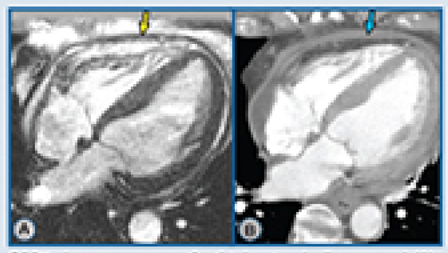
Multimodality Imaging of Pericardial Disease

American Society of Echocardiography

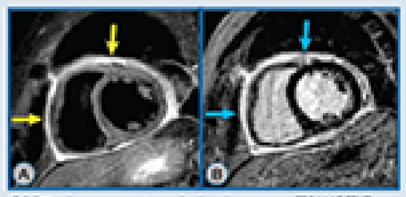
Acute/Recurrent Pericarditis



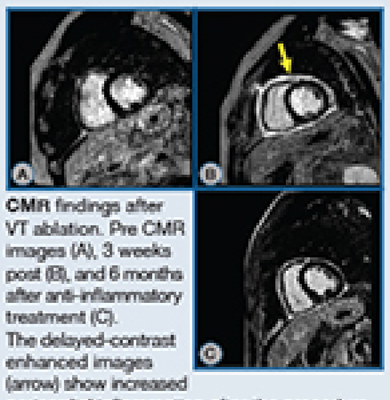
Echo showing small pericardial effusion (asterisks).



CMR shows non-specific thickening (yellow arrow) (A), and **Contrast CT** shows enhancement of parietal and visceral layers due to inflammation (blue arrow) (B).



CMR shows pericardial edema on T2WSTIR image (yellow arrows) (A), and inflammation on postgadolinium delayed enhancement (blue arrows) (B).



CMR findings after VT ablation. Pre CMR images (A), 3 weeks post (B), and 6 months after anti-inflammatory treatment (C). The delayed-contrast enhanced images (arrow) show increased pericardial inflammation after the procedure which partially resolves with treatment (C).

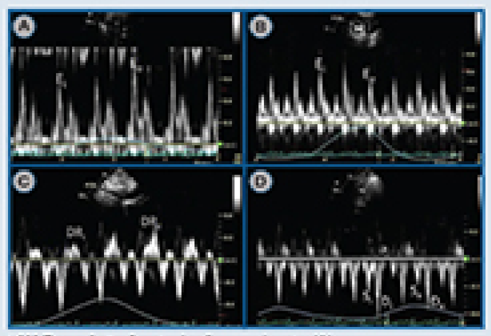
Summary of Imaging Findings

Echo
Pericardial effusion with or without tamponade, constrictive physiology
Wall motion abnormality
Normal findings
CT
Pericardial thickening
Enhancement of visceral and parietal surfaces with contrast
CMR
Enhancement of thickened pericardium on T1W SE images or LGE images consistent with inflammation
Significant signal in pericardial tissue on T2W images consistent with edema

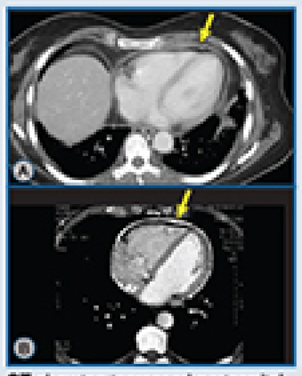
Key Points

- **TTE to assess for pericardial effusion / tamponade, constriction, or myocarditis.**
- **CT and CMR should be considered when there are complexities, such as:**
  - **Inconclusive echo**
  - **Failure to respond to anti-inflammatories**
  - **Atypical presentation**
  - **Suspicion of CP**
  - **Trauma**
  - **MI, neoplasm, lung or chest infection**

Constrictive Pericarditis



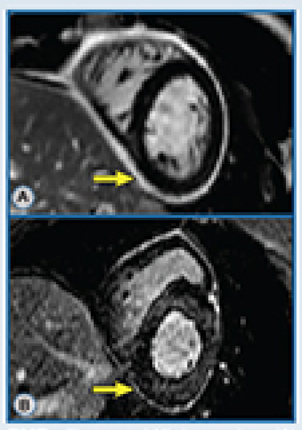
PW Doppler of mitral inflow velocity (A), tricuspid inflow velocity (B), hepatic vein (C), and SVC (D), with respiration.



CT showing increased pericardial thickness (arrow) (A).
CT showing calcification of the pericardium (arrow) (B).

Summary of Imaging Findings

Echo
M-mode: abrupt inspiratory posterior motion of the ventricular septum in early diastole with reciprocal changes in LV/RV with respiration
2D: diastolic septal bounce, respirophasic shift of ventricular septum, IVC plethora
Doppler: >25% decrease in mitral inflow velocity and >40% increase in tricuspid velocity with inspiration; opposite changes in expiration; HV expiratory end-diastolic reversal velocity/forward diastolic flow velocity ≥0.8; tissue Doppler: mitral medial annular velocity (≥9cm/sec); annulus reverses
CT
Pericardial thickness >4mm; calcification
Indirect findings: tubular deformity of ventricles, dilated IVC/HV, ascites, pleural effusions
CMR
Pericardial thickening; cine CMR showing abrupt cessation of diastolic filling, diastolic septal bounce
Pericardial edema and inflammation
Myocardial tagging sequences: pericardial –myocardial adherence
Real-time cine imaging: demonstration of respirophasic shift of septum

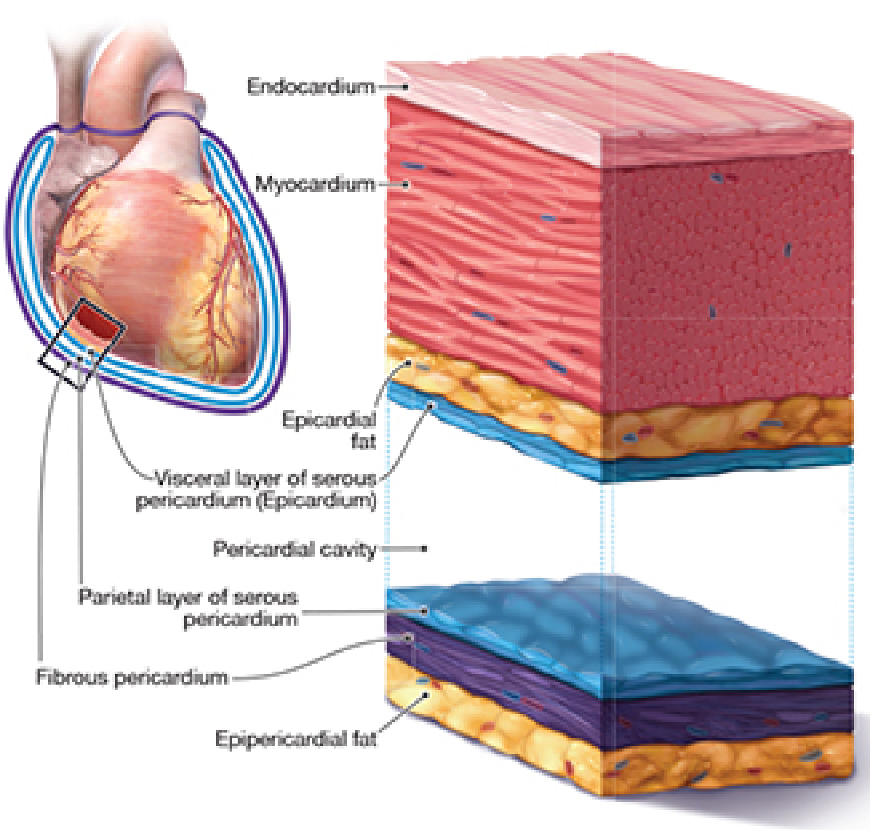


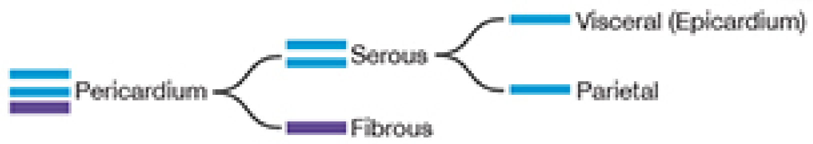
CMR with severe LGE (arrows) pre (A) and post prednisone therapy (B).

Key Points

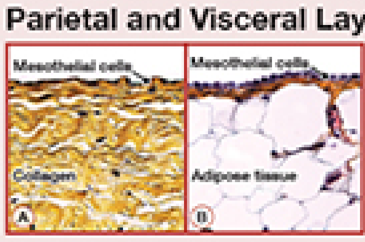
- **TTE with Doppler is the initial test.**
- **CMR/CT are complementary techniques to confirm CP and in selected patients with poor windows or unclear findings.**
- **CMR/CT can better assess pericardial thickness, edema and inflammation.**
- **CT can be used in preoperative planning.**

Pericardial Anatomy and Pathology



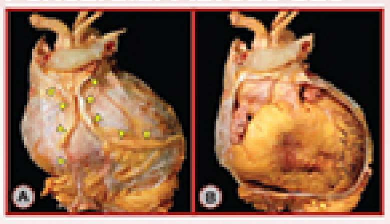


Parietal and Visceral Layers



Parietal pericardium consisting of mesothelial cells and collagen (yellow) (A). Visceral pericardium (or epicardium) consists of a mesothelial cell layer and epicardial adipose tissue (B).

Pericardial Fibrous Sac

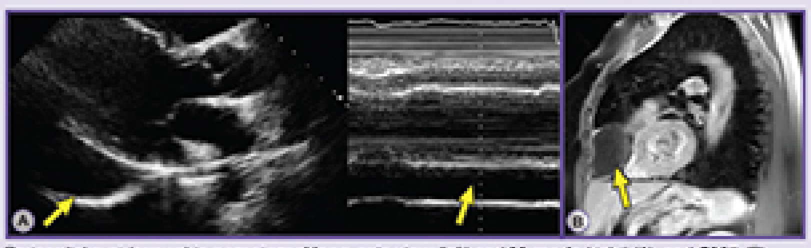


Intact pericardial sac (A), anterior portion removed (B).

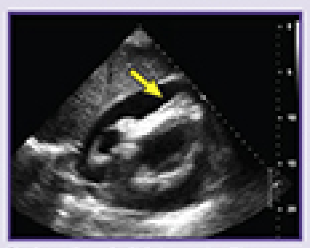
Effect of Pericarditis

Uremia (A) Neoplasm (B) Radiation (C)

Pericardial Masses, Cysts, and Diverticulum



Pericardial cyst (arrows) in parasternal long-axis view (left) and **M-mode** (right) (A), and **CMR** (B).



Pericardium is thickened with nodular regions (arrow) consistent with tumor.

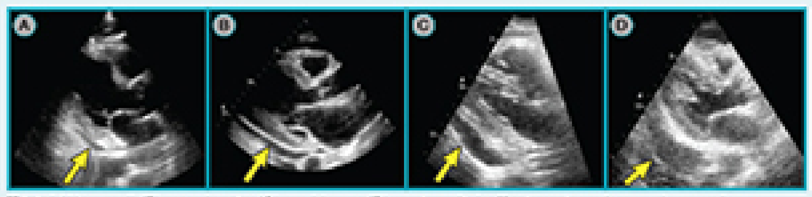
Key Points

- **Echo is the initial test.**
- **CMR/CT is better for tissue characterization and detecting metastasis.**
- **CMR/CT is better to assess diverticulum and cyst.**

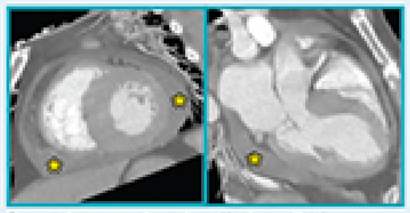
Summary of Imaging Findings

	Pericardial Cyst	Pericardial Diverticulum
Echo	Echo-free space adjacent to cardiac border	Echo-free space adjacent to cardiac border with defect in lining
CT	Well-circumscribed fluid sac with signal attenuation of water; location typically at CP angle	Similar to cyst but with communication to pericardial sac
CMR	Smooth-bordered, encapsulated lesions abutting the pericardium with characteristics of water	Defect in pericardial lining or communication to pericardial sac

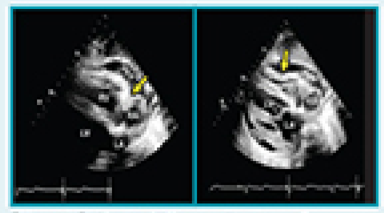
Pericardial Effusion/Tamponade



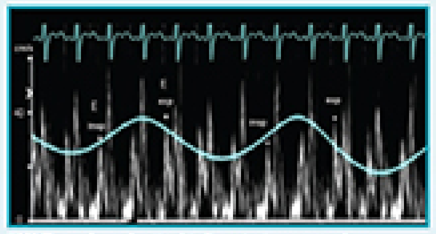
Trivial (A), small (B), moderate (C) and large (D) pericardial effusion sizes (arrows) on **echo**.



