

Ghana Journal of Echocardiography (GJE)

Introduction and Welcome!

Welcome to the **second** issue of the Ghana Journal of Echocardiography (GJE)! The second issue presents an overview of mitral regurgitation and provides the recommendations of the American Society of Echocardiography (ASE) on how to assess the severity of mitral regurgitation with multiple choice questions with answers. An original article with the findings for ejection fraction evaluated in 191 patients presenting for an echocardiogram in Tamale, Ghana is offered. A review of the updated left ventricular diastolic function guidelines from the American Society of Echocardiography is included with a questions with answers section. A Sonographer Communication on how to best acquire pulmonary vein flow using transthoracic echocardiography is presented. The GJE is available to review at washvu.org. The next issue of GJE will be posted January, 2027.

There is an invitation to contribute to one or more of the following sections of the journal:

Guidelines and Standards

Original Investigation

Pathology Review

Physician Communications

Sonographer Communications

Interesting Cases

Corrections

Ghana Echocardiography News and Calendar

Reader Services

Authors are encouraged to submit to one or more of the above – please submit to

reynoldsterry58@gmail.com

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Guidelines and Standards

Mitral Regurgitation (MR)

Echocardiography plays a major role in decision-making for mitral regurgitation, allowing for confirmation of diagnosis, quantitation of regurgitation severity and its consequences including clinical outcome. The American Society of Echocardiography (ASE) published echocardiography guidelines for the evaluation of valvular regurgitation in 2017 – the following is a review of the pathology and a presentation of the ASE recommendations including multiple choice questions and calculations with answers.

Definition

The backward flow of blood into the left atrium during ventricular systole; may be acute, chronic or intermittent.

Etiology – Mechanism – Classification

The etiology (cause, mechanism) of mitral regurgitation can be classified into two groups – Primary (Anatomic) and Secondary (Functional)

Primary (Anatomic) Mitral Regurgitation (Annulus-Leaflets-Chordae Tendineae-Papillary Muscles)

- Mitral annulus calcification - fibrosis
- Mitral valve prolapse (MVP) myxomatous changes: prolapse, flail, ruptured or elongated chordae
- Degenerative leaflet changes: calcification, thickening
- Infectious: endocarditis vegetations, perforations, aneurysm
- Inflammatory: rheumatic, collagen vascular disease, radiation, drugs
- Congenital: cleft leaflet, parachute mitral valve

Secondary (Functional) Mitral Regurgitation (MR) (ventricular remodeling) (Ventricular myocardium)

- Ischemic etiology secondary to coronary artery disease
- Nonischemic cardiomyopathy
- Annular dilation

History/Physical Examination

- Fatigue (earliest symptom)
- Dyspnea upon exertion (most common)
- Angina pectoris (may indicate coronary artery disease)
- Palpitations (suggests atrial fibrillation)
- Severe orthopnea/frank pulmonary edema may indicate severe acute mitral regurgitation
- Heart failure (dyspnea, orthopnea, paroxysmal nocturnal dyspnea, fatigue, cough, weight gain)
- Right heart failure (jugular venous distention, hepatomegaly, peripheral edema, ascites, anasarca) (late in course)

Cardiac Auscultation

- Blowing, high-pitched holosystolic murmur, heard best at the cardiac apex radiating to the axilla (best heard with patient in left lateral decubitus position)
- S3 (common)
- Accentuated P2 (pulmonary hypertension)
- Decrescendo systolic murmur (suggests acute mitral regurgitation)
- S4 (may indicate acute mitral regurgitation or appears late in course)

Electrocardiogram (EKG)

- May be normal in mild cases or in acute mitral regurgitation
- Left atrial enlargement/Atrial fibrillation (principal findings)
- Left ventricular hypertrophy with ST segment elevation and peaked T waves (diastolic volume overload pattern)
- Right ventricular hypertrophy (15%) (suggests pulmonary hypertension)
- Ischemic/infarction changes (suggests mitral regurgitation due to coronary artery disease)

Chest X-ray/CMR/CT

- Heart size may be normal in mild cases or in acute regurgitation
- Cardiomegaly (due to left atrial and left ventricular enlargement) in significant chronic mitral regurgitation
- Pulmonary congestion (vascular redistribution, interstitial edema, pleural effusion) (suggests heart failure)
- Acute pulmonary edema (acute or intermittent regurgitation)
- CMR assesses chamber dimensions, mass, jet length, jet area, volumetric flow

Cardiac Catheterization

- Coronary arteriography (primary role)
- The degree of regurgitation is determined during ventriculography (injection of contrast into the left ventricle) by observing reflux of the contrast into the left atrium
- Elevated v wave in the pulmonary capillary wedge pressure tracing

Medical/Surgical Treatment

- Vasodilators for afterload reduction (e.g., sodium nitroprusside, hydralazine, nitrates, ACE inhibitors)
- ACE inhibitors (e.g., enalapril) (severe chronic mitral regurgitation with left ventricular dysfunction)
- Anti-arrhythmic agents (e.g., beta blocker, calcium channel blocker)
- Electrocadioversion (new onset atrial fibrillation)
- Digitalis (atrial fibrillation, left ventricular failure)
- Diuretics (heart failure)
- Anticoagulation (warfarin) (atrial fibrillation)
- Resynchronization (dual ventricular chamber pacing)
- Intra-aortic balloon pump (severe acute MR)
- Treatment of underlying condition (e.g., revascularization for CAD)
- Valvular repair (e.g.; mitral valve clip) or mitral valve replacement (MVR) indications for surgery

include: - Symptomatic - Asymptomatic:

- Atrial fibrillation
- Ejection fraction < 60%
- Left ventricular end-systolic dimension > 40 mm
- Systolic pulmonary artery pressure > 50 mm Hg; > 60 mm Hg with exercise
- An ejection fraction of < 30% may be a contraindication

M-Mode/2-D

- Anatomic basis for the presence of mitral regurgitation (e.g., mitral annular calcification (MAC), mitral valve flail leaflet, mitral valve prolapse MVP)
- Left atrial dilatation (Normal LA linear dimension: women: 2.7 to 3.8 cm; men: 3.0 to 4.0 cm)
- Left ventricular dilatation (Normal LV end-diastolic dimension: women: 3.9 to 5.3 cm; men: 4.2 to 5.9 cm)
- Left ventricular volume overload pattern (left ventricular dilatation with hyperkinesis)
- Left atrial systolic expansion
- Left ventricular diastolic expansion
- Abnormal systolic bowing of the interatrial septum towards the right atrium
- Increased LA/RA ratio (normal is 1:1)
- Dilatation of the mitral annulus (normal 2.3 ± 0.5 cm) (apical four-chamber view) (> 3.7 cm significant)
- Evidence of pulmonary hypertension
- Color M-mode may be useful in determining the presence, timing, (early, mid, late) and duration of mitral regurgitation (important)



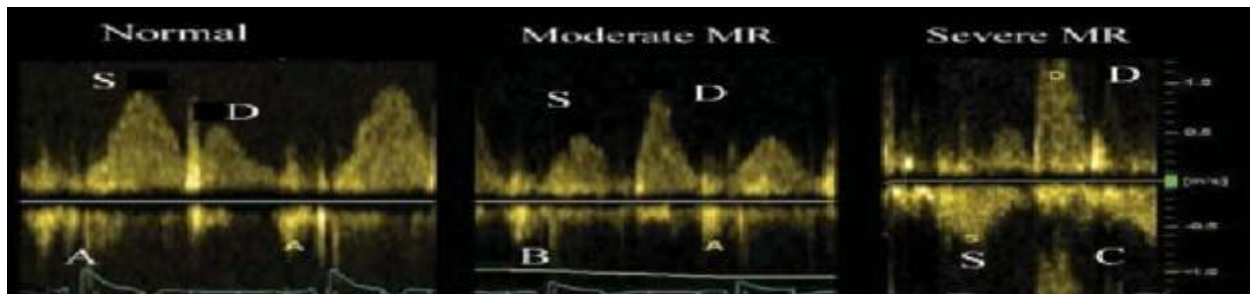
Dilated cardiomyopathy will result in secondary (functional) mitral regurgitation.



Flail posterior mitral valve leaflet will result in primary (anatomic) mitral regurgitation.

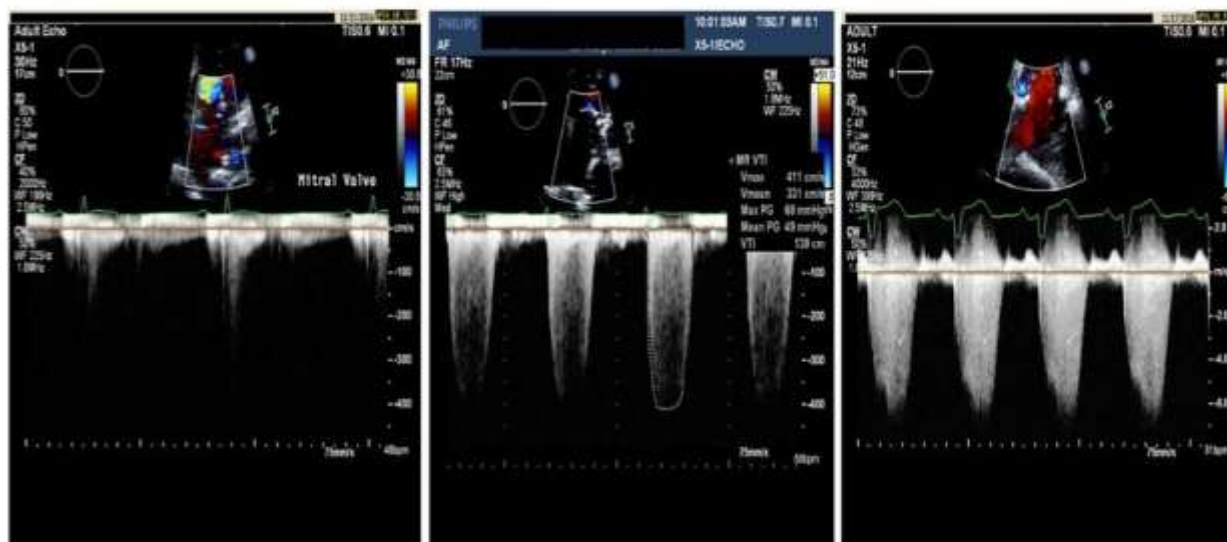
PW Doppler

- Increased mitral valve E velocity (> 1.2 m/s) may indicate significant regurgitation (assumes ejection fraction is $> 40\%$)
- Pulmonary venous inflow with a reversed S wave and increased D wave may indicate significant regurgitation
- Decreased mitral valve deceleration time (< 140 msec) may indicate significant regurgitation (assumes normal LV systolic function and diastolic function)
- Determine:
 - Mitral valve regurgitant volume, regurgitant fraction, effective regurgitant orifice area
 - Mitral valve/aortic valve peak velocity ratio (> 1.0 may indicate significant regurgitation)
 - Mitral valve VTI (increased with significant mitral regurgitation)
 - Left ventricular outflow tract velocity time integral (< 15 cm may indicate significant regurgitation)
 - Mitral valve VTI/LVOT VTI ratio (> 1.0 may indicate significant regurgitation)
 - E/e' (average) (> 15 suggests LV increased filling pressures) (most reliable if EF is $< 40\%$)
 - Presence of diastolic mitral regurgitation (common in atrial fibrillation, post-premature ventricular contractions, first- and second-degree atrioventricular block, complete heart block, increased left ventricular end-diastolic pressure)



