Aortic Regurgitation

NORMALS

Aortic valve leaflets are uniform in thickness except for a slightly more fibrous region at the anatomic midpoint of each cusp or nodules of Arantius.
Aortic Valve

Normal aortic valve area (AVA) 3-4 cm²; Normal opening usually 2 cm

Normal Aortic Valve M-Mode

Parallelogram in shape
Midline closure
RCC = right coronary cusp
NCC = non-coronary cusp
IVCT = isovolumetric contraction time
IVRT = isovolumetric relaxation time
Aortic Valve: Transthoracic

Aortic Valve: Transesophageal
Questions

Question 1

3. In the midesophageal TEE short axis of the aortic valve:
   A. The non-coronary cusp is the most anterior cusp.
   B. The left coronary cusp is the most anterior cusp.
   C. The right coronary is adjacent to the interatrial septum.
   D. The non-coronary cusp is adjacent to the interatrial septum.

18. This short-axis of the aortic valve shows (Fig. 5.3):
   A. Bicuspid aortic valve.
   B. Lamb's excrescence.
   C. Fibroelastoma of the left coronary cusp.
   D. Fibroelastoma of the noncoronary cusp.
Question 2

5. A 30-year-old woman is referred for management of a newly diagnosed subaortic stenosis. She is asymptomatic, but during a routine physical examination a loud systolic murmur was heard. An echocardiogram demonstrated a subaortic membrane with a gradient of 44 mm Hg and concomitant presence of moderate aortic valve regurgitation. The left ventricle is borderline enlarged, with an LVEF of 57%. At TEE, the aortic valve does not appear to be calcified. Which of the following statements are correct?

A. This type of lesion responds well to balloon dilatation.
B. The patient should undergo resection of the subaortic membrane and aortic valve replacement.
C. Careful inspection of the pulmonary valve and pulmonary artery should be carried out during TEE.
D. Doppler interrogation of the abdominal aorta provides no information in this case.

Question 3

6. Which of the following statements regarding aortic regurgitation (AR) is correct?

A. A PISA radius of 0.8 cm with an aliasing velocity of 40 cm/s and a peak aortic regurgitant velocity of 4 m/s is consistent with severe AR.
B. A pressure half-time greater than 250 ms is consistent with severe AR.
C. Vena contracta is best evaluated from the apical long-axis view.
D. The use of the suprasternal notch window is not useful in the assessment of AR.
Question 4

8. A 67-year-old man with aortic regurgitation underwent transthoracic echocardiographic examination. There was no mitral stenosis or regurgitation. The following values were obtained:

<table>
<thead>
<tr>
<th>Table 8-8</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Peak diastolic velocity of aortic regurgitant jet</td>
<td>5.0 m/s</td>
</tr>
<tr>
<td>End-diastolic velocity of aortic regurgitant jet</td>
<td>3.7 m/s</td>
</tr>
<tr>
<td>Pressure half-time of aortic regurgitant jet</td>
<td>650 ms</td>
</tr>
<tr>
<td>Peak aortic antegrade flow velocity</td>
<td>2.2 m/s</td>
</tr>
<tr>
<td>Blood pressure</td>
<td>130/85 mm Hg</td>
</tr>
</tbody>
</table>

Based on the aforementioned data, one can conclude that:

A. Pressure half-time is consistent with severe aortic regurgitation.
B. Aortic valve area can be estimated as 220 divided by pressure half-time.
C. Peak left ventricular systolic pressure (LVSP) is lower than the systolic blood pressure (SBP).
D. Left ventricular end-diastolic pressure (LVEDP) is estimated at 10 mm Hg.
E. Aortic valve area cannot be calculated using continuity equation because there is aortic regurgitation.