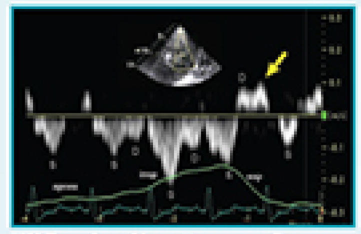
Small simple pericardial effusion with focal collections (asterisks) on **CT**.



RA and RV indentation or "collapse" (arrows) by **echo** in tamponade.



PW Doppler of mitral inflow in tamponade showing decreased E wave with inspiration (30%) compared with expiration.



PW Doppler of hepatic venous flow with tamponade, showing decreased expiratory diastolic HV velocities with large reversals (arrow).

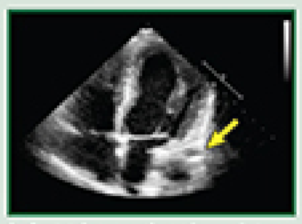
Summary of Imaging Findings

Echo	CT	CMR
Effusion		
Localization and quantitation of pericardial fluid	Localization and quantitation of pericardial fluid	Localization and quantitation of pericardial fluid
	Tissue characterization (CT attenuation)	Tissue characterization (signal intensity)
Tamponade		
Moderate to large effusion	Feasibility of surgery vs. pericardiocentesis	Same as CT
Reduced LV size and dilated IVC and HV	"Flattened heart" and dilated IVC and HV	
Chamber collapse		
Respiratory variation in chamber size (↑RV \ ↓LV with inspiration)		
Respiratory variation in Doppler velocities (↑tricuspid, ↓mitral, aortic with inspiration) and ↑IVRT with inspiration		
Decreased expiratory diastolic HV velocities, with large reversals		

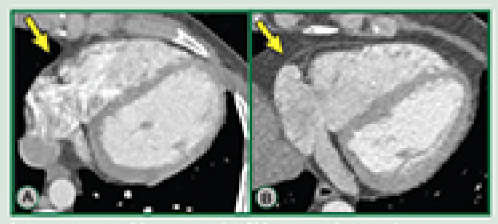
Key Points

- **TTE to assess extent of effusion and hemodynamic compromise.**
- **CT/CMR to evaluate complex pericardial effusions.**
- **CT/CMR to evaluate suspected hemopericardium and assess for malignancy or inflammation.**
- **TEE, CT/ CMR to assess regional tamponade.**

Congenital Absence of the Pericardium



Left atrial appendage (arrow), is herniated through a defect in a partial absence of the left pericardium on **echo**.



Interposition of lung at right AV groove (arrows) in congenital absence of pericardium on **CT** (A) vs normal subject (B).

Summary of Imaging Findings

Echo
M-mode: abnormal septal motion
2-D: RV dilation, and increased mobility of heart and posterior pointing of apex
Doppler: tricuspid regurgitation
CT/CMR
Absence of pericardial layer
Levorotation of the heart
Interposition of lung tissue in the anterior space between aorta and pulmonary artery

Key Points

- **Echo to assess bulging of cardiac chambers and excessive motion.**
- **CT/ CMR to assess morphologic identification of a pericardial defect.**

Allan L. Klein, MD, FASE, Chair, Suhny Abbara, MD, Deborah A. Agler, RCT, RDCS, FASE, Christopher P. Appleton, MD, FASE, Craig R. Asher, MD, Brian Hoit, MD, FASE, Judy Hung, MD, FASE, Mario J. Garcia, MD, Itzhak Kronzon, MD, FASE, Jae K. Oh, MD, FASE, E. Rene Rodriguez, MD, Hartzell V. Schaff, MD, Paul Schoenhagen, MD, Carmela D. Tan, MD, and Richard D. White, MD. American Society of Echocardiography Clinical Recommendations for Multimodality Cardiovascular Imaging of Patients with Pericardial Disease: Endorsed by the Society for Cardiovascular Magnetic Resonance and Society of Cardiovascular Computed Tomography. J Am Soc Echocardiogr 2013;26:965-1012.

Poster ordering information and full text of ASE guideline documents available at: www.asecho.org

Design and illustration by medmovie.com

American Society of Echocardiography

Guidelines for the Evaluation of Valvular Regurgitation

Aortic Valve

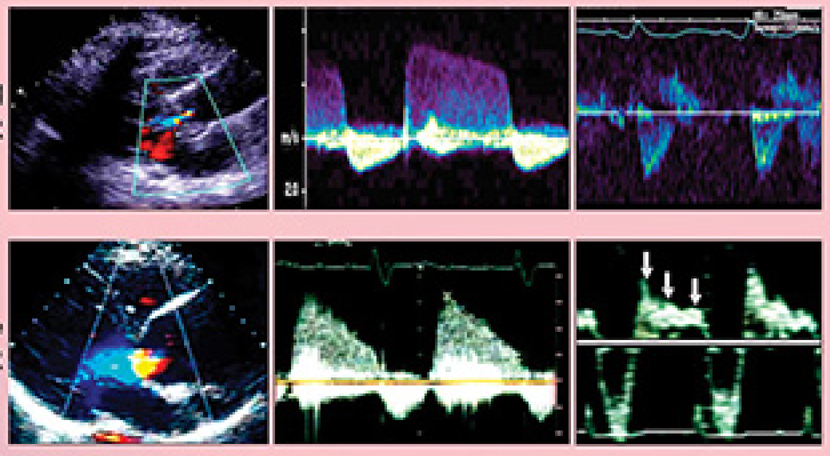
Central AR Jet

Eccentric AR Jet

Color Doppler | CW Doppler | Desc Aorta - PW

Mild AR

Severe AR



Central and eccentric aortic regurgitation (AR) jets. VC = vena contracta; LA = left atrium; LV = left ventricle.

Color Doppler, continuous wave, and pulsed wave (PW) Doppler recording of flow in the descending aorta in mild and severe aortic regurgitation (AR). Arrows: holodiastolic flow reversal in the descending (desc) aorta.

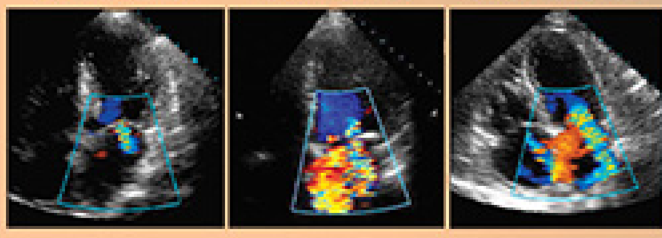
Grading of Aortic Regurgitation Severity

	Mild	Moderate		Severe
Specific Signs for AR severity	• Central Jet, width <25% of LVOT • Vena contracta < 0.3 cm[1] • No or brief early diastolic flow reversal in descending aorta	Signs of AR>mild present but no criteria for severe AR		• Central Jet, width ≥65% of LVOT • Vena contracta > 0.6 cm
Supportive Signs	• Pressure half-time > 500 ms • Normal LV size[2]	Intermediate values		• Pressure half-time <200 ms • Holodiastolic aortic flow reversal in descending aorta • Moderate or greater LV enlargement [3]
Quantitative Parameters				
RVol, ml/beat	< 30	30-44	45-59	≥ 60
RF, %	< 30	30-39	40-49	≥ 50
EROA, cm^2	< 0.10	0.10-0.19	0.20-0.29	≥ 0.30

1 At a Nyquist limit of 50-60 cm/s.
2 LV size applied only to chronic lesions.
3 In the absence of other etiologies of LV dilatation
AR = aortic regurgitation; EROA = effective regurgitant orifice area;
LV = left ventricle; LVOT = left ventricular outflow tract;
R Vol = regurgitant volume;
RF = regurgitant fraction.

Mitral Valve

Mild Central MR | Severe Central MR | Severe Eccentric MR



Examples of: mild regurgitation (MR) with no flow convergence and a small regurgitant jet area; severe central MR, with a prominent flow convergence and a large regurgitant jet area; a severe eccentric MR with a large flow convergence and a wide vena contracta.

Mitral regurgitation jet depicting its 3 components: flow convergence, vena contracta (VC), and jet area in the left atrium.

Flow Convergence Method

Reg Flow = $2\pi r^2 x Va$

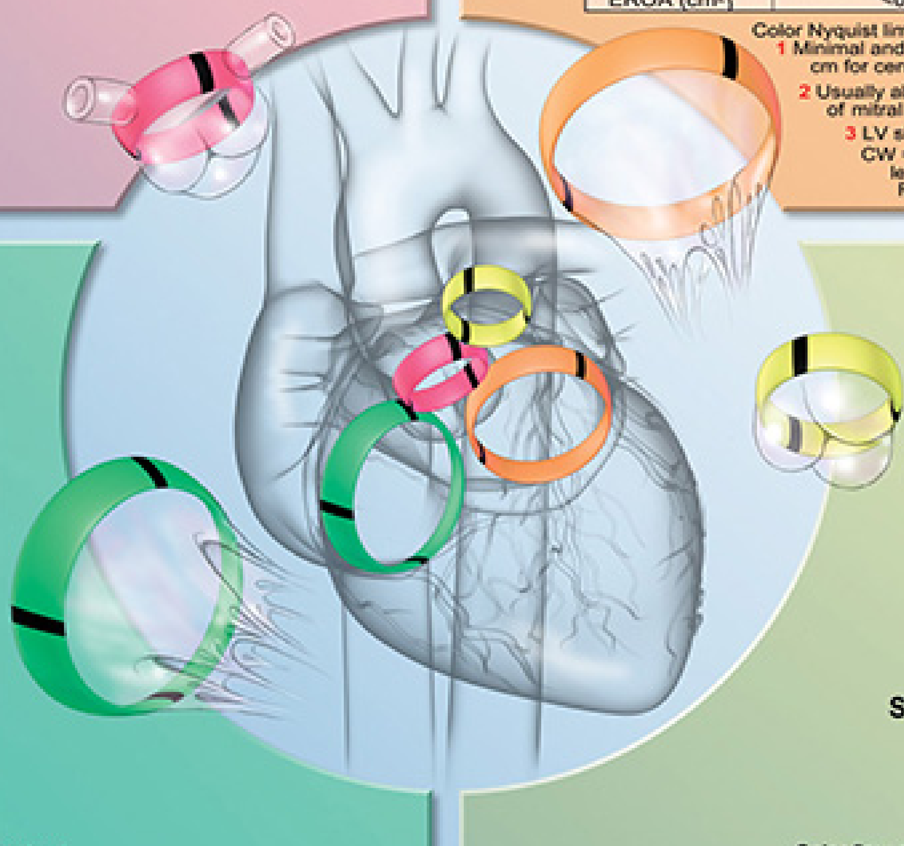
EROA = Reg Flow / PKV_{Reg}

Flow convergence or proximal isovelocity surface area (PISA) method for quantitation of regurgitation from the apical views. Va = aliasing velocity; PkVReg = peak velocity of the regurgitant jet by CW Doppler. Reg flow = regurgitant flow; EROA = effective regurgitant orifice area; Reg jet = regurgitation jet.

Grading Mitral Regurgitation Severity

	Mild	Moderate		Severe
Specific Signs of Severity	• Small central jet <4 cm^2 or < 20% of LA area. • Vena contracta width < 0.3 cm • No or minimal flow convergence [1]	Signs of MR>mild present but no criteria for severe MR		• Vena contracta width ≥ 0.7cm with large central MR Jet (area > 40% of LA) or with a wall-impinging jet of any size, swirling in LA • Large flow convergence[1] • Systolic reversal in pulmonary veins • Prominent flail MV leaflet or ruptured papillary muscle
Supportive Signs	• Systolic dominant flow in pulmonary veins • A-wave dominant mitral inflow [2] • Soft density, parabolic CW Doppler MR signal • Normal LV size[3]	Intermediate signs/findings		• Dense, triangular CW Doppler MR jet • E-wave dominant mitral inflow (E >1.2 m/s)[2] • Enlarged LV and LA size, particularly when normal LV function is present
Quantitative Parameters				
RVol (ml/beat)	<30	30-44	45-59	≥ 60
RF (%)	<30	30-39	40-49	≥ 50
EROA (cm^2)	<0.20	0.20-0.29	0.30-0.39	≥ 0.40

Color Nyquist limit of 50-60 cm/s
1 Minimal and large flow convergence defined as a flow convergence radius < 0.4 cm and ≥ 0.9 cm for central jets, respectively, with a baseline shift at a Nyquist of 40 cm/s.
2 Usually above 50 years of age or in conditions of impaired relaxation, in the absence of mitral stenosis or other causes of elevated LA pressure
3 LV size applied only to chronic lesions
CW = continuous wave; EROA = effective regurgitant orifice area; LA = left atrium; LV = left ventricle; MV= mitral valve; MR = mitral regurgitation; R Vol = regurgitant volume; RF = regurgitant fraction.