CW Doppler

- Jet density (spectral strength) indicates severity
- Dense, triangular (asymmetrical) shape (V wave cutoff sign) of mitral regurgitation flow velocity envelope suggests a rapid rise in left atrial pressure due significant regurgitation
- Decreased velocity of the mitral regurgitant jet (< 4 m/s) may indicate an elevated left atrial pressure due to significant regurgitation
- Determine:
 - Effective regurgitant orifice area (EROA)
 - Isovolumic relaxation time (< 60 msec may indicate severe regurgitation)
 - Left ventricular systolic dP/dt
 - Left atrial pressure (Systolic blood pressure $- 4 \times MR^2$)
 - SPAP/MPAP/PAEDP/PVR at rest and exercise



Trace/Mild MR

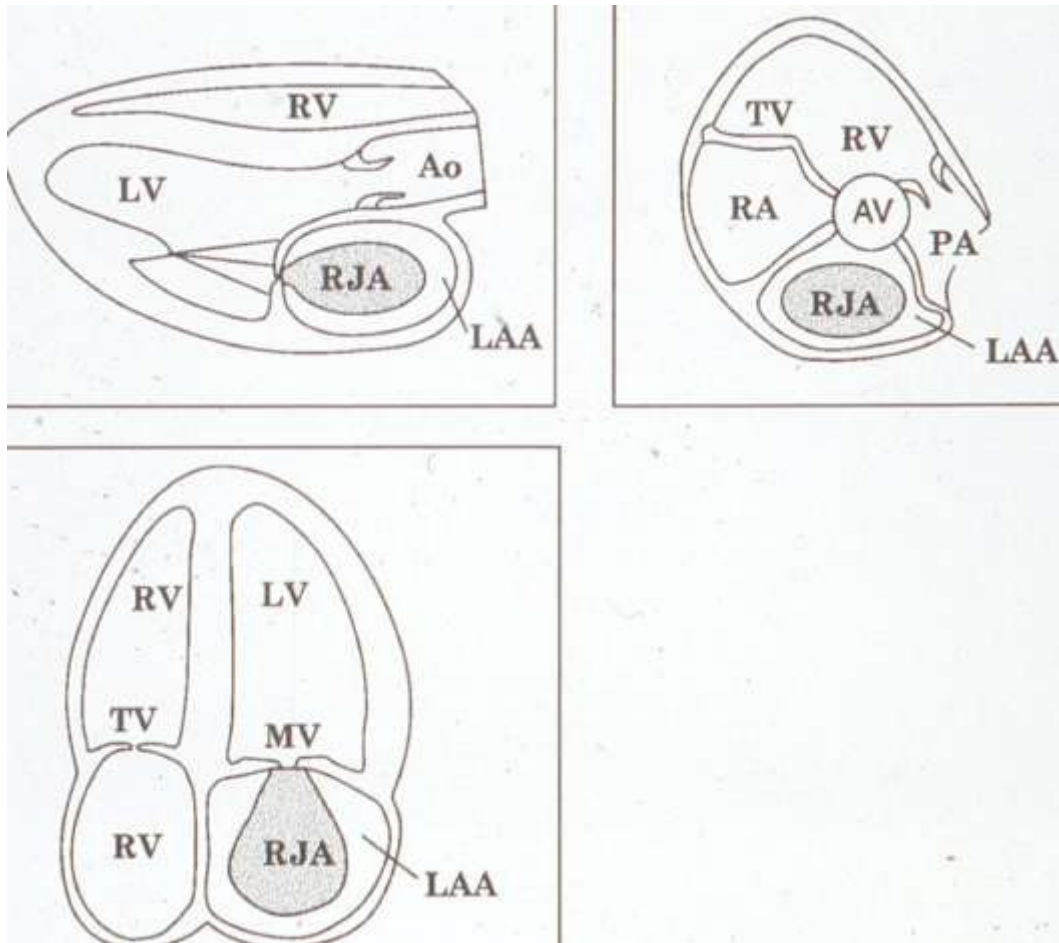
Moderate MR

Severe MR

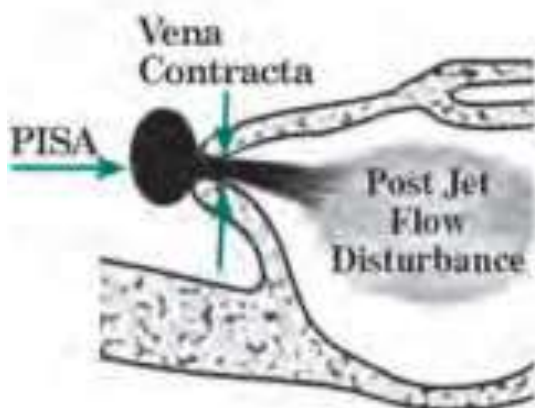
CW Doppler spectral strength is useful in determining the flow duration and severity of mitral regurgitation.

Color Flow Doppler

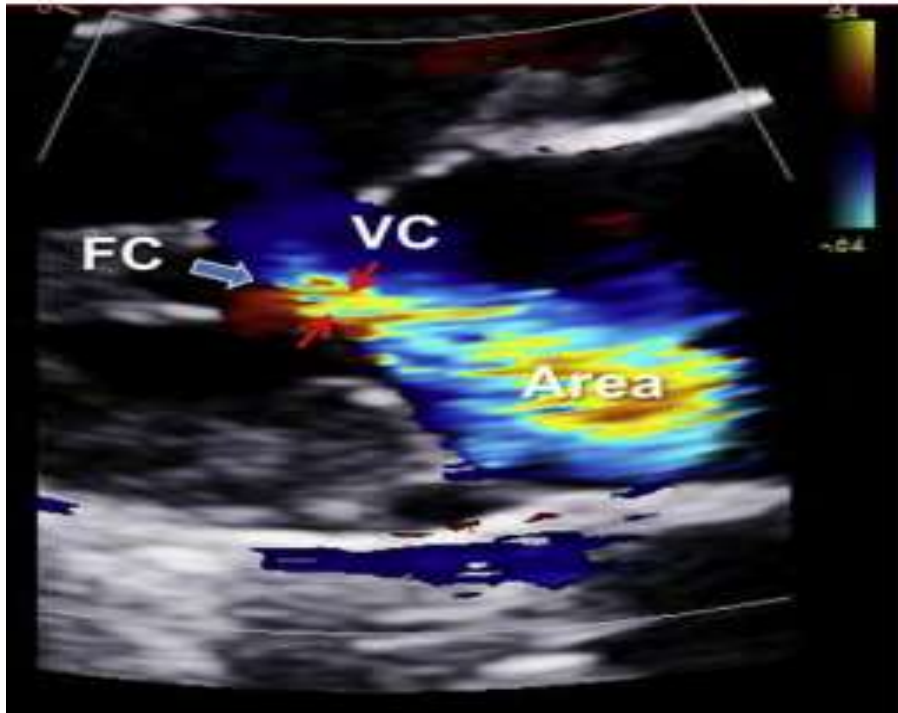
- Blood pressure should be recorded at the time of the echocardiographic examination (increased driving pressure may result in a larger jet)
- Nyquist limit (aliasing velocity) should be set to between 50 to 70 cm/sec
- Appropriate color flow Doppler gain setting should be chosen (increase color flow Doppler gain until speckling appears and then decrease color flow Doppler gain setting until speckling is eliminated)
- Duration of the color flow Doppler jet should be noted (Color M-mode, PW Doppler, CW Doppler)
- Eccentric, wall impinging jets may result in underestimation of severity (coanda effect) (presence may indicate structural abnormality of the mitral valve (e.g., prolapse, flail, vegetation, perforation))
- Determine:
 - Regurgitant jet area (RJA) (mild < 4 cm²; severe > 8 cm²)
 - Regurgitant jet area (RJA)/Left atrial area (LAA) ratio in three orthogonal views (choose view with largest ratio) (mild < 20%; severe > 50%)
 - Vena contracta (origin of the regurgitant jet) width in the parasternal long-axis view (mild < 0.3 cm; severe ≥ 0.7 cm)
 - PISA radius (mild < 0.4 cm; severe ≥ 0.9 cm), effective regurgitant orifice area (EROA) and regurgitant volume (RV) by the PISA method or conventional PW Doppler method
 - Regurgitant proximal jet width (mild < 0.8 cm; severe > 1.5 cm) and jet area (mild < 0.3 cm²; severe > 0.8 cm²) in parasternal short-axis view of mitral valve
- 3-D may improve evaluation of jet size, jet direction, flow convergence (PISA) region and vena contracta width



Regurgitant Jet Area (RJA) ÷ Left Atrial Area (LAA)



Components of a turbulent jet – PISA (flow convergence), vena contracta, post jet flow disturbance (jet area)



Components of a turbulent jet – Flow Convergence (FC) (PISA), Vena Contracta (VC), Area (post jet flow disturbance – jet area)



Severe mitral regurgitation in a patient with flail posterior mitral valve leaflet. Note the mitral regurgitation jet is baffled anterior.