Aortic Regurgitation
Aortic Regurgitation: Classification

<table>
<thead>
<tr>
<th>AI Class</th>
<th>Normal cusp motion with FAA dilation or cusp perforation</th>
<th>Type II Cusp Prolapse</th>
<th>Type III Cusp Restriction</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Type I</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>ia</td>
<td>lb</td>
<td>lc</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Mechanism</th>
<th>Repair Techniques (Primary)</th>
<th>Repair Techniques (Secondary)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>FAA = functional aortic annulus</td>
<td>STJ = sinotubular junction</td>
</tr>
<tr>
<td></td>
<td>SCA = subcommissural annuloplasty</td>
<td>SCA = subcommissural annuloplasty</td>
</tr>
</tbody>
</table>

Aortic Regurgitation: Jet Width/LVOT Diameter

Mild
- Jet width <25% of LVOT diameter

Moderate
- Jet width within 25-64%

Severe
- Jet width >65% LVOT diameter = jet more than 2/3 in comparison to LVOT

Color flow Doppler 2D
- Jet width/LVOT diameter
- Long-axis view
- Zoomed view
- Imaging plane for optimal VC measurement may be different from PDA
- Measure in LVOT within 1 cm of the VC

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
- Is affected by the size of the LVOT

*Nyquist limit at 50-60 cm/s

**Medium AR**
- Jet width <25% of LVOT
- Vena contracta <0.3 cm
- Regurgitant volume <30 mL/beat
- Regurgitant fraction <30%
- ERO ≤0.10 cm²
- Angiography grade 1

**Moderate AR**
- Jet width 25-64% of LVOT
- Vena contracta 0.3-0.6 cm
- Regurgitant volume 30-90 mL/beat
- Regurgitant fraction 30% to 40%
- ERO 0.10-0.20 cm²
- Angiography grade 2

**Severe AR**
- Jet width >65% of LVOT
- Vena contracta >0.6 cm
- Holosystolic flow reversal is the proximal subaortic stenosis
- Regurgitant volume >90 mL/beat
- Regurgitant fraction >40%
- ERO >0.5 cm²
- Angiography grade 3 to 4
- In addition, diagnosis of chronic severe AR requires evidence of LV dilatation
Aortic Regurgitation: Jet Area

Mild
- Cross sectional area <5%

Moderate
- In between

Severe
- Cross sectional area >60% = basically more than 2/3

<table>
<thead>
<tr>
<th>Semi-quantitative parameters</th>
</tr>
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<tbody>
<tr>
<td>VcW (cm)</td>
</tr>
<tr>
<td>&lt;0.3</td>
</tr>
<tr>
<td>0.3-0.8</td>
</tr>
<tr>
<td>&gt;0.8</td>
</tr>
</tbody>
</table>

Jet width/LVOT width, central jets (%):
- <25
- 25-45
- 46-64
- >65

Jet CSA/LVOT CSA, central jets (%):
- <5
- 5-20
- 21-50
- >80

Nyquist limit at 50-60 cm/s

Aortic Regurgitation: Vena Contracta

Mild
- Vena contracta < 0.3 cm

Moderate
- Vena contracta 0.3 – 0.6 cm

Severe
- Vena contracta > 0.6 cm

Nyquist limit at 50-60 cm/s

Nyquist limit at 50-60 cm/s

Parasternal long-axis view

Zoomed view

Imaging planes for optimal VC measurement may be different from that for PISA

Narrow area of jet at or just apical to the valve

Supraventricular 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

Problems in the presence of multiple jets or bicuspid valves

Convergence zone needs to be visualized

The direction of the jet (in relation to the imaging beam) will influence the appearance of the jet

Additional diagnosis of chronic stenosis AR requires evidence of LV dilation

Nyquist limit at 50-60 cm/s
Aortic Regurgitation: Proximal Flow Convergence

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<th>Example</th>
<th>Advantages</th>
<th>Pitfalls</th>
</tr>
</thead>
<tbody>
<tr>
<td>Proximal flow</td>
<td>• Align direction of flow with isocenteration beams to avoid distortion of hemispheres from non-occlusive imaging</td>
<td>Apical view</td>
<td>• Rapid qualitative assessment</td>
<td>• Multiple jets</td>
</tr>
<tr>
<td>convergence</td>
<td>• Zoomed view</td>
<td>Parasternal view</td>
<td>• Nonisotropic jet</td>
<td>• Constrained jet</td>
</tr>
<tr>
<td></td>
<td>• Change baseline of Nyquist limit in the direction of the jet</td>
<td></td>
<td>• Nonisotropic jet</td>
<td>• Tracing in early diastole</td>
</tr>
<tr>
<td></td>
<td>• Aligned lower Nyquist limit to obtain the most hemispheric flow convergence</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Coming later...