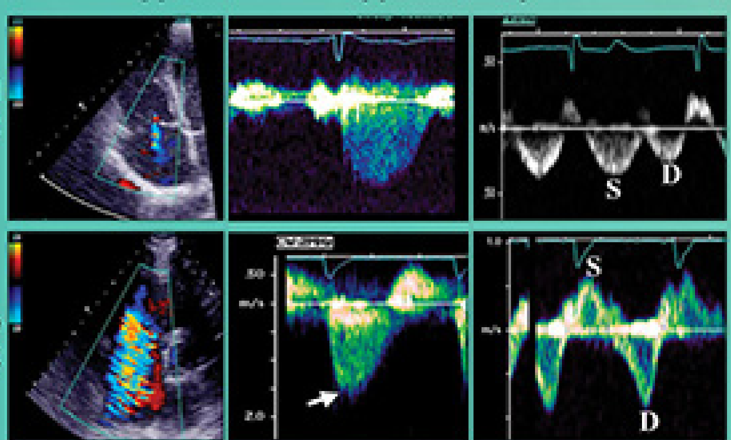


Tricuspid Valve

Color Doppler | CW Doppler | Hepatic Vein Flow

Mild TR

Severe TR



Jet recordings by color Doppler, continuous wave Doppler, and hepatic vein flow by pulsed Doppler in mild and severe tricuspid regurgitation (TR). Systole = S; Diastole = D.

Grading Tricuspid Regurgitation Severity

Parameter	Mild	Moderate	Severe
Tricuspid valve	Usually normal	Normal or abnormal	Abnormal/Flail leaflet/ Poor coaptation
RV/RA/IVC size	Normal[1]	Normal or dilated	Usually dilated[2]
Jet area- central jets (cm^2)[3]	< 5	5-10	>10
VC width (cm)	Not defined	Not defined, but <0.7	>0.7
PISA radius (cm)[4]	<0.5	0.6 – 0.9	>0.9
Jet density and contour –CW	Soft and parabolic	Dense, variable contour	Dense, triangular with early peaking
Hepatic vein flow[5]	Systolic dominance	Systolic blunting	Systolic reversal

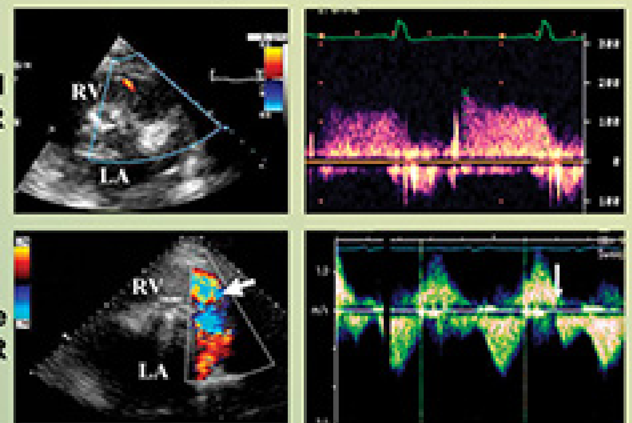
1 Unless there are other reasons for RA or RV dilation; 2 Exception: acute TR.
3 At a Nyquist limit of 50-60 cm/s.
4 Baseline shift with Nyquist limit of 28 cm/s.
5 Other conditions may cause systolic blunting (eg. atrial fibrillation, elevated RA pressure).
CW = Continuous wave Doppler; IVC = inferior vena cava; RA = right atrium; RV = right ventricle; VC = vena contracta width.

Pulmonic Valve

Color Flow Doppler | CW Doppler

Mild PR

Severe PR



Color flow and continuous wave Doppler recording in mild and severe pulmonary regurgitation (PR). Arrow: early termination of PR flow; LA = left atrium; RV = right ventricle.

Grading Pulmonary Regurgitation Severity

Parameter	Mild	Moderate	Severe
Pulmonic valve	Normal	Normal or abnormal	Abnormal
RV size	Normal[1]	Normal or dilated	Dilated[2]
Jet size by color Doppler	Thin (usually <10 mm in length) with a narrow origin	Intermediate	Usually large, with a wide origin; May be brief in duration
Jet density and deceleration rate –CW[3]	Soft; Slow deceleration	Dense; variable deceleration	Dense; steep deceleration, early termination of diastolic flow
Pulmonic systolic flow compared to systemic flow –PW	Slightly increased	Intermediate	Greatly increased

1 Unless there are other reasons for RV enlargement. 2 Exception: acute PR
3 Steep deceleration is not specific for severe PR
CW = Continuous wave Doppler; PR = pulmonic regurgitation; PW = pulsed wave Doppler; RV = right ventricle.

Poster ordering information and full text of ASE guideline documents available at: www.asecho.org

Adapted from: Zoghbi WA, Enriquez-Sarano M, Foster E, Grayburn PA, Kraft CD, Levine RA, Nihoyannopoulos P, Otto CM, Quinones MA, Rakowski H, Stewart WJ, Waggoner A, Weissman NJ. Recommendations for Evaluation of The Severity of Native Valvular Regurgitation with Two-Dimensional and Doppler Echocardiography. J Am Soc Echocardiogr. 2003 Jul;16(7):777-802.

Recommendations endorsed by the American College of Cardiology, the American Heart Association, and the European Society of Cardiology Working Group on Echocardiography.

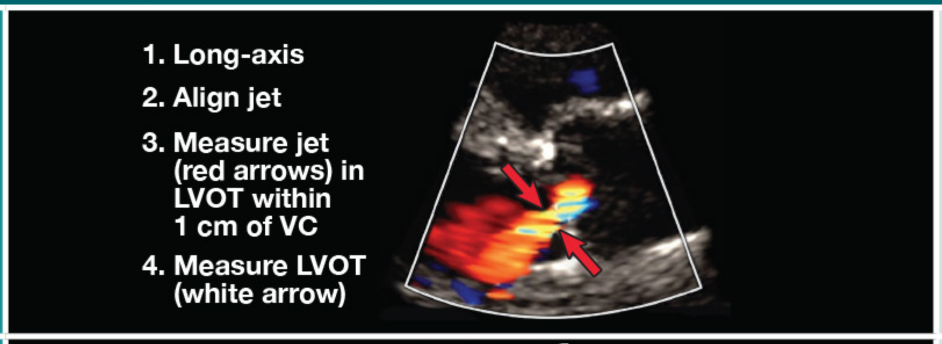
ASE American Society of Echocardiography

Evaluation of Aortic Regurgitation

A. Color Flow Doppler (2D and 3D)

Jet Width/LVOT Diameter

1. Long-axis, zoomed view
2. Align jet to optimize VC imaging (may be different from PISA)
3. Measure jet (red arrows) in LVOT within 1cm of VC
4. Measure LVOT (white arrow)



Advantages:
- Simple sensitive screen for AR
- Rapid qualitative assessment

Disadvantages:
- Underestimates AR in eccentric jets
- May overestimate AR in central jets as AR jet may expand unpredictably below the orifice
- Affected by the size of the LVOT

Jet Area/LVOT Area

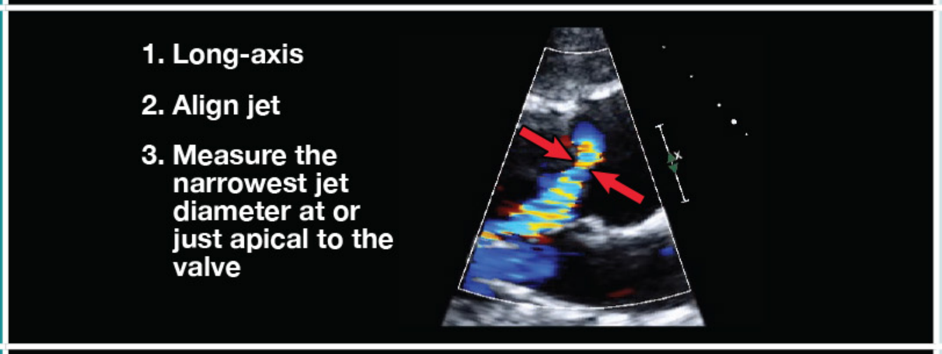
1. Short-axis, zoom view
2. Measure in LVOT within 1 cm of the VC

Advantage:
- Estimate of regurgitant orifice area

Disadvantages:
- Direction and shape of jet may overestimate or underestimate jet area

Vena Contracta

1. Long-axis, zoomed view
2. Align jet to optimize VC imaging (may be different from PISA)
3. Measure the narrowest jet diameter at or just apical to the valve

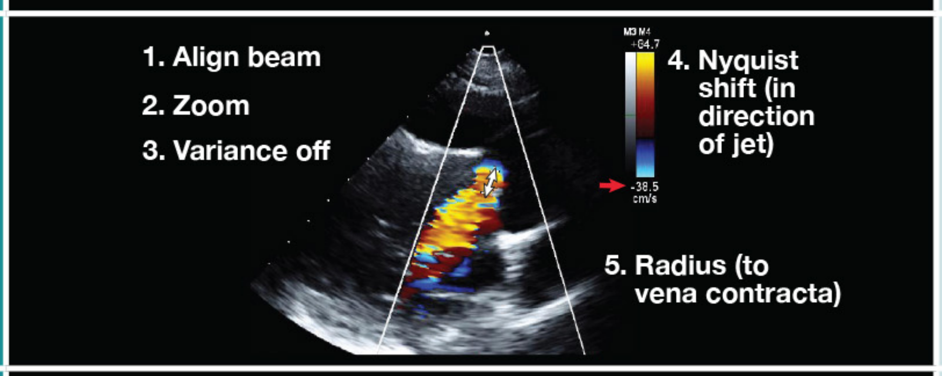


Advantages:
- Surrogate for regurgitant orifice size
- May be used in eccentric jets
- Independent of flow rate and driving pressure
- Less dependent on technical factors
- Good at identifying mild or severe AR

Disadvantages:
- Presence of multiple jets or bicuspid valves
- Convergence zone needs to be visualized
- The direction of the jet will influence its appearance

Proximal Flow Convergence

1. Align direction of flow with insonation beam
2. Zoomed view
3. Variance off
4. Change baseline of Nyquist limit (in direction of jet)
5. Measure radius (white arrow in image) from point of color aliasing to vena contracta

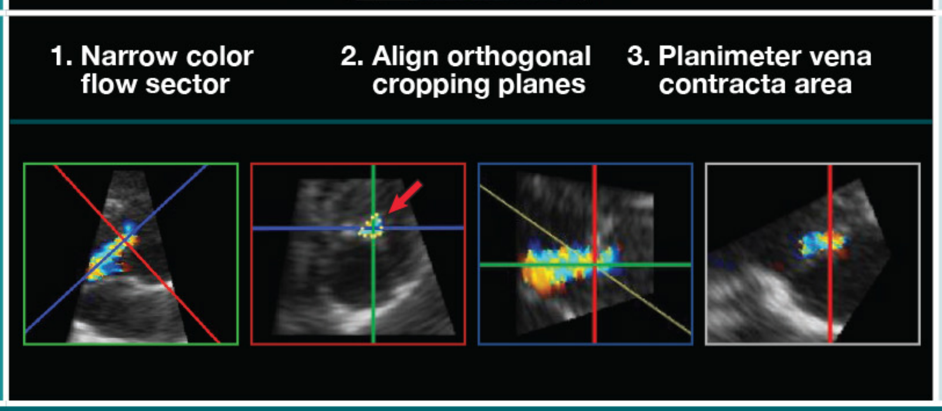


Advantage:
- Rapid qualitative assessment

Disadvantages:
- Multiple jets
- Constrained jet (aortic wall)
- Non-hemispheric shape
- Timing in early diastole

3D Vena Contracta

1. Color flow sector should be narrow
2. Align orthogonal cropping planes along the axis of the jet
3. Choose a mid-diastolic cycle
4. Non-coaxial jets or aliased flow may appear "laminar" but still represent regurgitant flow



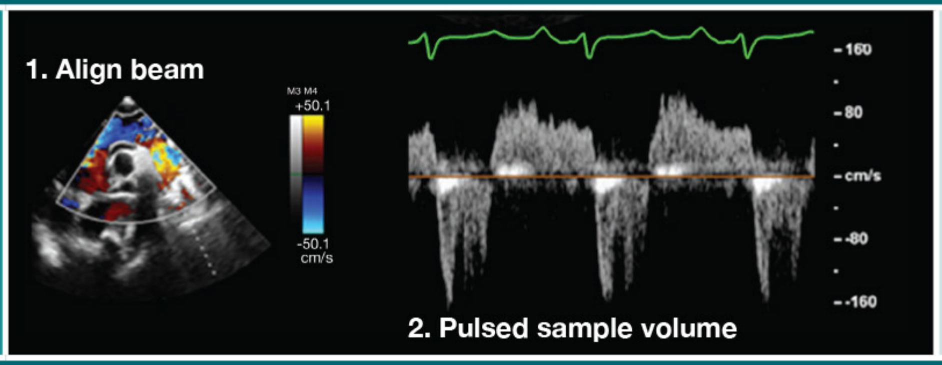
Advantage:
- Multiple jets of differing directions may be measured