Stress Echocardiography

- May be used to evaluate:
 - Severity of regurgitation with exercise
 - Presence of co-existing coronary artery disease
 - Assessment of functional capacity
 - Pulmonary artery pressures/right ventricular systolic function
 - Left ventricular systolic contractile reserve

Transesophageal Echocardiography (TEE)

- Indicated when TTE is inconclusive, identify underlying mechanism, planning mitral valve surgery
- Provides for the anatomic and hemodynamic assessment of the mitral valve and mitral valve regurgitation
- Generally superior to transthoracic echocardiography for determining the presence of chordal rupture/ruptured papillary muscle
- Due to the artifact of flow masking, TEE may be better than TTE in determining the severity of mitral regurgitation in patients with a mitral prosthetic heart valve or in patients with severe mitral annular calcification
- “Off axis” views are recommended when evaluating the mitral regurgitation jet by color flow Doppler
- Quantitation of the severity of mitral regurgitant jet by color flow Doppler
- Quantitation of the severity of mitral regurgitation by TEE is generally accomplished by determining jet area, jet width (vena contracta width), size of the flow convergence (PISA), jet geometry, evaluating pulmonary venous flow by PW Doppler, jet density by CW Doppler, regurgitant volume, regurgitant fraction and effective regurgitant orifice
- When determining regurgitant jet area by TEE, trace the mosaic portion of the jet only
- An eccentric jet that sweeps around the left atrium may indicate significant regurgitation (coanda effect)
- Quantitative techniques may be useful in determining the severity of mitral regurgitation (especially in patients with eccentric jets)

Quantitation of Mitral Regurgitation – American Society of Echocardiography (ASE) Recommendations (Please see attached chart)

Mild Mitral Regurgitation (Grade 1) is present if 4 or more of the following criteria are present:

- Small, narrow central jet
- Vena contracta width (VCW) ≤ 0.3 cm
- PISA radius absent or ≤ 0.3 cm at Nyquist 30-40 cm/s
- Mitral A wave dominant inflow
- Soft or incomplete jet by CW Doppler
- Normal LV and LA size
-

Severe mitral regurgitation (Grade 4) is present if 4 or more of the following criteria are present:

- Flail leaflet
- VCW ≥ 0.7 cm
- PISA radius ≥ 1.0 cm at Nyquist 30- 40 cm/s
- Central large jet $> 50\%$ of LA area
- Pulmonary vein systolic flow reversal
- Enlarged LV with normal function

To determine moderate to moderately severe mitral regurgitation is present, quantitative calculations are recommended (please see ASE chart below)

- Effective regurgitant orifice area (EROA)
- Regurgitant volume (RVol)
- Regurgitant fraction (RF)

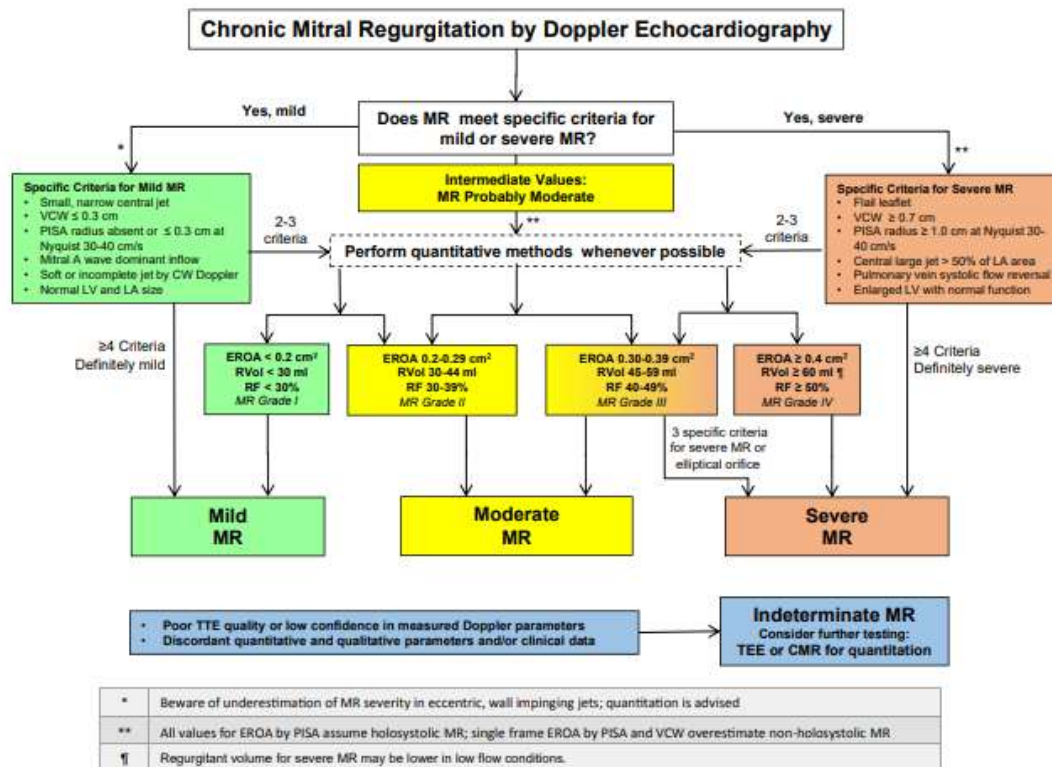


Figure 18 Algorithm for the integration of multiple parameters of MR severity. Good-quality echocardiographic imaging and complete data acquisition are assumed. If imaging is technically difficult, consider TEE or CMR. MR severity may be indeterminate due to poor image quality, technical issues with data, internal inconsistency among echo findings, or discordance with clinical findings.

American Society of Echocardiography Recommendations for the Evaluation of Mitral Regurgitation
<http://dx.doi.org/10.1016/j.echo.2017.01.007>

Mitral Regurgitation (MR) Review Questions

- When does mitral regurgitation occur?
 - Ventricular diastole
 - Atrial systole
 - Ventricular systole
 - Diastasis
- Which of the following is an example of secondary (functional) mitral regurgitation?
 - Mitral annular calcification (MAC)
 - Mitral valve prolapse (MVP)
 - Papillary muscle fibrosis-calcification
 - Dilated cardiomyopathy (DCM)

3. Which of the following is an example of acute mitral regurgitation?
 - A. Mitral annular calcification (MAC)
 - B. Mitral valve prolapse (MVP) (DCM)
 - C. Flail mitral valve
 - D. Dilated cardiomyopathy
4. The **MOST COMMON** presenting symptom for significant mitral regurgitation is:
 - A. Fatigue
 - B. Dyspnea upon exertion
 - C. Syncope
 - D. Angina pectoris (chest pain)
5. A holosystolic murmur best heard at the cardiac apex radiating to the axilla (armpit) is the description of the murmur of ____ regurgitation?
 - A. Aortic
 - B. Mitral
 - C. Pulmonary
 - D. Tricuspid
6. The expected initial EKG finding for chronic significant mitral regurgitation is:
 - A. Left atrial enlargement (LAE)
 - B. Right atrial enlargement (RAE)
 - C. Right ventricular hypertrophy (RVH)
 - D. Right bundle branch block
7. The chest x-ray finding for chronic significant mitral regurgitation is:
 - A. Cardiomegaly
 - B. Pulmonary edema
 - C. Pleural effusion
 - D. Pericardial effusion
8. The cardiac catheterization test for evaluating mitral regurgitation is:
 - A. Placement of a stent
 - B. Aortography
 - C. Ventriculography
 - D. Coronary arteriogram
9. Which of the following is **NOT** a catheter or surgical technique used to treat mitral regurgitation?
 - A. MitraClip
 - B. Mitral valve replacement (MVR)
 - C. Catheter balloon valvuloplasty
 - D. Chordal repair
10. Which of the following is **NOT** an expected M-mode/2-D echocardiography finding for chronic significant mitral regurgitation?
 - A. Aortic sclerosis
 - B. Left atrial dilatation
 - C. Left ventricular dilatation
 - D. Abnormal mitral valve apparatus

11. The mitral valve leaflet tip is pointing towards the left atrium during ventricular systole with lack of coaptation. This suggests:
 - A. Mitral stenosis (MS)
 - B. Mitral valve prolapse (MVP)
 - C. Mitral annular calcification (MAC)
 - D. Flail mitral valve
12. The PW Doppler finding for significant mitral regurgitation is:
 - A. Aliasing
 - B. S wave reversal of the pulmonary vein flow
 - C. E/A reversal
 - D. Prolonged deceleration time
13. Which CW Doppler finding suggests significant mitral regurgitation?
 - A. Increase in spectral strength (density)
 - B. Increase in peak velocity
 - C. Decrease in mitral valve E velocity
 - D. Flow reversal of the pulmonary veins
14. The blood pressure is 120/80 mm Hg. The CW Doppler mitral regurgitation peak velocity is 5 m/sec. Calculate the left atrial pressure (LAP). _____ mm Hg
 - A. 120
 - B. 80
 - C. 20
 - D. 5
15. The RJA/LAA is 58% and is holosystolic. This color flow Doppler finding suggests: _____ mitral regurgitation.
 - A. Trace (physiologic)
 - B. Mild
 - C. Moderate
 - D. Severe
16. Which color flow Doppler method may be used to quantitate the severity of mitral regurgitation?
 - A. Flow convergence region (PISA)
 - B. Vena contracta
 - C. Jet area
 - D. Relaminarization
 - E. All of the above may be used to determine the severity of mitral regurgitation
17. Which of the following is **LEAST** important when evaluating mitral regurgitation?
 - A. Systolic blood pressure
 - B. Respiratory rate
 - C. Color velocity scale (50 to 70 cm/sec)
 - D. Duration of the mitral regurgitation flow
18. Which of the following does **NOT** provide information concerning the duration of mitral regurgitation?
 - A. Color M-Mode (CMM)
 - B. PW Doppler
 - C. CW Doppler
 - D. Color flow Doppler

19. The mitral regurgitation ("hugs") the left atrial wall which reduces the jet area with color flow Doppler on. This is the _____ effect.
- Doppler
 - Coanda
 - Piezoelectric
 - Windshear
20. Yes or No: If four or more of the listed parameters are present; mitral regurgitation is mild.
- Small, narrow central jet
 - $VCW \leq 0.3$ cm
 - PISA radius absent or ≤ 0.3 cm at Nyquist 30-40 cm/s
 - Mitral A wave dominant inflow
 - Soft or incomplete jet by CW Doppler
 - Normal LV and LA size
21. Yes or No: If four or more of the following variables are present, mitral regurgitation is severe.
- Flail leaflet
 - $VCW \geq 0.7$ cm
 - PISA radius ≥ 1.0 cm at Nyquist 30- 40 cm/s
 - Central large jet > 50% of LA area
 - Pulmonary vein systolic flow reversal
 - Enlarged LV with normal function
22. Yes or No: To determine the presence of moderate to moderately severe mitral regurgitation, the following quantitative parameters are recommended to be acquired.
- Effective regurgitant orifice area (EROA)
 - Regurgitant volume (RVol)
 - Regurgitant fraction (RF)

Answers: 1.C; 2.D.; 3.C.; 4.B; 5.B; 6.A; 7.A; 8.C. 9.C; 10.A; 11.D; 12.B; 13.A; 14.C; 15.D; 16.E; 17.B; 18.D; 19.B; 20. Yes; 21. Yes; 22. Yes

BONUS QUESTIONS!