M-Mode: Severe Aortic Regurgitation

- Early opening of aortic valve
- Early closure of mitral valve
Aortic Regurgitation: Pulse Wave

Diastolic reversal in descending aorta

<table>
<thead>
<tr>
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<th>Optimization</th>
<th>Example</th>
<th>Advantage</th>
<th>Pitfalls</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pulsed wave Doppler</td>
<td>Pulsed reversal in proximal descending aorta</td>
<td>Example</td>
<td>Simple supportive sign of severe AR</td>
<td>Depends on correction of the aortic lesion in relationship with patient</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>More specific sign if seen in a dilated aorta</td>
<td>Short velocity reversal in heart</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Can be obtained with TTE and TEE</td>
<td>Increasing resistance in atherosclerotic, fibrosis in upper extremity,</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Russia, may not be visualized in acute AR</td>
</tr>
</tbody>
</table>

Aortic Regurgitation: Continuous Wave

Mild
- Pressure half time (PHT) >500 ms

Moderate
- In between 200-500

Severe
- Pressure half time (PHT) <200 ms
Severity of Chronic Aortic Regurgitation

<table>
<thead>
<tr>
<th>Structural parameters</th>
<th>Mild</th>
<th>Moderate</th>
<th>Severe</th>
</tr>
</thead>
<tbody>
<tr>
<td>Aortic annulus</td>
<td>Normal or abnormal</td>
<td>Normal or abnormal</td>
<td>Abnormal/flat, or wide coaptation defect</td>
</tr>
<tr>
<td>Jet width in LVOT, color flow</td>
<td>Small in central jets</td>
<td>Intermediate</td>
<td>Large in central jets, variable in IMH</td>
</tr>
<tr>
<td>Flow convergence, color flow</td>
<td>Normal or very small</td>
<td>Intermediate</td>
<td>Large</td>
</tr>
<tr>
<td>Jet density, Doppler</td>
<td>Incomplete or faint</td>
<td>Dense</td>
<td>Dense</td>
</tr>
<tr>
<td>Jet acceleration rate, CW (m/s², m/s²)</td>
<td>Incomplete or faint</td>
<td>Intermediate</td>
<td>Prominent holodiastolic reversal</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Semi-quantitative parameters</th>
<th>Mild (mild)</th>
<th>Moderate (moderate)</th>
<th>Severe (severe)</th>
</tr>
</thead>
<tbody>
<tr>
<td>VEDV (cm²)</td>
<td>&lt;0.3</td>
<td>0.3-0.5</td>
<td>&gt;0.5</td>
</tr>
<tr>
<td>Jet width/LVOT width, central jets (%)</td>
<td>&lt;25</td>
<td>25-45</td>
<td>46-64</td>
</tr>
<tr>
<td>Jet area/LVOT area (%)</td>
<td>&lt;15</td>
<td>15-33</td>
<td>34-50</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Quantitative parameters</th>
<th>Mild (mild)</th>
<th>Moderate (moderate)</th>
<th>Severe (severe)</th>
</tr>
</thead>
<tbody>
<tr>
<td>TF (m)</td>
<td>&lt;0.1</td>
<td>0.1-0.2</td>
<td>&gt;0.2</td>
</tr>
<tr>
<td>ERDA (cm²)</td>
<td>0.05-0.10</td>
<td>0.10-0.15</td>
<td>&gt;0.20</td>
</tr>
</tbody>
</table>

Chronic Aortic Regurgitation by Doppler Echocardiography

**Yes, mild**

- Intermediate criteria: AR Probability moderate

**Yes, severe**

- Specific criteria for Severe AR
  - IVol< 50 mL
  - RF > 50%
  - ERDA > 0.1 cm²
  - AR Grade 4

**Definitively mild** (quantitation not needed)

**Mild AR**

- Specific criteria for Mild AR
  - IVol< 50 mL
  - Central jet, with < 25% of LVOT
  - Small or no flow convergence
  - Flow convergence jet by CW
  - PHT < 1000

**Moderate AR**

- Specific criteria for Moderate AR
  - IVol< 50 mL
  - RF > 50%
  - ERDA 0.08-0.1 cm²
  - AR Grade 3