Disadvantage:
- Dynamic jets may be over- or underestimated

B. Pulsed Wave Doppler

Holodiastolic Flow Reversal in Proximal Descending Aorta

1. Align insonation beam with the flow
2. Pulsed sample volume in the proximal descending or abdominal aorta



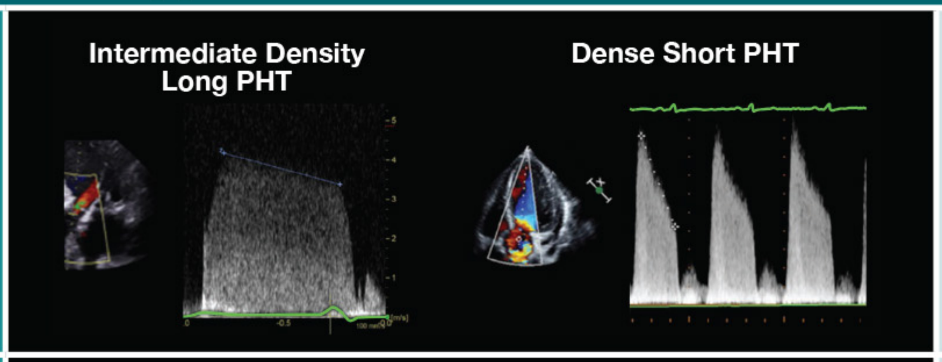
Advantages:
- Simple supportive sign of severe AR
- More specific sign if seen in abdominal aorta

Disadvantages:
- Depends on compliance of the aorta; less reliable in older patients
- Brief velocity reversal is normal
- May be seen in other conditions
- May not be holosystolic in acute AR

C. Continuous Wave Doppler

Density of Regurgitant Jet

1. Align insonation beam with the flow
2. Adjust overall gain

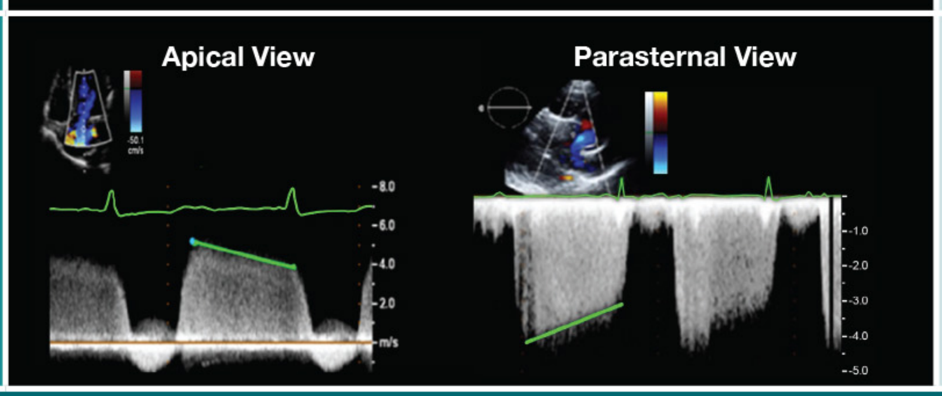


Advantages:
- Simple
- Faint or incomplete jet is compatible with mild or trace AR

Disadvantages:
- Qualitative
- Perfectly central jets may appear denser than eccentric jets of higher severity
- Overlap between moderate and severe AR

Jet Deceleration Rate (Pressure Half-time)

1. Align insonation beam with the flow
2. Usually best from apical windows
3. In eccentric jets, may be best from parasternal window, helped by color Doppler



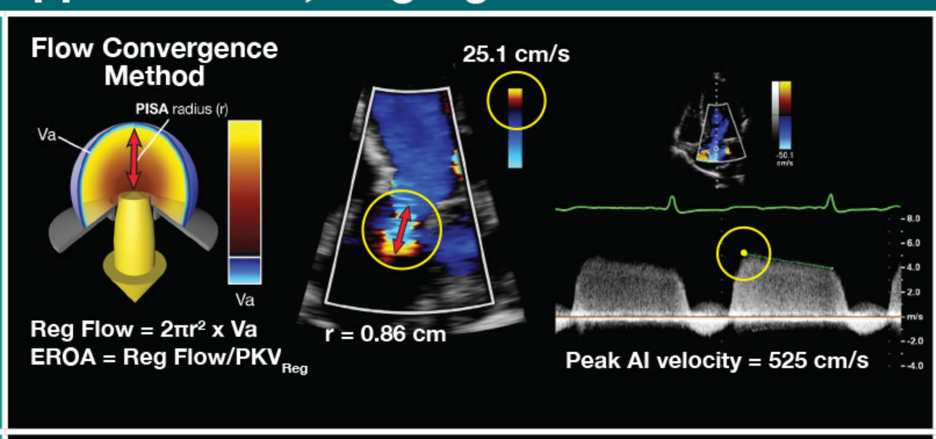
Advantages:
- Simple
- Specific sign of pressure relation between Ao and LV

Disadvantages:
- Qualitative
- Poor alignment of Doppler beam may result in lower PHT
- Affected by changes that modify LV-Ao pressure gradient (If short, implies significant AR or high LV filling pressure)

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

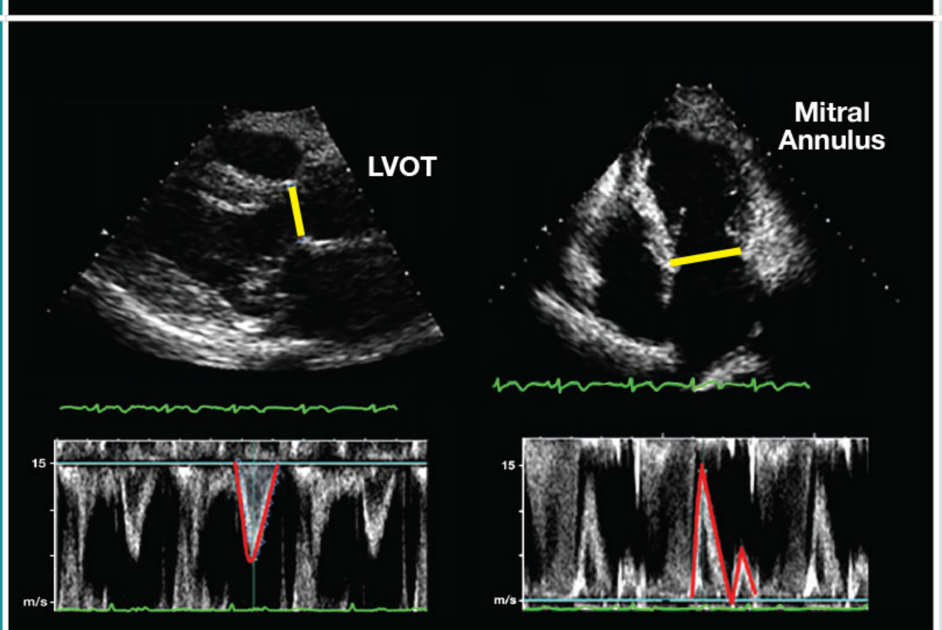


Advantage:
- Rapid quantitative assessment of lesion severity (EROA) and volume overload (R Vol)

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= SV_{LVOT} - SV_{MV}

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)

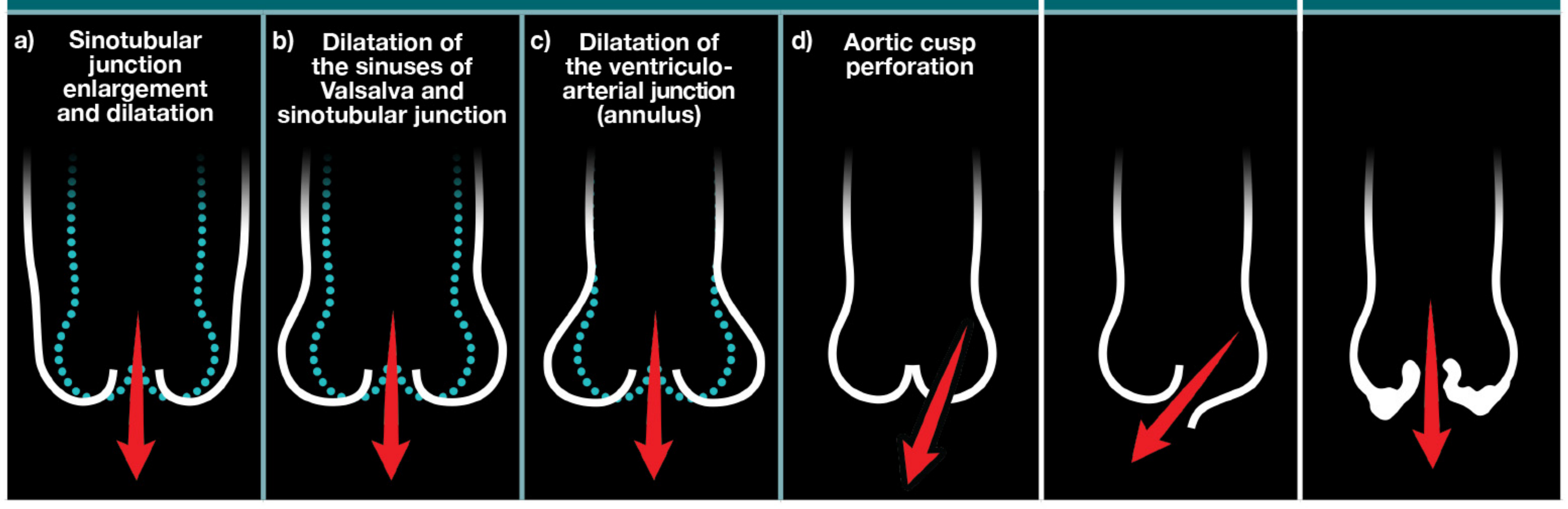


SV_{LVOT}= $Area_{LVOT}$ x VTI_{LVOT} SV_{MV}= $Area_{MV}$ x VTI_{MV}

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

Type I — Normal Cusp Motion with Aortic Dilation or Cusp Perforation | Type II — Cusp Prolapse | Type III — Cusp Restriction



Grading the Severity of Chronic AR by Echocardiography[1]

Parameters	Mild	Moderate		Severe
Structural Parameters				
Aortic leaflets	Normal or abnormal	Normal or abnormal		**Abnormal/flail, or wide coaptation defect**
LV size	**Normal**[2]	Normal or dilated		Usually dilated[3]
Qualitative Doppler				
Jet width in LVOT, color flow	**Small in central jets**	Intermediate		**Large in central jets;** variable in eccentric jets
Flow convergence, color flow	**None or very small**	Intermediate		**Large**
Jet density, CW	**Incomplete or faint**	Dense		Dense
Jet deceleration rate, CW (PHT, msec)[4]	Incomplete or faint, Slow >500	Medium 500-200		**Steep <200**
Diastolic flow reversal in descending aorta, PW	**Brief, early diastolic reversal**	Intermediate		**Prominent holodiastolic reversal**
Semiquantitative[5]				
VCW (cm)	<0.3	0.3-0.6		>0.6
Jet width/LVOT width, central jets (%)	<25	25-45	46-64	≥65
Jet CSA/LVOT CSA, central jets (%)	<5	5-20	21-59	≥60
Quantitative parameters[5]				
RVol (mL/beat)	<30	30-44	45-59	≥60
RF	<30%	30-39%	40-49%	≥50%
EROA (cm^2)	<0.10	0.10-0.19	0.20-0.29	≥0.30

PHT, Pressure half-time; *PW,* pulsed wave Doppler.
Color Doppler usually performed at Nyquist limit of 50-70 cm/sec.

1. Bolded signs are considered specific for their AR 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. Unless there are other reasons for LV dilation.
3. Specific in normal LV function, in absence of causes of volume overload. Exception: acute AR, in which chambers have not had time to dilate.
4. PHT is shortened with increasing LV diastolic pressure and may be lengthened in chronic adaption to severe AR.
5. Quantitative parameters can subclassify the moderate regurgitation group.

Chronic Aortic Regurgitation by Echocardiography

Does AR meet specific criteria for mild or severe AR?

Yes, mild* → **Specific Criteria for Mild AR**
- VCW <0.3 cm
- Central Jet, <25% of LVOT
- Small or no flow convergence
- Soft or incomplete jet by CW
- PHT >500 ms
- Normal LV size

Yes, severe* → **Specific Criteria for Severe AR**
- Flail Valve
- VC width >0.6 cm
- Central jet, width ≥65% of LVOT
- Large flow convergence
- Prominent holodiastolic flow reversal in the decending aorta
- Enlarged LV with normal function

Intermediate Values: AR Probably Moderate

2-3 criteria → **Perform quantitative methods whenever possible to refine assessment** ← 2-3 criteria

≥4 criteria definitely mild (quantitation not needed) → Mild AR

≥4 criteria definitely severe (may still quantitate) → Severe AR

AR Grade I	AR Grade II	AR Grade III	AR Grade IV
RVol <30 ml RF <30% EROA <0.10 cm^2	RVol 30-44 ml RF 30-39% EROA 0.10-0.19 cm^2	RVol 45-59 ml RF 40-49% EROA 0.20-0.29 cm^2	RVol ≥60 ml RF ≥50% EROA ≥0.30 cm^2

AR Grade I → **Mild AR**; AR Grade II, AR Grade III → **Moderate AR**; AR Grade IV → **Severe AR**; 3 specific criteria for severe 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.

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; Neil J. Weissman, MD, FASE. 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. J Am Soc Echocardiogr 2017; 30: 303-371.