- The mitral regurgitation vena contract measured 1.0 cm in the parasternal long axis view. This suggests: ____ mitral regurgitation.
 - Trace (physiologic)
 - Mild
 - Moderate
 - Severe
- The view of choice for measuring the mitral regurgitation vena contracta is the:
 - Parasternal long axis
 - Parasternal short axis of the mitral valve
 - Apical four chamber
 - Subcostal four chamber
- The PISA radius measures 1.0 cm. The color flow scale aliasing velocity is 40 cm/sec. The mitral regurgitation peak velocity is 500 cm/sec. The mitral regurgitation velocity time integral (VTI) is 150 cm. Using the PISA method, determine the following:
 Effective regurgitant orifice area (EROA): _____ cm^2 or _____ mm^2
 Regurgitant volume (RV): _____ mL
 Severity: _____

4. Yes or No: To determine the severity of mitral regurgitation using the PISA method, the sonographer needs to: 1. Use the apical 4 (or apical long axis); 2. Decrease (shift downward) the color velocity scale to between 20 to 40 cm/sec; 3. Measure the PISA radius; 4. Trace the CW Doppler of the mitral regurgitation
5. Determine regurgitant volume, regurgitant fraction, effective regurgitant orifice area using the following data:
 - Mitral valve annulus: 3.0 cm
 - Mitral Valve VTI: 20 cm
 - LVOT diameter: 2.0 cm
 - LVOT VTI: 15 cm
 - Mitral regurgitation VTI: 200 cm

BONUS Questions Answers: 1. D; 2. A; 3.0.50 cm²; 50 mm²; 75 mL; Severe; 4. Yes; 5. Regurgitant volume: 94 mL; Regurgitant fraction: 67%; Effective regurgitant orifice area: .47 cm² (47 mm²)

Formulas

PISA Method

EROA (cm²) = 6.28 x Radius²(cm) x Aliasing Velocity (cm/sec) ÷ Mitral Regurgitation Peak Velocity (cm/sec)

RV (mL) = EROA (cm²) x Mitral Regurgitation Velocity Time Integral (VTI) (cm)

PW Doppler Method

SV_{MV} (mL) = CSA_(MV) (cm²) x VTI_(MV) (cm)

SV_{LVOT} (mL) = CSA_{LVOT} (cm²) x VTI_{LVOT} (cm)

RV_{MR} (mL) = SV_{MV} (mL) – SV_{LVOT} (mL)

RF (%) = RV_{MR} (mL) ÷ SV_{MV} (mL)

EROA (cm²) = RV_{MR} (mL) ÷ VTI_{MR} (cm)

Note: Cross-sectional area (CSA) (cm²) = .785 x diameter²

Cardiovascular Credentialing International (CCI) MUST KNOW – The following checklist would be considered important to know for the CCI adult echocardiography board examination.

1. When does MR occur?
2. Primary MR versus Secondary MR?
3. Most common presenting symptom for significant chronic mitral regurgitation?
4. Most common presenting symptom for significant acute mitral regurgitation?
5. Classic auscultatory finding for chronic mitral regurgitation?
6. EKG finding(s)?
7. CXR finding(s)?
8. Cardiac catheterization test?
9. Cardiac Catheterization pressure tracing finding?
10. Cardiac Catheterization treatment?
11. Medical treatment?
12. Surgical treatment?
13. 2-D findings?
14. PW Doppler?
15. CW Doppler?
16. Color flow Doppler findings?
17. Coanda effect?
18. Nyquist limit important?
19. Blood pressure important?
20. Duration important?
21. Calculation of left atrial pressure (LAP) using CW Doppler?

Answers: 1.Ventricular systole; 2.Primary involves the mitral valve apparatus – annulus, leaflets, chordae tendineae, papillary muscles – Secondary involves the LV myocardium – e.g.; dilated cardiomyopathy, ischemia; 3.Dyspnea upon exertion; 4.Pulmonary edema; 5.Holosystolic murmur heard best at the cardiac apex; 6.left atrial dilatation – atrial fibrillation; 7.Cardiomegaly due to left atrial dilatation and left ventricular dilatation; 8.Left ventriculogram; 9.Elevated v wave; 10.MitralClip, Transcatheter valve replacement; 11.Vaodilators, diuretics, anticoagulation, intra-aortic balloon pump; 12.Mitral valve replacement, chordal repair; 13.Abnormal mitral valve, left atrial dilatation, LVVO pattern - left ventricular dilatation with left ventricular wall hyperkinesis, pulmonary hypertension; 14.Pulmonary vein S wave reversal;15.Spectral strength, flow duration; 16.PISA, Vena contracta, Jet area;17.Jet “hugging” a wall-valve leaflet -reducing the jet area size; 18.Color flow Doppler velocity should be set at between 50 to 70 cm/sec;19.Importance because driving pressure may influence jet characteristics;20.Duration is important to note when determining severity;21.LAP (mm Hg) = Systolic blood pressure – 4 x MR peak velocity²

Original Investigations

A One-Year Retrospective Review of Ejection Fraction Acquired in Tamale, Ghana

Introduction

Ejection fraction is the most important indicator of global left ventricular systolic function. Ejection fraction has proven to be a powerful predictor of cardiac mortality especially in patients with heart failure, post-myocardial infarction, chemotherapy and is used as one of the primary criteria for the treatment of valvular heart disease¹. A first of its kind cardiovascular ultrasound school was established in Tamale, Ghana (West Africa School of Heart and Vascular Ultrasound) and this paper presents a retrospective examination of the range of ejection fractions acquired for the first calendar school year of 2021.

Methods

All adult echocardiograms were acquired at two institutions – Tamale Teaching Hospital and Central Hospital located in Tamale, Ghana. Echocardiograms were acquired following a standard adult echocardiography protocol² using either a Sonosite Micromaxx or Acuson Cypress ultrasound machine. 197 echocardiograms were acquired – 152 males; 45 females. Ejection fraction was determined by visual estimation following the American Society of Echocardiography recommendations^{3,4}.

Results

Normal ejection fraction was present in 115 males; 34 females. Mildly reduced ejection fraction (Males: 41 to 51%; Females: 41 to 53%) was present in 7 males; 3 females. Moderately reduced ejection fraction (Males: 30 to 41%; Females: 30 to 40%) was present in 2 males and 4 females. Severely reduced ejection fraction (Less 30% in males and females) was present in 28 males; 4 females. (Table 1, Table 2)

Summary

Ejection fraction is an important parameter used in the evaluation of cardiovascular health. This retrospective review of adult echocardiograms acquired in Tamale, Ghana has provided an important overview of the range of ejection fractions patients admitted to Tamale Teaching Hospital and Central Hospital. 18% of males presented with a severely reduced ejection fraction. 0.08% of females presented with severely reduced ejection fraction.

Table 1. Number of Patients Separated by Ejection Fraction Grades			
	Male		Female
52-72%	115	54-74%	34
41-51%	7	41-53%	3
30-40%	2	30-40%	4
<30%	28	<30%	4

Table 2. Percentage of Patients Separated by Ejection Fraction Grades			
	Male (%)		Female (%)
52-72%	76	54-74%	76
41-51%	0.04	41-53%	0.06
30-40%	0.01	30-40%	0.08
<30%	18	<30%	0.08

Pathology Review

The Evaluation of Left Ventricular Diastolic Function – A Summary of the American Society of Echocardiography (ASE) July, 2025 Update

Introduction

The evaluation of left ventricular diastolic function has become an integral part of the echocardiography examination. A recent guideline paper published in the Journal of the American Society of Echocardiography in July, 2025 provided an update to the previous 2016 left ventricular diastolic function guidelines. The following consists of a summary of the important components of the new 2025 diastolic function guidelines.

Two Steps

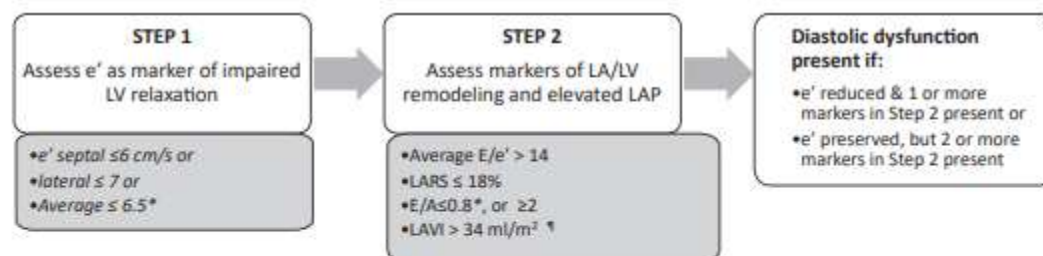
There are now two recommended steps to take when attempting to evaluate left ventricular diastolic function.

Step One

The first step (Table 1) is to determine if left ventricular diastolic dysfunction is present. The ASE has published a chart on how to perform the first step (Table 1). First, determine if the e' peak velocity (lateral, septal or average) is normal or abnormal (Age dependent – Table 2). If abnormal, determine if one or more of the following are present: Average $E/e' > 14$; Left atrial reservoir strain (LARS) ≤ 18 ; E/A ratio ≤ 0.8 or ≥ 2.0 ; Left atrial volume index $> 34 \text{ mL/m}^2$. If the e' is abnormal and one or more of the four variables listed are present, left ventricular diastolic dysfunction is present.

If the e' is normal and two or more of the four variables listed are present, left ventricular diastolic dysfunction is present.

Step 1 – Table 1



* : can also consider age specific cutoff values to identify abnormally reduced e' velocity or abnormally reduced E/A ratio

: after excluding LA enlargement in athletes, or due to anemia, atrial fibrillation or flutter, and mitral valve disease

† : another finding consistent with diastolic dysfunction: LV mass index $> 95 \text{ g/m}^2$ in women or 115 g/m^2 in men, after exclusion of increased LV mass in athletes

Nagueh SF, Sanborn DY, Oh J, et al. Recommendations for the Evaluation of Left Ventricular Diastolic Function by Echocardiography and for Heart Failure with Preserved Ejection Fraction Diagnosis: An Update. J Am Soc Echocardiogr 2025;38:537-569.

Table 2

	20-39 y	40-65 y	>65 y
1. Septal e' , cm/s	<7	<6	<6
2. Lateral e' , cm/s	<10	<8	<7
3. Average e' , cm/s	<9	<7	<6.5

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Step 2

Step 2 requires determination of the left ventricular diastolic grade and the left atrial pressure (LAP). (Table 3)

If the following three variables – e' peak velocity (lateral $\leq$, septal, average), E/e' and the tricuspid regurgitation (TR) peak velocity or the pulmonary artery systolic pressure (PASP) are normal (Table 3), the diastolic grade is normal and the left atrial pressure is normal.

If all three variables listed above are abnormal, then if the E/A ratio is < 2.0 , Grade 2 left ventricular diastolic function is present and the left atrial pressure is mild to moderately increased. If the E/A ratio is ≥ 2 , left ventricular diastolic function Grade 3 is present and the left atrial pressure is markedly increased.

If the TR/PASP is increased only or the E/e' is increased only or if any 2 variables are abnormal, then the pulmonary vein S/D ratio ($\leq .67$ is abnormal), LAVI (abnormal LAVI: $> 34 \text{ mL/m}^2$) or LARS (abnormal LARS: ≤ 18) or IVRT (isovolumic relaxation time $\leq 70 \text{ msec}$ is abnormal) may be referred to with ≥ 1 variable being an indication of increased left atrial pressure and Grade 2 or Grade 3 (depending on the E/A ratio) is present.

If only the e' is abnormal, then if the E/A ratio of ≤ 0.8 , Grade 1 is present with normal left atrial pressure.

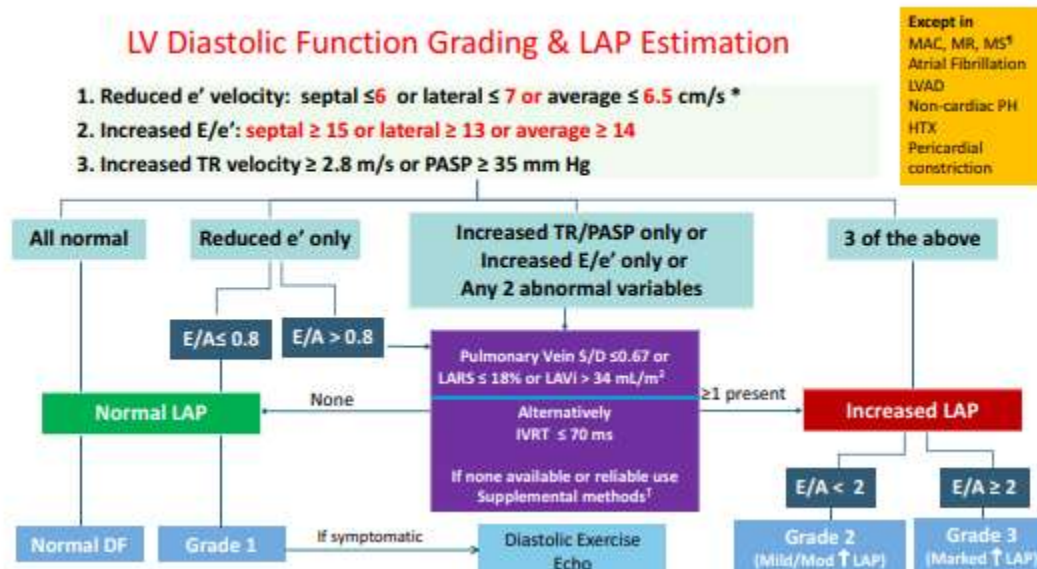
If the e' is abnormal and the E/A ratio is > 0.8 , then the pulmonary vein ratio, LAVI, LARS or IVRT should be referred to and if one or more are abnormal, Grade 2 or Grade 3 (depending on the E/A ratio) is present with increased left atrial pressure present.

If the pulmonary vein S/D ratio LAVI, LARS or IVRT are not available, the following parameters may be used as substitutes – pulmonary regurgitation end-diastolic velocity $\geq 2.0 \text{ m/sec}$, pulmonary artery pressure end-diastolic pressure $\geq 16 \text{ mm Hg}$, mitral inflow L-wave velocity $\geq 50 \text{ cm/sec}$, pulmonary vein Ar-A duration $> 30 \text{ msec}$, and/or a decrease in mitral E/A ratio of $\geq 50\%$ with Valsalva maneuver.

Diastolic Stress Test

If diastolic function appears normal at rest but the patient presents with dyspnea upon exertion or symptoms of heart failure, a diastolic stress test may be indicated. The mitral valve e' peak velocities (lateral, septal), the mitral valve peak E velocity and the tricuspid regurgitation peak velocity pre and post exercise are acquired. The result is considered positive when during exercise, the average E/e' ratio is ≥ 14 (or septal E/e' ratio is ≥ 15) and peak TR velocity is $\geq 3.2 \text{ m/sec}$. A normal response would be no change or slight increase in the e' peak velocities.

Table 3



Algorithm for estimation of mean LAP for patients in sinus rhythm and who do not have severe primary MR, any degree of mitral stenosis (MS), or moderate or severe MAC. The algorithm should also not be applied to patients in atrial fibrillation, heart transplant (HTX) recipients, noncardiac PH, pericardial constriction or LV assist device (LVAD). For annular e' velocity, age-adjusted lower limits of normal values shown in Table 2 can be applied in place of the values shown in this table. (The algorithm should also not be applied to patients with mitral valve repair, mitral valve replacement, or mitral-transcatheter edge-to-edge repair). DF, Diastolic function; $\geq$ PR end-diastolic velocity 2m/sec, PA diastolic pressure ≥ 16 mm Hg, mitral inflow L-wave velocity ≥ 50 cm/s, Ar-A duration > 30 msec, and/or a decrease in mitral E/A ratio of $\geq 50\%$ with Valsalva maneuver.

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Diastolic Function Simplified

The above described above can be challenging. The following simplifies the above approach. The goal of the evaluation of left ventricular function is to identify patients with increased left atrial pressure.

Identifying Increased Left Atrial Pressure (LAP)

e' peak velocity abnormal values: - ≤ 6 , ≤ 7 or Average ≤ 6.5 cm/sec

E/e' ratio abnormal values: Septal ≥ 15 ; Lateral ≥ 13 ; Average ≥ 14

TR peak velocity/SPAP abnormal values: ≥ 2.8 m/sec or SPAP ≥ 35 mm Hg

All three normal: LAP is normal.

All three abnormal: LAP is elevated.

Mixed results: move to supplemental parameters before you call it.

A mixed result requires referencing the supplemental parameters

Supplemental Parameters

Pulmonary vein S/D ratio abnormal value: ≤ 0.67

LA Reservoir strain (LARS) abnormal value: $\leq 18\%$

LA volume index abnormal value: $> 34 \text{ mL/m}^2$

IVRT: $\leq 70 \text{ msec}$

None of these are present: Left atrial pressure is normal.

Any of these present: Left atrial pressure is increased.

One additional note – if e' is abnormal but the E/e' and PASP are normal, review the E/A ratio. If the E/A ratio is ≤ 0.8 , left atrial pressure is normal and is considered Grade 1. If the patient is symptomatic, a diastolic stress test may be performed. If E/A ratio is > 0.8 evaluate the supplemental parameters before deciding if the left atrial pressure is normal.

Questions - The Evaluation of Left Ventricular Diastolic Function – A Summary of the American Society of Echocardiography (ASE) July, 2025 Update

1. Which parameter is **BEST** to use to evaluate left ventricular impaired relaxation?
 - A. e' peak velocity
 - B. E/e'
 - C. Tricuspid regurgitation peak velocity
 - D. Left atrial volume index (LAVI)
2. Which two pathologies are most commonly associated with left ventricular diastolic dysfunction?
 - A. Mitral valve prolapse; Mitral regurgitation
 - B. Systemic hypertension; Coronary artery disease
 - C. Aortic sclerosis; Mitral annular calcification (MAC)
 - D. Ostium secundum atrial septal defect; Patent ductus arteriosus
3. Yes or No: The new ASE diastolic function recommendations (July, 2025) involve two steps: Step 1: Determine if left ventricular diastolic dysfunction is present; 2. Determine the left ventricular diastolic function grade and the left atrial pressure.
4. The following is acquired from a 33-year-old who presents with a history of a systolic murmur:
Yes or N: Is left ventricular diastolic dysfunction present?
 - EF: 60 to 65%
 - e' peak velocity (average) is 19 cm/sec
 - Average E/e' : 4
 - E/A ratio: 1.3
 - LAVI: 23 mL/m^2
 - LARS: 28%

5. For the case presented above (Question #4): Determine the left ventricular diastolic grade and the left atrial pressure.
 - e' peak velocity (average): 19 cm/sec
 - Average E/e': 4
 - Tricuspid regurgitation peak velocity: 201 cm/sec
 - A. Normal diastolic function – Normal left atrial pressure
 - B. Grade 1 diastolic dysfunction – Normal left atrial pressure
 - C. Grade 2 diastolic dysfunction – Mildly increased left atrial pressure
 - D. Grade 3 diastolic dysfunction – Moderate to Severely increased left atrial pressure
 - E. Indeterminate
6. The following is acquired from a 68-year-old with a history of systemic hypertension:

Yes or No: Is left ventricular diastolic dysfunction present?