Poster ordering information and full text of ASE guideline documents available at: ASEcho.org

American Society of Echocardiography

Evaluation of Tricuspid and Pulmonic Regurgitation

Tricuspid Regurgitation

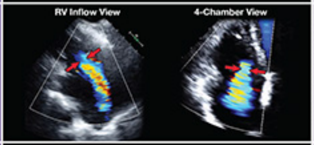
A. Color Flow Doppler (2D and 3D)

Proximal Flow Convergence
1. Align direction of flow with insonation beam
2. Zoomed view
3. Variance off
4. Change baseline of Nyquist limit in the direction of the jet and adjust to obtain hemispheric flow convergence (typically ~28 cm/s)
5. Measure the radius (white arrow in image) from the point of color aliasing to the vena contracta

Advantage:
- Rapid qualitative assessment

Disadvantages:
- Multiple jets
- Non-hemispheric shape

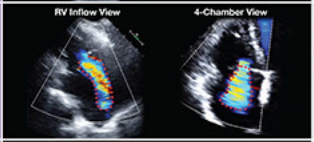
Vena Contracta
1. Zoomed view
2. Apical 4 ch view
3. RV Inflow view



Advantages:
- Surrogate for regurgitant orifice size
- Independent of flow rate and driving pressure for a fixed orifice
- Less dependent on technical factors
- Good at identifying severe TR (>0.7cm)

Disadvantages:
- Underestimates severity with multiple jets
- Imaging of convergence zone for measurement

Jet Area:
1. 4 ch, RV inflow or subcostal views

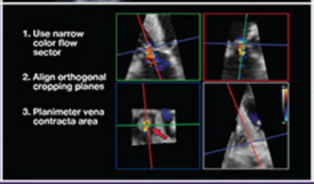


Advantage:
- Easy to measure

Disadvantages:
- Dependent on the driving pressure and jet direction
- Direction and shape of jet may overestimate (central entrainment) or underestimate (eccentric, wall-impinging) jet area

3D Vena Contracta
1. Color flow sector should be narrow
2. Align orthogonal cropping planes along the axis of the jet
3. Choose a mid-systolic cycle and planimeter the vena contracta area

Note: Non-coaxial jets or aliased flow may appear "laminar" but still represent regurgitant flow

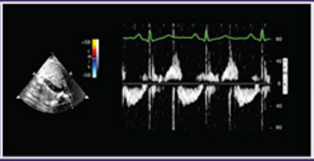


Advantage:
- Multiple jets of differing directions may be measured

Disadvantages:
- Dynamic jets may be over- or underestimated
- Time consuming
- Limited spatial resolution will lead to overestimation

B. Pulsed Wave Doppler

Hepatic Vein Flow Reversal
1. Align insonation beam with the flow in the hepatic vein

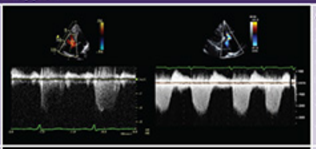


Advantages:
- Simple supportive sign of severe TR
- Can be obtained with both TTE and TEE

Disadvantages:
- Depends on compliance of the right atrium
- May not be reliable in patients with atrial fibrillation, paced rhythm with retrograde atrial conduction

C. Continuous Wave Doppler

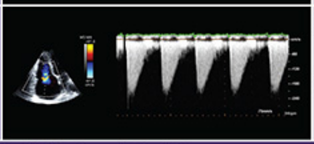
Density of Regurgitant Jet
1. Align insonation beam with the flow



Advantages:
- Simple
- Density is proportional to the number of red-blood cells reflecting the signal
- Faint or incomplete jet is compatible with mild TR

Disadvantages:
- Qualitative
- Perfectly central jets may appear denser than eccentric jets of higher severity
- Overlap between moderate and severe TR

Jet Contour
1. Align insonation beam with the flow

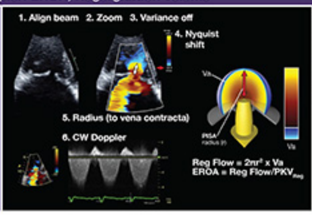


Advantages:
- Simple
- Specific sign of pressure equalization in low velocity, early peaking dense TR jet

Disadvantages:
- Qualitative
- Affected by changes that modify RV and RA pressures

D. Quantitative Doppler: EROA, Regurgitation Volume

PISA:
1. Align direction of flow with insonation beam
2. Zoomed view
3. Variance off
4. Change baseline of Nyquist limit in the direction of the jet and adjust to obtain hemispheric flow convergence (typically ~28 cm/s)
5. Measure the radius (white arrow) from the point of color aliasing to the vena contracta
6. CW Doppler of regurgitant jet for peak velocity and VTI



Advantage:
- Quantitative assessment of lesion severity (EROA) and volume overload (RVol)

Disadvantages:
- Not valid for multiple jets, less accurate in eccentric jets
- Limited experience and evidence
- Typically lower RV pressures (than LV) lead to greater contour flattening and underestimation in proportion to the ratio of the aliasing velocity to the peak TR velocity

Grading the Severity of Chronic TR by Echocardiography[1]

Parameters	Mild	Moderate	Severe
Structural			
TV morphology	**Normal or mildly abnormal leaflets**	Moderately abnormal leaflets	**Severe valve lesions** (e.g., flail leaflet, severe retraction, large perforation)
RV and RA size	Usually normal	Normal or mild dilation	Usually dilated[2]
Inferior vena cava diameter	Normal <2cm	Normal or mildly dilated 2.1-2.5cm	Dilated >2.5cm
Qualitative Doppler			
Color flow jet area[3]	**Small, narrow, central**	Moderate central	**Large central jet** or eccentric wall-impinging jet of variable size
Flow convergence zone	**Not visible, transient or small**	Intermediate in size and duration	**Large throughout systole**
CWD jet	**Faint/partial**/parabolic	Dense, parabolic or triangular	Dense, often triangular
Semiquantitative			
Color flow jet area (cm²)[3]	Not defined	Not defined	>10
VCW (cm)[3]	<0.3	0.3-0.69	≥0.7
PISA radius (cm)[4]	≤0.5	0.6-0.9	>0.9
Hepatic vein flow[5]	Systolic dominance	Systolic blunting	**Systolic flow reversal**
Tricuspid inflow[5]	**A-wave dominant**	Variable	E-wave >1.0m/sec
Quantitative			
EROA (cm²)	<0.20	0.20-0.39[6]	≥0.40
RVol (mL/beat)	<30	30-44[6]	≥45

RA, Right Atrium
1. Bolded signs are considered specific for their TR grade.
2. RV and RA size can be within the "normal" range in patients with acute severe TR.
3. With Nyquist limit >50-70 cm/sec.
4. With baseline Nyquist limit shift of 28 cm/sec.
5. Signs are nonspecific and are influenced by many other factors (RV diastolic function, atrial fibrillation, RA pressure).
6. There are little data to support further seperation of these values.

Chronic Tricuspid Regurgitation by Echocardiography

Does TR meet specific criteria for mild or severe TR?

Yes, mild → **Criteria for Mild TR**
- Thin, small central color jet
- VC width <0.3 cm
- PISA Radius ≤0.5 cm and Nyquist 30-40 cm/s
- Incomplete or faint CW jet
- Systolic dominant Hepatic vein flow
- Tricuspid A-wave dominant inflow
- Normal RV/RA

→ Mild TR

No → **Minority of criteria or intermediate values: TR probably moderate** → **Perform VC measurements and may perform quantitative PISA method whenever possible***
- VC width <0.3 cm, *EROA <0.2 cm², *RVol <30 mL → Mild TR
- VC width 0.3-0.69 cm, *EROA 0.2-0.4 cm², *RVol 30-44 mL → Moderate TR
- VC width ≥0.7 cm, *EROA >0.4 cm², *RVol ≥45 mL → Severe TR

Yes, severe → **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 30-40 cm/s
- Dense, triangular CW jet or sine wave pattern
- Systolic reversal of Hepatic vein flow

→ Severe TR

* Clinical experience in quantitation of TR is sparce

Chronic Pulmonic Regurgitation by Echocardiography

Does PR meet specific criteria for mild or severe PR?

Yes, mild → **Criteria for Mild PR**
- Small jet, with narrow width
- Soft or faint CW jet
- Slow deceleration time
- Normal RV size

→ Mild PR

No → **Minority of criteria or intermediate values: PR probably moderate** → **May perform volumetric quantitative methods, if possible whenever significant PR is suspected***
- RF <20% → Mild PR
- RF 20-40% → Moderate PR
- RF >40% → Severe PR

Yes, severe → **Specific Criteria for Severe PR**
- Jet width/annulus ≥70%
- Dense jet, PHT < 100 ms
- Early termination of PR flow
- Diastolic flow reversal in PA branches
- Dilated RV with NL function

→ Severe PR

* Clinical experience in quantitation of PR is sparce

- Poor TTE quality or low confidence in measured Doppler parameters
- Discordant quantitative and qualitative parameters and/or clinical data

→ **Indeterminate Regurgitation** Consider CMR for quantitation

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; Neil J. Weissman, MD, FASE.

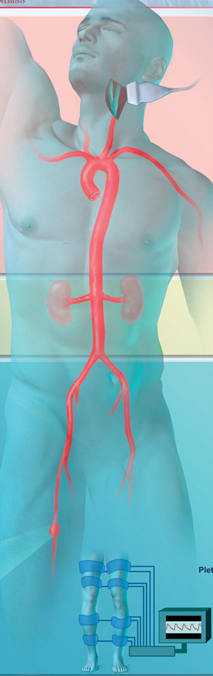
Recommendations for Noninvasive Evaluation of Native Valvular Regurgitation: A Report from the American Society of Echocardiography Developed in Collaboration with the Society for Cardiovascular Magnetic Resonance. J Am Soc Echocardiogr 2017; 30: 303-371.

Poster ordering information and full text of ASE guideline documents available at: ASEcho.org

Design and illustration by medmovie.com

American Society of Echocardiography
Heart and Circulation Ultrasound Specialists

Guidelines for Noninvasive Vascular Testing

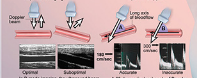


Carotid Arteries

Criteria for Arterial Stenosis

Elevated velocities: Diagnostic criteria include elevations in: (1) peak systolic velocity (e.g.>125 cm/sec), (2) ratios of distal to proximal sequential peak systolic velocities (e.g., 2:1); (3) end-diastolic velocity. Supportive criteria include aliasing of color Doppler signal.
Diameter reduction: Transverse or longitudinal measurements indicating reduction in luminal diameter are supportive, not diagnostic.
Spectral Broadening or Color Mosaic Pattern: Presence of turbulent flow is supportive, not diagnostic. It is most prominent just distal to significant stenosis.
Color Bruit, Color Persistence: Color bruit, providing evidence of vibration in tissue surrounding arterial narrowing, is supportive, not diagnostic. Continuous forward flow, or persistence, is supportive evidence.

Recording Techniques

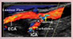


In B-mode imaging, the ultrasound beam should be aligned perpendicular to the vessel of interest (arrows, left panel) to produce the most distinct echoes, as in the optimal carotid B-mode image, which demonstrates the trilaminar structure of the arterial wall. In contrast, the wall structure is suboptimally defined using a non-perpendicular imaging angle (arrows, right panel).

A 60-degree (or less) angle of Doppler insonation relative to the long axis of blood flow (e.g., angle A above) provides clinically acceptable Doppler velocity measurements. With Doppler angles >60°, as shown in the right panel (angle B), angle correction may be inaccurate and often over-estimates (peak) Doppler velocities.

Color Doppler Carotid Examination

Color Doppler image obtained at carotid bifurcation. Laminar flow in the external carotid artery (ECA) is demonstrated by homogenous color with lightest color toward center of vessel. Aliasing is evident at origin of ICA by abrupt color change from red to blue at origin of the internal carotid artery (ICA) where a large echolucent plaque (*) is present. A mosaic of color fills remainder of ICA, consistent with poststenotic turbulence.



Differentiation of ICA and ECA

Internal Carotid Artery	External Carotid Artery
Usually larger	Usually smaller
Usually lateral and posterior	Usually medial and anterior
Usually incorporates carotid bulb	Usually does not incorporate bulb
No branches in the neck	Eight branches in the neck
Low resistance spectral waveform	High resistance spectral waveform at rest
Usually no oscillations in Doppler on temporal tap test	Visible and audible oscillations on Doppler signal waveform on temporal tap test

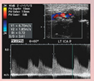
Pulsed Doppler Spectral Waveform Analysis

Degree of Stenosis(%)	ICA/PSV (cm/sec)	Plaque Estimate(%)	ICA EDV(cm/sec)	ICA: CCA PSV Ra.
Normal	<125	0	<40	<2
<50	<125	<50	<40	<2
50-69	125-230	>50	40-100	2-4
>70	>230	>50	>100	>4
Subtotal Occlusion	Variable	>50 Narrow Lumen	>0	Variable
Total Occlusion	0	>50	0	<1

CCA Common Carotid Artery, EDV End-Diastolic Velocity, ICA Internal Carotid, PSV PeakSystolic Velocity

Internal Carotid Artery (ICA) Stenosis

This Duplex image demonstrates the sample volume cursor parallel to the artery wall, at the site of color aliasing and luminal narrowing. The spectral Doppler demonstrates high peak systolic velocity (670 cm/sec), high end-diastolic velocity (185 cm/sec) and spectral broadening (turbulence). These findings indicate severe (80-99%) internal carotid artery stenosis.