 - EF: 60 to 65%
 - e' peak velocity (average): is 5 cm/sec
 - Average E/e': 8
 - E/A ratio: 0.6
 - LAVI: 44 mL/m²
 - LARS: 22%
7. For the case presented above (Question #6): Determine the left ventricular diastolic grade and the left atrial pressure.
 - e' peak velocity (average): 5 cm/sec
 - Average E/e': 8
 - Tricuspid regurgitation peak velocity: 233 cm/sec
 - A. Normal diastolic function – Normal left atrial pressure
 - B. Grade 1 diastolic dysfunction – Normal left atrial pressure
 - C. Grade 2 diastolic dysfunction – Mildly increased left atrial pressure
 - D. Grade 3 diastolic dysfunction – Moderate to Severely increased left atrial pressure
 - E. Indeterminate
8. The following is acquired from a 73-year-old female with a history of coronary artery disease.

Yes or No: Is left ventricular diastolic dysfunction present?

 - EF: 45 to 50%
 - e' peak velocity (average): 6 cm/sec
 - Average E'/e': 16
 - E/A ratio: 1.3
 - LAVI: 53 mL/m²
 - LARS: Not available
9. For the case above (Question #8), determine the left ventricular diastolic grade and the left atrial pressure.
 - e' peak velocity (average): 6 cm/sec
 - Average E/e': 16
 - Tricuspid regurgitation peak velocity: 302 cm/sec
 - A. Normal diastolic function – Normal left atrial pressure
 - B. Grade 1 diastolic dysfunction – Normal left atrial pressure
 - C. Grade 2 diastolic dysfunction – Mildly increased left atrial pressure
 - D. Grade 3 diastolic dysfunction – Moderate to Severely increased left atrial pressure
 - E. Indeterminate

10. The following is acquired from a 79-year-old with a history of coronary artery disease.

Yes or No: Is left ventricular diastolic dysfunction present?

- EF: 20 to 25%
- e' peak velocity (average) 4 cm/sec
- Average E/e': 21
- E/A ratio: 2.3
- LAVI: 48 mL/m²
- LARS: 13%

11. For the above (Question #10), determine the left ventricular diastolic function grade and the left atrial pressure.

- e' peak velocity (average) 4 cm/sec
 - Average E/e': 21
 - Systolic pulmonary artery pressure (tricuspid regurgitation peak velocity method): 52 mm Hg
- A. Normal diastolic function – Normal left atrial pressure
B. Grade 1 diastolic dysfunction – Normal left atrial pressure
C. Grade 2 diastolic dysfunction – Mildly increased left atrial pressure
D. Grade 3 diastolic dysfunction – Moderate to Severely increased left atrial pressure
E. Indeterminate

12. The following is acquired in a 58-year-old with a history of systemic hypertension.

Yes or No: Is diastolic dysfunction present?

- EF: 60 to 65%
e' peak velocity (average): 4 cm/sec
Average E/e': 8
E/A ratio: 1.2
LAVI: 48 mL/m²
LARS: N/A

13. For the above question (Question #12), determine the left ventricular diastolic grade and the left atrial pressure.

- e' peak velocity (average) 4 cm/sec
Average E/e': 8
Tricuspid regurgitation peak velocity: 3.8 m/sec
Pulmonary vein S/D ratio: 0.46
LAVI: 48 mL/m²
LARS: N/A
E/A ratio: 1.2

- A. Normal diastolic function – Normal left atrial pressure
B. Grade 1 diastolic dysfunction – Normal left atrial pressure
C. Grade 2 diastolic dysfunction – Mildly increased left atrial pressure
D. Grade 3 diastolic dysfunction – Moderate to Severely increased left atrial pressure
E. Indeterminate

14. All three variables - e' peak velocity, E/e' and tricuspid regurgitation peak velocity/SPAP are normal. The left atrial pressure is:

- A. Normal
B. Increased
C. Requires reference to supplemental parameters (e.g.; pulmonary vein S/D ratio, LARS, LAVI, IVRT)

15. The three variables – e' peak velocity, E/e' and tricuspid regurgitation peak velocity/ PASP are abnormal. The left atrial pressure is:
 - A. Normal
 - B. Increased
 - C. Requires reference to supplemental parameters (pulmonary S/D ratio,
16. All three variables – e' peak velocity, E/e' and tricuspid regurgitation peak velocity/PASP are mixed. The left atrial pressure is:
 - A. Normal
 - B. Increased
 - C. Requires reference to supplemental parameters (e.g.; pulmonary vein S/D ratio, LARS, LAVI, IVRT)
17. The e' peak velocity is abnormal but the E/e' and tricuspid regurgitation peak velocity/PASP are normal. The mitral valve E/A ratio is less than or equal to 0.8. The left atrial pressure is:
 - A. Normal (Grade 1)
 - B. Increased
 - C. Requires supplemental parameters (pulmonary vein S/D ratio, LARS, LAVI, IVRT)
18. The e' peak velocity is abnormal but the E/e' and tricuspid regurgitation peak velocity/PASP are normal. The mitral valve E/A ratio is greater than 0.8. The left atrial pressure is:
 - A. Normal (Grade 1)
 - B. Increased
 - C. Requires supplemental parameters (pulmonary vein S/D ratio, LARS, LAVI, IVRT)

Answers: 1.A; 2.B; 3.Yes; 4.No; 5.A; 6.Yes; 7.B; 8.Yes; 9.C; 10.Yes; 11.D; 12.Yes; 13.C; 14.A; 15.B; 16.C; 17.A; 18.C

Addendum

Indicators of elevated LV filling pressures in special populations

Atrial Fibrillation

1. DT < 160 msec in patients with depressed LVEF
2. Peak acceleration rate of mitral E velocity ($\geq 1,900$ cm/sec²)
3. IVRT (≤ 65 msec)
4. DT of pulmonary venous diastolic velocity (≥ 220 msec)
5. E/Vp ratio (≥ 1.4)
6. Septal E/e' ratio (≥ 11)
7. Peak TR velocity > 2.8 m/sec

Sinus Tachycardia

1. Predominant early LV filling pattern with depressed LVEF
2. IVRT ≤ 70 msec is specific (79%)
3. Pulmonary vein systolic filling fraction $\leq 40\%$ is specific (88%)
4. Average E/e' ratio > 14 (high specificity but low sensitivity)
5. When E and A velocities are partially or completely fused, the presence of a compensatory period after premature beats often leads to separation of E and A velocities which can be used for assessment of diastolic function

Hypertrophic Cardiomyopathy (HCM)

1. Average E/e' (> 14)
2. Ar-A (≥ 30 msec)
3. Peak TR velocity (> 2.8 m/sec)
4. LA maximum volume index (> 34 mL/m²)

Restrictive Cardiomyopathy

1. Average E/e' (> 14)
2. DT < 140 msec*
3. E/A ratio $> 2.5^*$
4. 4. IVRT < 50 msec*

Pulmonary Hypertension (PH)

1. E/A ≥ 2 favors postcapillary PH
2. E/A ≤ 0.8 favors precapillary PH
3. When E/A ratio is > 0.8 but < 2 , lateral E/e' > 13 , LA maximum volume index > 34 mL/m² and LARS $< 18\%$ favor the diagnosis of postcapillary PH

Mitral Stenosis (MS)

1. IVRT < 60 msec*
2. Mitral A peak velocity > 1.5 m/sec
3. IVRT/TE-e' ratio < 4.2

Mitral Regurgitation (MR)

1. IVRT < 60 msec*
2. Ar-A (≥ 30 msec)
3. IVRT/TE-e' ratio < 5.6
4. Average E/e' ratio > 14 in patients with depressed EF

Moderate to Severe Mitral Annular Calcification (MAC)

1. LV filling pressure normal when mitral E/A ratio is < 0.8
2. LV filling pressure elevated when mitral E/A ratio is > 1.8
3. E/A ratio > 0.8 but < 1.8 , IVRT should be measured. LV filling pressure normal when IVRT is ≥ 80 msec, whereas it is elevated if IVRT < 80 msec.

Left Ventricular Assist Device (LVAD)

1. E/A ratio > 2
2. RAP > 10 mm Hg
3. PASP > 40 mm Hg
4. Average E/e' ratio > 14 or septal E/e' ratio ≥ 15
5. LA maximum volume index > 33 mL/m
6. Interatrial septum position†

Cardiac Transplant Recipients

1. Average E/e' ratio < 7 denotes normal LV filling pressures
2. Average E/e' ratio > 14 denotes elevated LV filling pressures
3. For E/e' ratio > 7 and < 14 , SR_{IVR} , from all three apical views, is measured, and the ratio of mitral E velocity to SR_{IVR} is derived. A ratio ≤ 200 cm is consistent with normal LV filling pressure, but > 200 cm denotes elevated LV filling pressure.
4. In patients in whom SR_{IVR} cannot be measured, peak TR velocity is relied on. Peak TR velocity ≤ 2.8 m/sec is consistent with normal LV filling pressures, but > 2.8 m/s denotes elevated LV filling pressure.

Note

*Specific but not sensitive indicators of elevated LV filling pressure. † LAP = RAP if the interatrial septum position is neutral. If septum bulges to right, then LAP is 5 mm Hg higher than RAP. If septum bulges to left, then LAP is 5 mm Hg lower than RAP.

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Important to Note

The overall clinical presentation of the patient and the echocardiographic findings should always be incorporated when evaluating left ventricular diastolic function. Common presenting symptoms of left ventricular diastolic dysfunction include shortness of breath upon exertion (dyspnea) (most common presenting symptom), fatigue, exercise intolerance, swelling (edema), persistent cough or wheezing and rapid or irregular heartbeat (e.g; atrial fibrillation). The patient's history should be recognized especially by noting a history of systemic hypertension, coronary artery disease, diabetes mellitus, obesity (body mass > 30 kg/m²) and/or valvular heart disease. Levels of natriuretic peptides (NPs), including brain NP and N-terminal pro-B-type NP, should be checked in patients presenting with suspected left ventricular diastolic dysfunction or undifferentiated dyspnea. Chest radiography may show signs of volume overload (Kerley B-lines, pleural effusion, pulmonary congestion) or reveal other noncardiac causes of dyspnea. The ejection fraction is important to know and left ventricular hypertrophy or left ventricular mass (abnormal: ≥ 115 g/m² for men and ≥ 95 g/m² for women) should be carefully evaluated.

Physician Communication – An Invitation

The Ghana Journal of Echocardiography invites physicians to correspond with the journal. Correspondence will be placed here. Please submit to reynoldsterry58@gmail.com

Sonographer Communication

How to Acquire Pulmonary Vein Flow Using Transthoracic Echocardiography (TTE)

Pulmonary vein flow may be useful in the evaluation of the severity of mitral regurgitation, pulmonary vein stenosis and in the evaluation of left ventricular diastolic function. Due to the updated American Society of Echocardiography (ASE) diastolic function guidelines (2025), there is a renewed interest on how to best acquire diagnostic pulmonary vein flow.

Image Acquisition

The most common two-dimensional view recommended for acquiring pulmonary vein flow is the apical four chamber view. Usually not all four pulmonary veins may be seen in the apical four chamber view, but the right upper pulmonary vein can be visualized routinely and is usually the target pulmonary vein for the evaluation of mitral regurgitation and left ventricular diastolic function. (Figure 1) Pulmonary vein stenosis may require examination of all four pulmonary veins which may require additional two-dimensional views.

With color flow Doppler on, place the color box over the left atrium to include the right upper pulmonary vein flow. The color flow Doppler velocity should be reduced to between 20 to 40 cm/sec to best detect the low velocity pulmonary vein flow with optimal alignment for PW Doppler interrogation the goal.

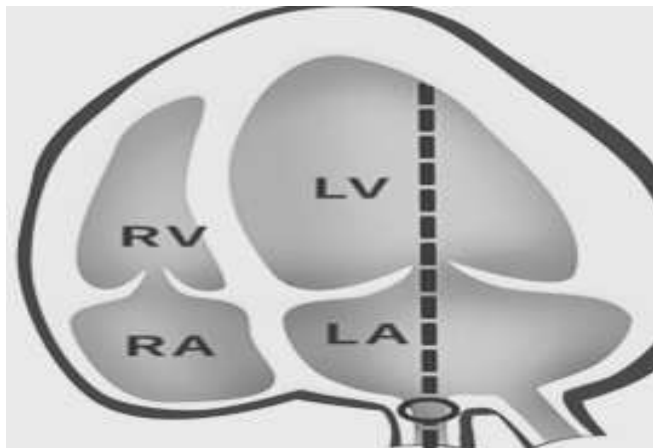


Figure 1. PW Doppler acquisition of the right upper pulmonary vein – apical four chamber view

Pulsed-Wave (PW) Doppler Interrogation

Place the PW Doppler sample volume approximately 0.5 centimeter to 1 centimeter deep into the right upper pulmonary vein. (Figure 1) The sample volume length may be increased to 3 to 5 mm to improve acquisition of the pulmonary vein flow. The Doppler wall filter should be set to 100 to 200 MHz. Optimal PW Doppler alignment (parallel to flow) is important. A sweep speed of 100 mm/second may be useful once a diagnostic flow pattern is acquired.

Normal Pulmonary View Wave Components

The pulmonary vein has three distinct components: Systolic wave (S-wave), Diastolic wave (D wave) and the atrial reversal (A wave) (Note: The pulmonary vein may also be labeled as the Ar wave).

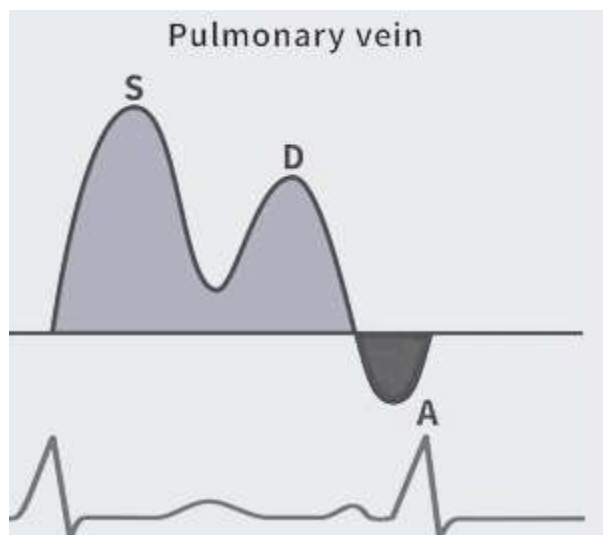


Figure 2. Normal PW Doppler pulmonary vein flow pattern (S – Systolic wave; D – Diastolic wave; A – atrial reversal (A wave))

S Wave (Systolic)

The S wave represents antegrade blood flow into the left atrium during ventricular systole. The S wave peak velocity represents the peak pressure gradient between the pulmonary vein and the left atrium and may be used as an indicator of the mean left atrial pressure. The S wave may be split into two separate peaks (biphasic), S1 (early systole) and S2 (mid-to-late systole). (Figure 3) The split of the S wave is normal with S1 caused by the relaxation of the left atrium immediately after the mitral valve closes and S2 is a result of the longitudinal shortening of the left ventricle during ventricular systole – the mitral annulus is pulled downward which expands the space in the left atrium creating an increase in the pressure gradient between the pulmonary vein and the left atrium resulting in an increase in blood flow.

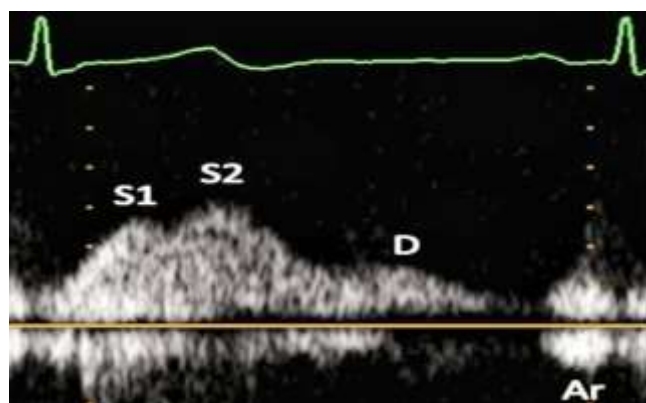


Figure 3. The biphasic S wave - S1 and S2

D Wave (Diastolic)

The D wave is the antegrade flow into the left atrium during early ventricular diastole.

A Wave (Atrial reversal)

Since there are no pulmonary vein valves to guard the opening of the pulmonary veins, retrograde flow into the pulmonary veins will occur during atrial contraction creating the pulmonary vein A wave. The A wave duration compared to the PW Doppler of the mitral valve A wave duration may be useful in

determining increased left ventricular end-diastolic pressure. The peak velocity of the A wave may also be useful in the evaluation of the left ventricular end-diastolic pressure (LVEDP).

Important Measurements – Mitral Regurgitation – Pulmonary Vein Stenosis - Left Ventricular Diastolic Function

Mitral Regurgitation

S wave reversal (S wave appears below the Doppler baseline) may occur in severe mitral regurgitation. An increase in the peak velocity of the D wave may also be present. (Figure 4)

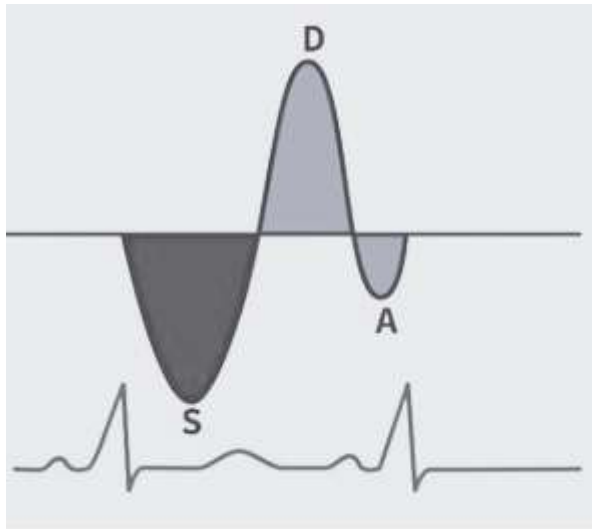


Figure 4. Pulmonary vein S wave reversal in severe mitral regurgitation (S – Systolic wave; D – Diastolic wave; A – Atrial reversal wave)

Pulmonary Vein Stenosis

Pulmonary vein stenosis is a rare condition. Although congenital was the most common cause but radiofrequency ablation for atrial fibrillation has become the main cause of the disease. Transthoracic echocardiography is limited since all four pulmonary veins can be difficult to image, with transesophageal echocardiography preferred for the detection and evaluation of pulmonary vein stenosis. A peak systolic or diastolic velocity greater than 110 cm/sec, mean pressure gradient greater than 5 mm Hg, monophasic flow pattern and/or mosaic flow pattern with color flow Doppler on may indicate pulmonary vein stenosis. (Figure 5)

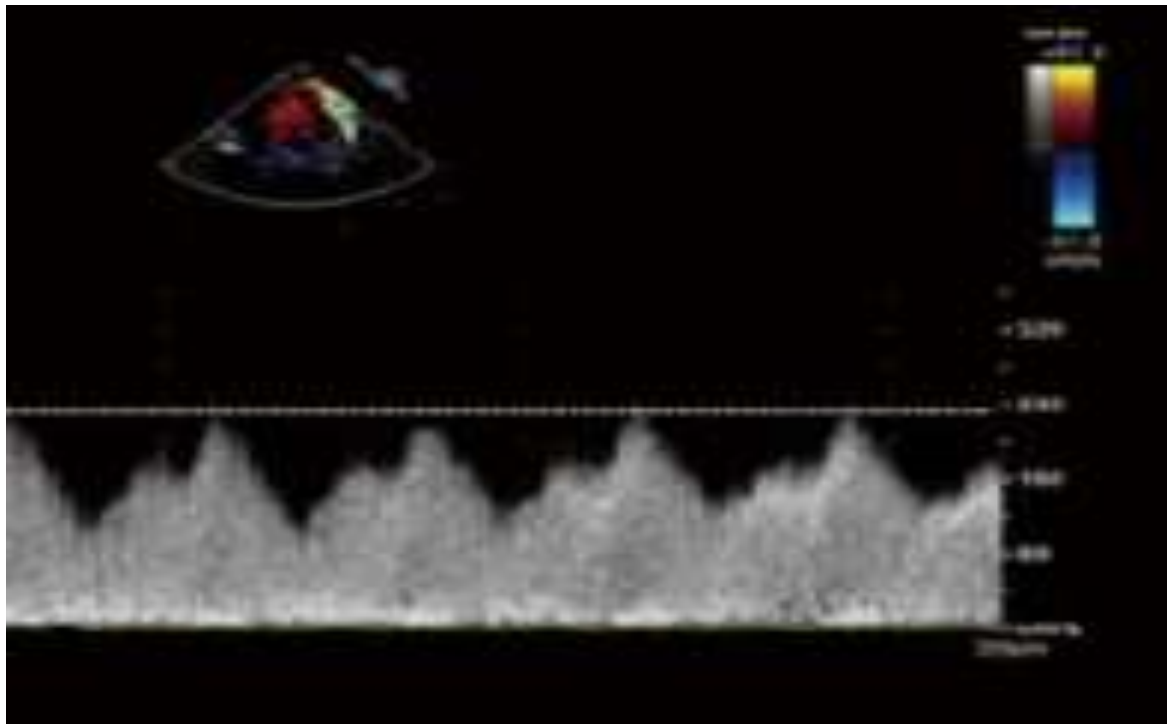


Figure 5. Pulmonary vein stenosis with increased peak velocity (> 110 m/sec) and monophasic flow pattern.