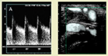
Renal Arteries

Criteria for Renal Artery Stenosis

Renal artery to aorta peak systolic velocity ratio is >3.5
PSV>200 cm/sec with evidence of post stenotic turbulence
EDV>150 cm/sec (population with >80% renal artery stenosis)
RI>0.8 (used to predict response of blood pressure, renal function, to renal revascularization)
An occluded renal artery demonstrates no flow in the affected vessel

RI=Resistive Index (1-[End Diastolic Velocity/Maximum Systolic Velocity] x 100)
(PSV) Peak Systolic Velocity, (EDV)End Diastolic Velocity

Duplex Evidence for Renal Artery Stenosis



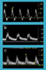
Panel A demonstrates renal artery stenosis. Doppler spectral waveform demonstrates turbulence with marked elevation in peak systolic and end-diastolic velocities. Panel B demonstrates "power" Doppler recording indicating the luminal narrowing (*) at the site of stenosis.

Lower Extremities

Criteria for Abnormal Segmental Pressure

Level of Disease	Findings
Aortoiliac	High Thigh/brachial index <0.9 bilaterally
Iliac	High Thigh/brachial index <0.9
Superficial Femoral Artery (SFA) Disease	Gradient between high and low thigh cuffs
Distal SFA/Popliteal	Gradient between thigh cuff and calf cuff
Infrapopliteal	Gradient between calf and ankle cuffs
Pressure gradient between 20-30 mmHg is borderline, ≥ 30 mmHg is abnormal	

Peripheral Arteries



A. Normal laminar flow with narrow range of velocities throughout cardiac cycle. The cross is placed above a clear spectral envelope.

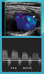
B. Biphasic Doppler waveform with loss of reverse diastolic flow and and mild widening of the spectral envelope (spectral broadening) suggestive of mild atherosclerosis without hemodynamically significant stenosis.

C. Turbulent flow with spectral broadening and low peak systolic velocities indicative of hemodynamically-significant stenosis proximal to this waveform.

Pseudoaneurysm

A. Color Doppler of a pseudoaneurysm sac demonstrating thrombus (*) lining the cavity. Color flow is evident within cavity.

B. Unique "to and fro" spectral Doppler recording in neck of pseudoaneurysm is diagnostic of pseudoaneurysm.



Criteria for Diagnosis of Pseudoaneurysm Sac

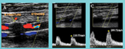
Extravascular arterial sac with flow
Communication between sac and artery
Native artery with forward and reverse flow, i.e. "to and fro"

Criteria for Peripheral Arterial Diameter Reduction

	Diameter Reduction	Waveform	Spectral Broadening	PSV distal/PSV proximal
Normal	0	Triphasic	Absent	no change
Mild	1-19%	Triphasic	Present	< 2:1
Moderate	20-49%	Biphasic	Present	< 2:1
Severe	50-99%	Monophasic	Present	> 2:1*

(* >4:1 suggests >75% stenosis, > 7:1 suggests > 90% stenosis)

Superficial Femoral Artery Post-Intervention



A. Color Doppler with laminar flow, followed by loss of color signal at site of stent fracture and a complex calcific atherosclerotic plaque, with aliasing distal to stent fracture.

B. Spectral Doppler proximal to site of fracture with turbulent flow.

C. Peak systolic velocity increases distal to fracture within an area suggestive of 50-99% stenosis

Criteria for Arterial Stenosis Post-Revascularization

Peak Systolic Velocity(PSV) > 180 cm/s
PSV ratios >2 indicate significant stenosis
Changes in waveform shape and velocity measurements on serial examinations warrant close interval follow-up.

Plethysmography

Normal
- Sharp upstroke
- Scooped or flat interval between peaks
- Dicrotic notch

Mildly Abnormal
- Sharp upstroke
- No flat period or scooping between peaks
- No dicrotic notch

Moderately Abnormal
- Flat peak
- Equal upslope and downslope time
- No dicrotic notch

Severely Abnormal
- Flat peak
- Equal upslope and downslope time
- Low amplitude

Poster ordering information and full text of ASE guideline documents available at: www.asecho.org

Adapted from: Gerhard-Herman M, Gardin JM, Jaff M, Mohler E, Roman M, Naqvi TZ. Guidelines for Noninvasive Vascular Laboratory Testing: A Report from the American Society of Echocardiography and the Society of Vascular Medicine and Biology. J Am Soc Echocardiogr 2006;19:955-972.

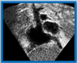
American Society of Echocardiography
Heart and Circulation Ultrasound Specialists

Guidelines for Pediatric Echocardiography

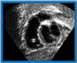

A1 Suprasternal transverse

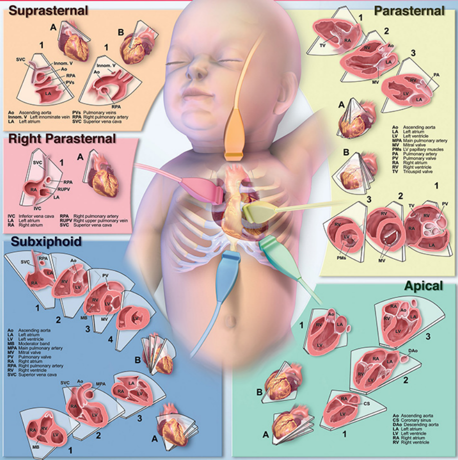

B1 Suprasternal aortic arch


A1 Right parasternal


B1 Subxiphoid short-axis


B2 Subxiphoid short-axis

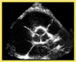

B3 Subxiphoid short-axis




A1 Parasternal long-axis

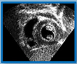

A2 Parasternal long-axis

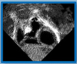

A3 Parasternal long-axis


B1 Parasternal short-axis


B2 Parasternal short-axis

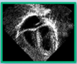

B3 Parasternal short-axis

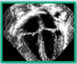

B4 Subxiphoid short-axis


A1 Subxiphoid long-axis

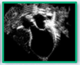

A2 Subxiphoid long-axis


A3 Subxiphoid long-axis


A1 Apical 4-chamber


A2 Apical 4-chamber


A3 Apical 4-chamber


B1 Apical long-axis

Measurements of Structures

Measurement	Timing	View(s)
Tricuspid Valve Annulus	Diastole	Apical 4
Pulmonary Valve Annulus	Systole	PSAX/PLAX
Main Pulmonary Artery	Systole	PSAX/PLAX
Left/Right Pulmonary Artery	Systole	PSAX/PLAX
Left Atrial Diameter	Diastole	PLAX
Mitral Valve Diameter	Diastole	PLAX/Apical 4
Aortic Valve Annulus	Systole	PLAX
Aortic Root	Systole	PLAX
Ascending Aorta	Systole	PLAX
Transverse Aortic Arch	Systole	SSN
Aortic Isthmus	Systole	SSN

Apical 4-chamber (Apical 4), Parasternal long axis (PLAX), Parasternal short axis (PSAX), Suprasternal notch view (SSN)

Doppler Measurements

Structure	Measurements*
Tricuspid Valve	E wave velocity, A wave velocity, deceleration time, IVRT, mean gradient, regurgitant jet velocity
RV Outflow	peak gradient, mean gradient, VTI
Pulmonary Valve	peak gradient, mean gradient, regurgitant jet velocity, VTI
Branch Pulmonary Artery	peak gradient, mean gradient, VTI
Mitral Valve	E wave velocity, A wave velocity, deceleration time, IVRT, mean gradient
LV Outflow	peak gradient, mean gradient, VTI
Aortic Valve	peak gradient, mean gradient, VTI, pressure half-time
Aortic Arch	peak gradient, mean gradient, VTI

Isovolumic relaxation time (IVRT), Velocity time integral (VTI)
*Recording of images adequate for the measurements listed should be considered for inclusion in a complete examination protocol. This is not intended to be a comprehensive list of recommended Doppler measurements.

Report Elements

- Patient identifier data
  - Name
  - Date of birth
  - Medical record identifier
- Date of study
- Location of study
- Referring physician
- Patient height & weight (for body surface area calculation)
- Sedation used
- Indications for pediatric echocardiographic study
- Sonographer/Physician who performed the study
- Findings section
  - Structural/anatomic features
  - Quantitative data
  - Doppler (hemodynamic) findings
- Summary section

Poster ordering information and full text of ASE guideline documents available at: www.asecho.org

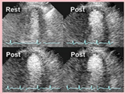
Adapted from: Wyman W. Lai, MD, MPH, FASE, Tal Geva, MD, FASE, Girish S. Shirali, MD, Peter C. Frommelt, MD, Richard A. Humes, MD, FASE, Michael M. Brook, MD, Ricardo H. Pignatelli, MD, and Jack Rychik, MD Guidelines and Standards for Performance of a Pediatric Echocardiogram: A Report from the Task Force of the Pediatric Council of the American Society of Echocardiography. J Am Soc Echocardiogr 2006; 19:1413-1430.

Design and illustration by medmovie.com

ASE American Society of Echocardiography
Heart & Circulation Ultrasound Specialists

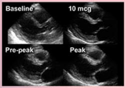
Guidelines for Stress Echocardiography

Exercise Stress Testing

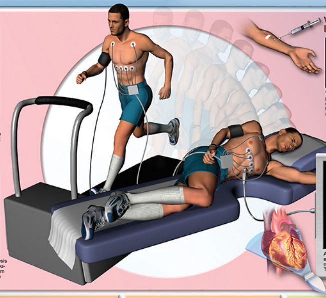


Apical two-chamber view of a single rest image is compared with three post exercise images. With exercise, there was an increase in end systolic volume with akinesis of the apex in this patient with severe left anterior descending stenosis.

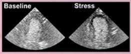
Dobutamine Stress Echocardiography



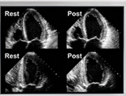
Parasternal long axis views show mild global hypokinesis at rest, augmentation of contractility with low dose dobutamine (viability), hypokinesis of the distal anteroseptum at pre-peak, and near global hypokinesis at peak. The patient had multivessel coronary artery disease.



Vasodilator Stress Echocardiography

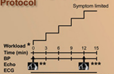


Vasodilator stress echocardiography with myocardial perfusion imaging. Perfusion and wall motion were normal at baseline. With stress, there was severe hypoperfusion (contrast defect) of the apex with accompanying akinesis of this region.



Apical images before (left) and after (right) treadmill exercise. There were no regional wall motion abnormalities, but the end systolic volume did not decrease. This may occur with a hypertensive response.

Exercise Echocardiography Protocol

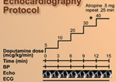


* Increase treadmill speed and grade or bicycle resistance
** Longer echo exam
*** Echo imaging completed in 1 min after exercise, then repeated

Images obtained at rest and immediately post exercise.

Reasons for Stopping Test
- Maximum exercise until fatigue or symptoms
- Significant arrhythmia
- Hypotension, severe hypertension

Dobutamine Echocardiography Protocol



* Atropine may be administered at an earlier stage

Images obtained at rest and at each stage of stress.

Reasons for Stopping Test
- Peak dose
- Target heart rate .85 (220-age)
- Moderate or extensive wall motion abnormalities
- Significant arrhythmia
- Hypotension, severe hypertension
- Intolerable symptoms

Stress Echocardiography Report

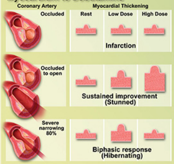
Wall Motion: Rest
Score index 1.06 (normal 1.00)

Wall Motion: Stress (Worsening wall motion abnormality)
Score index 1.12

Legend and score values
- Normal
- Hypokinesis
- Akinesis
- Dyskinesis
- Aneurysm
- Not seen
- Scarred

Summary
- Exercise echo mildly positive for ischemia
- Good exercise capacity (8 minutes Bruce protocol, 102% functional aerobic capacity)
- Rest images: Normal left ventricular size, ejection fraction of 56%, inferior wall hypokinesis
- Exercise images: Decrease in end systolic size; inferior wall worsened

Response of Infarcted and Viable Myocardium to Dobutamine



Stress Echocardiography Predictors of Risk

	Regional		Global	
Stress Method	**Normal Response**	**Ischemic Response**	**Normal Response**	**Ischemic Response**
Treadmill	Post-exercise increase in function compared to rest	Post-exercise decrease in function compared to rest	Decrease in ESV Increase in EF	Increase in ESV Decrease in EF in multivessel or L main disease
Supine Bicycle	Peak exercise increase in function compared to rest	Peak exercise decrease in function compared to rest	Decrease in ESV Increase in EF	Increase in ESV and decrease in EF in multivessel or L main disease
Dobutamine	Increase in function, velocity of contraction compared to rest and usually to low dose	Decrease in function, velocity of contraction compared to low dose; may be less compared to rest	Greater decrease in ESV, marked increase in EF	Infrequently, ischemia produces decreased EF; cavity dilatation rarely occurs
Vasodilator	Increase in function compared to rest	Decrease in function compared to rest	Decrease in ESV Increase in EF	Occasionally, ischemia produces decreased EF; cavity dilatation occurs infrequently
Atrial Pacing	No change or increase in function compared to rest	Decrease in function compared to rest	Decrease in ESV No change in EF	No change or increase ESV, decrease in EF

Normal and Ischemic Responses for Stress Modalities

Very Low Risk MI, Cardiac Events < 1% per yr	**Low Risk** MI, Cardiac Death < 2% per yr	**Factors Increasing Risk**	**High Risk** RR > 4 Fold Over Low Risk
• Normal exercise echocardiogram with good exercise capacity • 7 METs men • 5 METs women	• Normal pharmacologic stress echocardiogram with adequate stress, defined as achievement of HR > 85% age-predicted maximum for dobutamine stress, and low to intermediate pretest probability of CAD	• Increasing age • Male gender • Diabetes • High pretest probability • History of dyspnea or CHF • History of myocardial infarction • Limited exercise capacity • Inability to exercise • Stress ECG with ischemia • Rest WMA • Left ventricular hypertrophy • Stress echo with ischemia • Reduced baseline EF • No change or increase ESV with stress • No change or decrease EF with stress • Increasing wall motion score with stress	• Extensive Rest WMA (4 to 5 segments of LV) • Baseline EF < 40% • Extensive ischemia (4 to 5 segments of LV) • Multivessel ischemia • Rest WMA & remote ischemia • Low ischemic threshold • Ischemia with 0.56 mg/kg dipyridamole or 20 mcg/kg/min dobutamine or based on heart rate • Ischemic WMA, no change or decrease in exercise EF

Poster ordering information and full text of ASE guideline documents available at: www.asecho.org

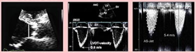
Adapted from: Pellikka PA, Nagueh SF, Elhendy AA, Kuehl CA, Sawada SG. American Society of Echocardiography Recommendations for Performance, Interpretation, and Application of Stress Echocardiography. J Am Soc Echocardiogr 2007 Sept; 20(9):1021-1041.

ASE American Society of Echocardiography
Heart & Circulation Ultrasound Specialists

Echocardiographic Assessment of Valve Stenosis

EUROPEAN ASSOCIATION OF Echocardiography
A Registered Branch of the ESC
EUROPEAN SOCIETY OF CARDIOLOGY®

Aortic Stenosis



Left ventricular outflow tract diameter measured within 0.5 to 1.0 cm of the valve orifice. Left ventricular outflow tract velocity as measured from the apical approach. Continuous wave Doppler of severe aortic stenosis jet.

Data recording and measurement for AS quantitation

Data element	Recording	Measurement
LVOT diameter	• 2D parasternal long axis view. • Zoom mode. • Adjust gain to optimize the blood tissue interface.	• Inner edge to inner edge. • Mid-systole. • Parallel and adjacent to the aortic valve or at the site of velocity measurement (see text). • Diameter is used to calculate a circular CSA.
LVOT velocity	• Pulsed wave Doppler. • Apical long axis or 5-chamber view. • Sample volume positioned just on LV side of valve and moved carefully into the LVOT if required to obtain laminar flow curve. • Velocity baseline and scale adjusted to maximize size of velocity curve. • Time axis (sweep speed) 100 mm/s. • Low wall filter setting. • Smooth velocity curve with a well defined peak and a narrow velocity range at peak velocity.	• Maximum velocity from peak of dense velocity curve. • VTI traced from modal velocity.
AS jet velocity	• CW Doppler (dedicated transducer). • Multiple acoustic windows (e.g. apical, suprasternal, right parasternal, etc). • Decrease gains, increase wall filter, adjust baseline and scale to optimize signal. • Gray scale spectral display with expanded time scale. • Velocity range and baseline adjusted so velocity signal fits but fills the vertical scale.	• Maximum velocity at peak of dense velocity curve. • Avoid noise and fine linear signals. • VTI traced from outer edge of dense signal curve. • Mean gradient calculated from traced velocity curve. • Report window where maximum velocity obtained.
Valve anatomy	• Parasternal long and short axis views. • Zoom mode.	• Identify number of leaflets in systole, raphe if present. • Assess leaflet mobility and commissural fusion. • Assess valve calcification.

CSA: cross sectional area, VTI: velocity-time integral.

Measures of AS severity obtained by Doppler-echocardiography

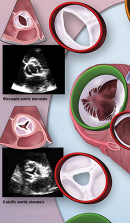
	Units	Formula / Method	Cutoff for Severe	Concept	Advantages
AS jet velocity	m/s	Direct measurement	4.0	Velocity increases as stenosis severity increase.	Direct measurement of velocity. Strongest predictor of clinical outcome.
Mean gradient	mm Hg	$\sum 4v^2 / N$	40* or 50**	Pressure gradient calculated from velocity using the Bernoulli equation.	Mean gradient is averaged from the velocity curve.
Continuity equation valve area	cm^2	$AVA = (CSA_{LVOT} \times VTI_{LVOT}) / VTI_{AV}$	1.0	Volume flow proximal to and in the stenotic orifice is equal.	Measures effective orifice area. Feasible in nearly all patients. Relatively flow independent.
Simplified continuity equation	cm^2	$AVA = (CSA_{LVOT} \times V_{LVOT}) / V_{AV}$	1.0	The ratio of LVOT to aortic velocity is similar to the ratio of VTIs with native aortic valve stenosis.	Uses more easily measured velocities instead of VTIs.

VTI: velocity-time integral, CSA: cross sectional area, V=velocity, N: number of samples. * AHA/ACC Guidelines; ** ESC Guidelines

Classification of AS severity

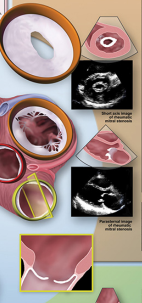
	Aortic sclerosis	Mild	Moderate	Severe
Aortic jet velocity (m/s)	≤2.5 m/s	2.6-3.0	3-4	>4
Mean gradient (mm Hg)		<20 (<30**)	20-40* (30-50**)	>40* (>50**)
AVA (cm^2)		>1.5	1.0-1.5	<1.0
Indexed AVA (cm^2/m^2)		>0.85	0.60-0.85	<0.6
Velocity ratio		>0.50	0.25-0.50	<0.25

* AHA/ACC Guidelines; ** ESC Guidelines



Bicuspid aortic stenosis

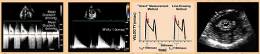
Calcific aortic stenosis



Short axis image of rheumatic mitral stenosis

Parasternal image of rheumatic mitral stenosis

Mitral Stenosis



Determination of mean mitral gradient from Doppler diastolic mitral flow in a patient with severe mitral stenosis in atrial fibrillation. Estimation of mitral valve area using the pressure half-time method. Determination of T1/2 with a bimodal, non-linear slope of the E-wave. The deceleration slope should not be traced from the early part (left), but using the extrapolation of the linear mid-portion of the mitral velocity profile (right). Planimetry of the mitral orifice. Transthoracic echocardiography, parasternal short-axis view.

Approaches to evaluation of mitral stenosis

Measurement	Units	Formula / Method	Concept	Advantages	Disadvantages
Valve area					
- planimetry by 2D echo	cm^2	tracing mitral orifice using 2D echo	direct measurement of anatomic MVA	- accuracy - independence from other factors	- experience required - not always feasible (poor acoustic window, severe valve calcification)
- pressure half-time	cm^2	$220 / T_{1/2}$	rate of decrease of transmitral flow is inversely proportional to MVA	easy to obtain	dependence on other factors (AR, LA compliance, LV diastolic function)
Mean gradient	mm Hg	$\Delta P_{mitral} = \sum 4v^2_{mitral} / N$	pressure gradient calculated from velocity using the Bernoulli equation	easy to obtain	dependent on heart rate and flow conditions
Systolic pulmonary artery pressure	mm Hg	$sPAP = 4v^2_{Tricuspid} + RA_{Pressure}$	addition of RA pressure and maximum gradient between RV and RA	obtained in most patients with MS	- arbitrary estimation of RA pressure - no estimation of pulmonary vascular resistance

AR: aortic regurgitation, LA: left atrium, LV: left ventricle, MVA: mitral valve area, ΔP: gradient, sPAP: systolic pulmonary artery pressure, RA: right atrium, RV: right ventricle, $T_{1/2}$: pressure half-time, V=velocity.

Data recording and measurement in routine use for mitral stenosis quantitation

Data element	Recording	Measurement
Planimetry	- determine the smallest orifice by scanning from apex to base - positioning of measurement plan can be oriented by 3D echo - lowest gain setting to visualize the whole mitral orifice	- contour of the inner mitral orifice - include commissures when opened - in mid-diastole (use cine-loop) - average measurements if atrial fibrillation
Mitral flow	- continuous-wave Doppler - apical windows often suitable (optimize intercept angle) - adjust gain setting to obtain well-defined flow contour	- mean gradient from the traced contour of the diastolic mitral flow - pressure half-time from the descending slope of the E-wave (mid-diastole slope if not linear) - average measurements if atrial fibrillation
Systolic pulmonary artery pressure	- continuous-wave Doppler - multiple acoustic windows to optimize intercept angle	- maximum velocity of tricuspid regurgitant flow - estimation of right atrial pressure according to inferior vena cava diameter
Valve Anatomy	- parasternal short-axis view	- valve thickness (maximum and heterogeneity) - commissural fusion - extension and location of localized bright zones (fibrous nodules or calcification)
	- parasternal long-axis view	- valve thickness - extension of calcification - valve pliability - subvalvular apparatus (chordal thickening, fusion, or shortening)
	- apical two-chamber view	- subvalvular apparatus (chordal thickening, fusion, or shortening) Detail each component and summarize in a score

Classification of mitral stenosis severity

	Mild	Moderate	Severe
Specific findings			
Valve area (cm^2)	> 1.5	1.0 - 1.5	< 1.0
Supportive findings			
Mean gradient (mm Hg)*	< 5	5-10	> 10
Pulmonary artery pressure (mm Hg)	< 30	30-50	> 50

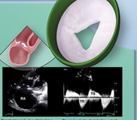
* at heart rates between 60 to 80 beats per minute and in sinus rhythm

Tricuspid Stenosis

Findings indicative of hemodynamically significant tricuspid stenosis

Specific Findings	
Mean pressure gradient	≥ 5 mm Hg
Inflow time velocity integral	> 60 cm
T½	≥ 190 ms
Valve area by continuity equation*	≤ 1 cm^2
Supportive Findings	
Enlarged right atrium ≥ moderate	
Dilated inferior vena cava	

*Stroke volume derived from left or right ventricular outflow. In the presence of more than mild tricuspid regurgitation, the derived valve area will be underestimated. Nevertheless a value ≤ 1 cm^2 implies a significant hemodynamic burden imposed by the combined lesion.

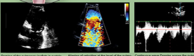


Stenotic tricuspid valve obtained in a modified apical 4-chamber view during diastole. The peak velocity, diastolic time-velocity integral, mean gradient, and pressure half-time by continuous wave Doppler.

Pulmonic Stenosis

Grading of Pulmonary Stenosis

	Mild	Moderate	Severe
Peak Velocity (m/s)	< 3	3-4	>4
Peak gradient (mm Hg)	< 36	36 to 64	>64



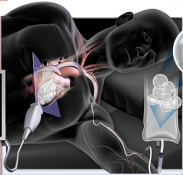
Doming of the pulmonary leaflets in systole noted in valvular pulmonary stenosis. Aliasing of velocities at the level of the pulmonary valve in pulmonary stenosis. Continuous wave Doppler across the pulmonary valve showing increased velocities.

Poster ordering information and full text of ASE guideline documents available at: www.asecho.org

Adapted from: Baumgartner H, Hung J, Bermejo J, Chambers JB, Evangelista A, Griffin BP, Iung B, Otto CM, Pellikka PA, Quiñones M. Echocardiographic Assessment of Valve Stenosis: EAE/ASE Recommendations for Clinical Practice. Eur J Echocardiogr and J Am Soc Echocardiogr 2009.