Left Ventricular Diastolic Function

For the evaluation of left ventricular diastolic function, the peak velocity of the S wave, D wave and A wave are measured. The pulmonary vein A wave flow duration is measured (A dur) with the A dur to be compared with the PW Doppler mitral valve A wave duration (A dur-A ratio).

A S/D ratio of less than or equal to 0.67 may suggest increased mean left atrial pressure (Figure 6). A pulmonary vein A dur- to mitral valve A dur ratio greater than 30 milliseconds may indicate increased left ventricular end-diastolic pressure. (Figure 7) A pulmonary vein A peak velocity greater than 35 cm/seconds may indicate increased left ventricular end-diastolic pressure. (Figure 7)

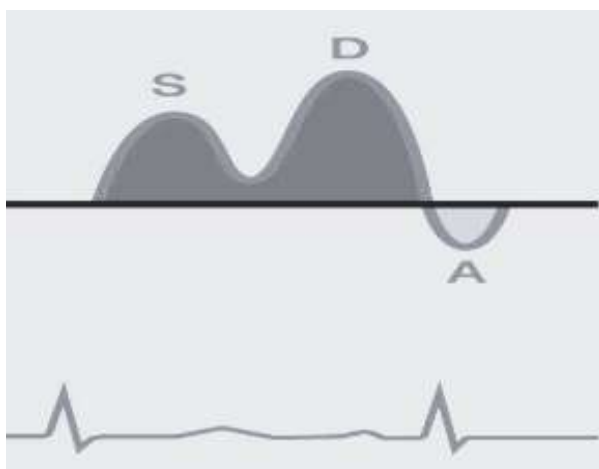


Figure 6. S/D ratio less than 0.67 suggesting increased left atrial pressure.

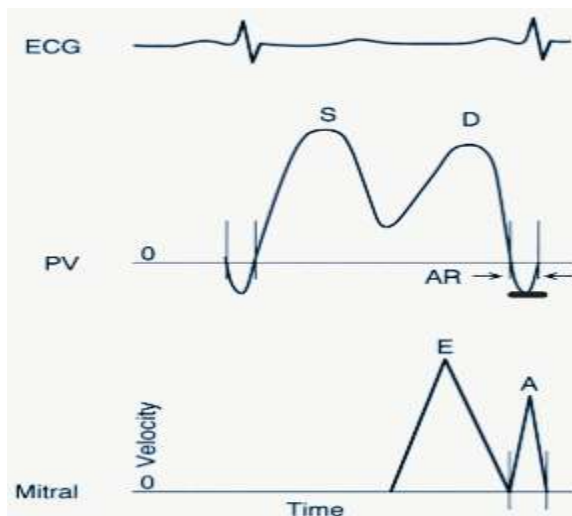


Figure 7. Measurement of pulmonary vein A duration and mitral valve A wave duration with measurement of the pulmonary vein A peak velocity (horizontal line).

Sonographer Technical Hints

A diagnostic pulmonary vein tracing may be difficult to obtain on every patient. The following may be useful:

- Reduce the color flow Doppler velocity scale to 20 to 40 cm/sec
- Choose to zoom (magnify) the left atrium to include the pulmonary vein with color flow Doppler on to better visualize the pulmonary vein flow
- Increase the PW Doppler sample volume length to 3 to 5 mm
- Position the PW Doppler sample volume 0.5 to 1.0 cm into the pulmonary vein
- Change the PW Doppler wall filter setting to 100 to 200 MHz
- Increase the PW Doppler sweep from 50 to 100 mm/sec
- Adjust the Doppler zero baseline to display the full pulmonary vein Doppler signal
- Tilt the transducer slightly anterior almost to an apical five chamber view from the standard apical four chamber view
- Move the transducer up the chest wall ("closer to the pulmonary vein")
- Have the patient hold their breath at end-expiration
- Choose alternate two-dimensional views (e.g.; parasternal long axis, parasternal short axis of the aortic valve, suprasternal short axis) and try to attempt acquiring pulmonary vein from these alternate two-dimensional views
- An average of three or more consecutive cycles should be measured.
- In atrial fibrillation, there is no pulmonary vein A wave and the systolic wave is blunted.
- Sinus tachycardia and first-degree AV block may make the measurement of the pulmonary vein A duration difficult.
- The S wave peak velocity represents the pressure gradient between the pulmonary vein and left atrium and may be used to predict mean left atrial pressure (S/D ratio less than or equal to 0.67 may indicate increased mean left atrial pressure)
- The D wave will follow the mitral valve E wave – a tall mitral valve E wave will result in a tall pulmonary vein D wave – a low mitral valve E wave will result in a low pulmonary vein D wave.
- In young patients, the S/D ratio may be decreased due to preserved diastolic function – meaning using the S/D ratio to evaluate left atrial pressure should be used with caution.

- Pulmonary vein stenosis has become more common due to radio frequency ablation treating atrial fibrillation. A peak systolic velocity greater than 110 cm/sec, mean pressure gradient greater than 5 mm Hg, monophasic flow pattern and/or mosaic flow pattern with color flow Doppler on may indicate pulmonary vein stenosis.

Summary

Acquisition of pulmonary vein flow has re-emerged as an important component of the routine echocardiogram examination due to the updated ASE diastolic function guidelines. The pulmonary vein S/D ratio and A duration to mitral valve A duration ratio are now considered useful parameters to evaluate when establishing the diastolic function grade and the mean left atrial pressure. Interrogation of the pulmonary vein(s) may also be useful in evaluation the severity of mitral regurgitation (S wave reversal) and in the evaluation of pulmonary vein stenosis (increased peak velocity, increased mean pressure gradient, monophasic flow pattern, mosaic color flow Doppler pattern).

Review Questions

1. Which of the following is **NOT** recommended for acquiring pulmonary vein flow?
 - A. Apical four chamber view
 - B. CW Doppler
 - C. Color flow Doppler velocity scale set between 20 to 40 cm/sec
 - D. Right upper pulmonary vein is the target
2. Which of the following is **NOT** a component of the pulmonary vein Doppler flow pattern?
 - A. S wave
 - B. D wave
 - C. A (atrial reversal wave)
 - D. L wave
3. Which pulmonary vein wave may be used as an indicator of mean left atrial pressure?
 - A. S wave
 - B. D wave
 - C. A (Ar) wave peak velocity
 - D. A (Ar) wave duration compared to the mitral A wave duration
4. The S/D ratio is 0.53. This may indicate:
 - A. Severe mitral regurgitation
 - B. Increased mean left atrial pressure
 - C. Reduced left ventricular end-diastolic pressure
 - D. Left atrial thrombus
5. The pulmonary atrial reversal A wave peak velocity is 44 cm/sec. This may indicate:
 - A. Severe mitral regurgitation
 - B. Increased mean left atrial pressure
 - C. Increased left ventricular end-diastolic pressure
 - D. Left atrial thrombus
6. The pulmonary vein A wave duration is 38 milliseconds longer than the mitral valve A wave duration. This suggests:
 - A. Severe mitral regurgitation
 - B. Increased mean left atrial pressure
 - C. Increased left ventricular end-diastolic pressure
 - D. Left atrial thrombus

7. There is S wave reversal of the pulmonary vein flow pattern. This suggests:
 - A. Severe mitral regurgitation
 - B. Increased mean left atrial pressure
 - C. Increased left ventricular end-diastolic pressure
 - D. Left atrial thrombus
8. Which of the following pulmonary vein parameters is **NOT** useful in the evaluation of left ventricular diastolic function?
 - A. S/D ratio
 - B. A peak velocity
 - C. A duration compared to the mitral valve A wave duration
 - D. S wave reversal
9. Which if the following is **INCORRECT** concerning pulmonary vein stenosis?
 - A. Most common cause is congenital
 - B. Results in increased peak velocity > 110 cm/second
 - C. Mean pressure gradient > 5 mm Hg suggests pulmonary vein stenosis
 - D. Monophasic flow pattern
 - E. Mosaic color flow Doppler pattern may indicate pulmonary vein stenosis
10. Which is **INCORRECT** concerning pulmonary vein flow?
 - A. There is an increased A wave with atrial fibrillation
 - B. The S wave is blunted in atrial fibrillation
 - C. Sinus tachycardia and first-degree AV block make measurement of the pulmonary vein flow difficult
 - D. A tall mitral valve E wave predicts a tall pulmonary vein D wave
11. Which of the following would **NOT** be useful in acquisition of a diagnostic pulmonary vein flow pattern?
 - A. Patient held inspiration
 - B. Slight anterior transducer tilt from the apical four chamber view
 - C. Adjust the Doppler wall filter to 100 to 200 MHz
 - D. Increase the PW Doppler sample volume length to 3 to 5 mm

Answers: 1.B; 2.D; 3.A; 4.B; 5.C; 6.C; 7.A; 8.D; 9.A; 10.A; 11.A

Interesting Cases

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Corrections

Spelling correction to the article entitled "Mitral Stenosis" published in Volume 1, Issue 1 – Multiple Choice question number 12 – "man" – should read mean.

12. Which of the following is **NOT** considered a Level 1 method recommended for evaluating the severity of mitral stenosis?
 - A. Mitral valve planimetry using the parasternal short axis of the mitral valve
 - B. Mitral valve resistance
 - C. Mitral valve area by the pressure half-time method
 - D. Calculation of the **man** pressure gradient

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