Consensus Statement on the Clinical Applications of Ultrasonic Contrast Agents in Echocardiography

ASE American Society of Echocardiography
Heart & Circulation Ultrasound Specialists



How to Perform Contrast Ultrasound Imaging

Ultrasound Machine Settings for Left Ventricular Opacification and Endocardial Border Delineation (LVO/EBD)

- Select the low Mechanical Index (MI) preset provided by machine vendor
- Adjust MI to 0.2 to 0.3
- Optimize transmit focus location:
  - Usually far-field location at mitral valve plane
- Minimize background gain prior to contrast injection
- Minimize depth and narrow the sector width to include only those cardiac structures of interest
- Optimize TGCs:
  - Start with TGC's in midline
  - After contrast injection, adjust according to image
  - Decreased in near-field
  - Increased in far-field

LVO/EBD Troubleshooting

- If "swirling": Reduce MI
- If low MI, but contrast not visible:
  - Inject more contrast
  - Use a higher-volume and/or more rapid saline flush
  - Adjust transmit focus to apex
  - Increase MI slightly

Myocardial Perfusion Contrast Echocardiography

Low MI, real-time imaging (destruction-replenishment) for simultaneous assessment of myocardial function (wall motion) and perfusion
[Off-label application]

- Destruction/replenishment technique using "real time" low MI (< 0.2) imaging with intermittent "flash" of high-MI (>1.0)
- At Rest, if normal, homogeneous myocardial contrast replenishment is observed < 5 sec after flash
- At Peak Stress (chronotropic or vasodilator), if normal, homogeneous myocardial contrast replenishment is observed < 2 sec after flash
- In the presence of infarct or ischemia, decreased or absent myocardial contrast is observed

2-Chamber View at End-Systole: Normal Myocardial Perfusion

Before flash | Immediately after flash | 5 seconds after flash

Intravenous Contrast Injection

Infusion Method

- May dilute contrast agent in saline for a total volume of 10 ml (if in syringe), or 50 ml (if in saline bag)
  - for 50-mL saline bag of saline: start infusion at 150 to 200 mL/h
  - for 10-mL syringe, give a slow push of 0.5 to 1 mL every few min
- Adjust infusion rate in accordance with appearance of contrast in the image
- Either method can be used: infusion pump (ideal) or hand push (acceptable)

Bolus Method

Rest Study

- Rate of bolus injection is generally 0.5 to 1.0 mL/s
- After bolus or diluted bolus injections, administer a slow saline flush (2 to 3 mL over 3 to 5 sec)
- When contrast agent is seen in right ventricle, stop flush
- Administer additional IV doses as required

Peak Stress

Treadmill Echocardiography

- Inject contrast agent about 30 sec before exercise termination

Bicycle Exercise Echocardiography

- Inject contrast agent at each stress stage where imaging will be recorded
- About 1- 2 min before image acquisition

Dobutamine Echocardiography

- Contrast agent can be injected through the dobutamine line
- Use Y connectors and 3-way stopcocks
- Turn off stopcock towards dobutamine infusion
- Inject contrast dose through dedicated stopcock port; then close
- Open dobutamine stopcock port to resume infusion, which acts as flush
- Avoid 90° angle connections; avoid having IV line and blood pressure cuff on same arm

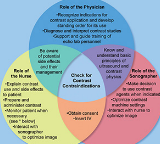
[See package insert for specific details]

Echocardiographic Contrast Agents

Agent	Mean (range) µm	Gas	Shell Composition
Levovist®	2.0-3.0 (2.0-8.0)	Air	Lipid (palmitic acid)
Optison™*	3.0-4.5 (1.0-10.0)	Perfluoropropane	Protein-Type A
Definity®*	1.5 (1.0-10.0)	Perfluoropropane	Phospholipid
SonoVue®	2.5 (1.0-10.0)	Sulfur hexafluoride	Phospholipid

*Available in U.S.

Implementation of Contrast Agent Use: A Team Approach



*When to Monitor (HR, BP, O2 saturation)?
- if cardiopulmonary instability or pulmonary hypertension

How long to monitor?
- for 30 min after contrast injection

Always have resuscitation equipment and trained personnel readily available

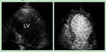
Contrast Ultrasound Contraindications

- Ultrasound contrast agents are not to be administered to patients in whom the following conditions are known or suspected:
  - Right-to-left, bidirectional, or transient right-to-left cardiac shunts
  - Hypersensitivity to perflutren
  - Hypersensitivity to blood, blood products, or albumin (applies to Optison only)

Applications for Ultrasound Contrast Agents

Rest Echo: Poorly Visualized Endocardial Border

- In difficult-to-image patients (≥ 2 endocardial segments not seen)
- If tissue harmonic imaging does not provide adequate cardiac structural definition
- In unique clinical settings: ICU, CCU, ER



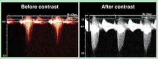
Apical 4-chamber view at end-systole. Left panel: without contrast. Right panel: with contrast; the mid to apical hypokinesis of the left ventricle (LV) is seen well, in this patient with LV apical ballooning syndrome

Contrast Enhancement of Doppler Signals

[Off-label application]

- To enhance Doppler signals
- For a clear definition of Doppler spectral profile when not visible

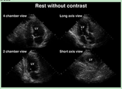
Aortic Stenosis Continuous Wave Doppler Signal

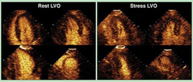


Stress Echo

[Off-label application]

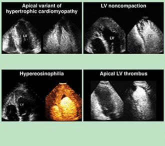
- In patients with reduced image quality
- To obtain diagnostic assessment of segmental wall motion and thickening at rest and stress





Assessment of Cardiac Structural Abnormalities

- To confirm or exclude the echocardiographic diagnosis of cardiac structural abnormalities, when nonenhanced images are suboptimal for definitive diagnosis
- To assist in the detection and correct classification of intracardiac masses including tumors and thrombi

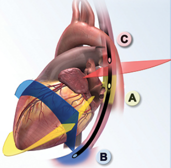


Adapted from: Mulvagh SL, Rakowski H, Vannan MA, Abdelmoneim SS, Becher H, Bierig SM, Burns PN, Castello R, Coon PD, Hagen ME, Jollis JG, Kimball TR, Kitzman DW, Kronzon I, Labovitz AJ, Lang RM, Mathew J, Moir WS, Nagueh SF, Pearlman AS, Perez JE, Porter TR, Rosenbloom J, Strachan GM, Thanigaraj S, Wei K, Woo A, Yu EHC, Zoghbi WA, American Society of Echocardiography Consensus Statement on the Clinical Applications of Ultrasonic Contrast Agents in Echocardiography, J Am Soc Echocardiogr 2008 Nov; 21(11): 1179-1201.

Poster ordering information and full text of ASE guideline documents available at: www.asecho.org

ASE American Society of Echocardiography

Guidelines for Performing a Comprehensive Transesophageal Echocardiographic Examination



A. Midesophageal Views

Acquisition Protocol

1. ME 5 Chamber View — **Transducer Angle:** ~ 0 - 10˚ **Level:** Mid-esophageal **Maneuver** (from prior image): NA

2. ME 4 Chamber View — **Transducer Angle:** ~ 0 - 10˚ **Level:** Mid-esophageal **Maneuver** (from prior image): Advance ± Retroflex

3. ME Mitral Commissural View — **Transducer Angle:** ~ 50 - 70˚ **Level:** Mid-esophageal **Maneuver** (from prior image): NA

4. ME 2 Chamber View — **Transducer Angle:** ~ 80 - 100˚ **Level:** Mid-esophageal **Maneuver** (from prior image): NA

5. ME Long Axis View — **Transducer Angle:** ~ 120 - 140˚ **Level:** Mid-esophageal **Maneuver** (from prior image): NA

6. ME AV LAX View — **Transducer Angle:** ~ 120 - 140˚ **Level:** Mid-esophageal **Maneuver** (from prior image): Withdrawl ± anteflex

7.ME Ascending Aorta LAX View — **Transducer Angle:** ~ 90 - 110˚ **Level:** Upper-Esophageal **Maneuver** (from prior image): Withdrawl

8.ME Ascending Aorta SAX View — **Transducer Angle:** ~ 0 - 30˚ **Level:** Upper-Esophageal **Maneuver** (from prior image): Clockwise

9.ME Right Pulmonary Vein View — **Transducer Angle:** ~ 0 - 30˚ **Level:** Upper-esophageal **Maneuver** (from prior image): CW, Advance

10.ME AV SAX View — **Transducer Angle:** ~ 25 - 45˚ **Level:** Mid-esophageal **Maneuver** (from prior image): CCW, Advance, Anteflex

Acquisition Protocol

11. ME RV Inflow-Outflow View — **Transducer Angle:** ~ 50 - 70˚ **Level:** Mid-esophageal **Maneuver** (from prior image): CW, Advance

12. ME Modified Bicaval TV View — **Transducer Angle:** ~ 50 - 70˚ **Level:** Mid-esophageal **Maneuver** (from prior image): CW

13. ME Bicaval View — **Transducer Angle:** ~90 - 110˚ **Level:** Mid-esophageal **Maneuver** (from prior image): CW

14. UE Right and Left Pulmonary Veins View — **Transducer Angle:** ~ 90 - 110˚ **Level:** Upper-esophageal **Maneuver** (from prior image): Withdraw, CW for the right veins, CCW for the left veins

15. ME Left Atrial Appendage View — **Transducer Angle:**~90 - 110˚ **Level:** Mid-esophageal **Maneuver** (from prior image): Advance

B. Transgastric Views

Acquisition Protocol

16. TG Basal SAX View — **Transducer Angle:** ~ 0 - 20˚ **Level:** Transgastric **Maneuver** (from prior image): Advance ± Anteflex

17. TG Mid Papillary SAX View — **Transducer Angle:** ~ 0 - 20˚ **Level:** Transgastric **Maneuver** (from prior image): Advance ± Anteflex

18. TG Apical SAX View — **Transducer Angle:** ~ 0 - 20˚ **Level:** Transgastric **Maneuver** (from prior image): Advance ± Anteflex

19. TG RV Basal View — **Transducer Angle:** ~ 0 - 20˚ **Level:** Transgastric **Maneuver** (from prior image): Anteflex

20. TG RV Inflow-Outflow View — **Transducer Angle:** ~ 0 - 20˚ **Level:** Transgastric **Maneuver** (from prior image): Right-flex

21. Deep TG 5 Chamber View — **Transducer Angle:** ~ 0 - 20˚ **Level:** Transgastric **Maneuver** (from prior image): Left-flex, Advance, Anteflex

22. TG 2 Chamber View — **Transducer Angle:** ~ 90 - 110˚ **Level:** Transgastric **Maneuver** (from prior image): Neutral flexion, Withdraw

23. TG RV Inflow View — **Transducer Angle:** ~90 - 110˚ **Level:** Transgastric **Maneuver** (from prior image): CW

24.TG LAX View — **Transducer Angle:** ~120 - 140˚ **Level:** Transgastric **Maneuver** (from prior image): CCW

C. Aortic Views

Acquisition Protocol

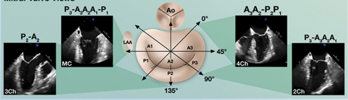
25. Descending Aorta SAX View — **Transducer Angle:** ~ 0 - 10˚ **Level:** Transgastric to Mid-esophageal **Maneuver** (from prior image): Neutral flexion

26. Descending Aorta LAX View — **Transducer Angle:** ~ 90 - 100˚ **Level:** Transgastric to Mid-esophageal **Maneuver** (from prior image): Neutral flexion

27. UE Aortic Arch LAX View — **Transducer Angle:** ~ 0 - 10˚ **Level:** Upper Esophageal **Maneuver** (from prior image): Withdrawl

28. UE Aortic Arch SAX View — **Transducer Angle:** ~ 70 - 90˚ **Level:** Transgastric to Mid-esophageal **Maneuver** (from prior image): NA

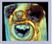
Mitral Valve Views



3D TEE Image Acquisition

Structures Imaged	Acquisition Protocol	
Left Ventricle (Acquire using wide-angle, multi-beat mode)	•Obtain a view of the left ventricle from the 0˚, 60˚, or 120˚ mid-esophageal positions •Use the biplane mode to check that the left ventricle is centered in a second view 90˚ to the original.	
Right Ventricle (Acquire using wide-angle, multi-beat mode)	•Obtain a view of the right ventricle from the 0˚ mid-esophageal position with the right ventricle tilted so that it is in the center of the image	

Structures Imaged	Acquisition Protocol	
Interatrial Septum (Acquire using narrow-angle, single-beat or wide-angle, multi-beat modes)	•Obtain a view of the interatrial septum from the 0˚ mid-esophageal with the probe rotated to the interatrial septum	
Aortic Valve (Acquire using narrow-angle, single-beat or wide-angle, multi-beat modes)	•Obtain a view of the aortic valve from either the 60˚ mid-esophageal, short-axis view or the 120˚ mid-esophageal, long-axis view	

Structures Imaged	Acquisition Protocol	
Mitral Valve (Acquire using narrow-angle, single-beat mode)	•Obtain a view of the mitral valve from the 0˚, 60˚, 90˚, or 120˚ mid-esophageal views •Use the biplane mode to check that the mitral valve annulus is centered in a second view 90˚ to the original.	
Tricuspid Valve (Acquire using narrow-angle, single-beat mode)	•Obtain a view of the tricuspid valve from either the 0˚ to 30˚ mid-esophageal, 4-chamber view tilted so that the valve is centered in the imaging plane or the 40˚ transgastric view with anteflextion	

Rebecca T. Hahn, MD, FASE, Chair, Theodore Abraham, MD, FASE, Mark S. Adams, RDCS, FASE, Charles J. Bruce, MD, FASE, Kathryn E. Glas, MD, MBA, FASE, Roberto M. Lang, MD, FASE, Scott T. Reeves, MD, MBA, FASE, Jack S. Shanewise, MD, FASE, Samuel C. Siu, MD, FASE, William Stewart, MD, FASE and Michael H. Picard, MD, FASE, Guidelines for Performing a Comprehensive Transesophageal Echocardiographic Examination: Recommendations from the American Society of Echocardiography and the Society of Cardiovascular Anesthesiologists. J Am Soc Echocardiogr 2013;26:921-965.

Poster ordering information and full text of ASE guideline documents available at: www.asecho.org