**Severe AR**

- Specific criteria for Severe AR
  - IVol< 50 mL
  - RF > 50%
  - ERDA 0.18-0.20 cm²
  - AR Grade 4

**Indeterminate AR**

- Consider further testing TEE or CMR for quantitation

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

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Zoghbi et al. JASE 2017.
Aortic Regurgitation

Key Points

Chronic Aortic Regurgitation
- Severity graded using a combination of structural, qualitative Doppler, and semiquantitative parameters
- Jet often visible in all views
- Assess left ventricular size and volume
  - Globular and dilated
- Ejection fraction may fall as late finding
- Normal chamber volumes are unusual with chronic severe aortic regurgitation

Acute Severe Aortic Regurgitation
- Diagnostically more challenging
  - Color Doppler with short duration
  - Tachycardia
  - Low aortic regurgitation velocity
  - Eccentric jet
- Left ventricle not dilated
- Ejection fraction likely reduced
- M-Mode findings for aortic and mitral valves
- Low threshold for transesophageal echocardiogram (TEE)
Specific Diseases

Transthoracic

<table>
<thead>
<tr>
<th>Transthoracic</th>
<th>Transesophageal</th>
</tr>
</thead>
<tbody>
<tr>
<td>RCC</td>
<td>NCC</td>
</tr>
<tr>
<td>LCC</td>
<td>LCC</td>
</tr>
</tbody>
</table>

Bicuspid Aortic Valve
Bicuspid Aortic Valve

- Male predominance 2:1
- 1-2% of general population
- Most common is RCC-LCC fusion
  - RCC and NCC fusion 32%
  - Anterior/Posterior 14%
- Eccentric closure line on M-Mode
- Diagnose in SYSTOLE
- TTE 92% sensitivity; 96% specificity for detection
- 50% have associated aortopathy
- Coarctation
  - If bicuspid, 5% have coarctation
  - If coarctation, 50% have bicuspid
Quadricuspid Aortic Valve
Quadricuspid Aortic Valve

- No gender preference
- Associated with aortic regurgitation
- Associated with anomalous coronary arteries (10%)
- Rare

Ventricular Septal Defect
Endocarditis with Valve Destruction

Subaortic Membrane

- Discrete fibrous membrane (90%)
- Muscular narrowing of LVOT (10%)
- Most common associated lesion are PDA, VSD, coarctation of the aorta, pulmonary valve stenosis
- Treatment is surgical resection
  - Symptomatic with peak LVOT gradient 50 mmHg or more
  - Peak LVOT gradient < 50 mmHg with heart failure or ischemia
  - Asymptomatic with mild aortic regurgitation and peak gradient 50 mmHg or more
Connective Tissue Disorder (Marfan’s)

- Marked aortic root dilation

Aortic Dissection
Principles

*Continuity = conservation of mass*
  - Continuity for aortic valve
  - Area = volume / distance
    - Aortic valve area
    - Stroke volume = LVOT area x stroke distance
    - Transaortic distance (velocity time integral (VTI))

*Bernoulli = conservation of energy*
  - Simplified $\Delta P = 4V^2$
    - Account for $V_1$ if LVOT velocity $> 2$ m/s
    - $4(V_2^2 - V_1^2)$

*Flow Convergence* = as blood approaches a regurgitant orifice, its velocity increases forming concentric, roughly hemispheric shells of increasing velocity and decreasing surface area
**Flow Convergence Method**

- **Effective Regurgitant Orifice Area (EROA)**
  - Area $cm^2 = \frac{\text{flow cm/s}}{\text{peak velocity cm/s}}$

- **Proximal Isovelocity Surface Area (PISA) radius in cm**

  \[ 2\pi r^2 = 6.28r^2 \]
  \[ (6.28r^2)(\text{nyquist}) / \text{peak AR velocity} \]
  \[ \text{Equals EROA} \]

---

**Flow Convergence & PISA Example**

- **Example:**
  - Align ionization beam with the flow
  - Look for the hemispheric shape to guide the best lower Nyquist limit
  - CWD of regurgitant jet for peak velocity and VTI

- **Advantages:**
  - Rapid quantitative assessment of lesion severity (EROA) and volume overload (RI/a)

- **Pitfalls:**
  - Feasibility is limited by aortic valve calcifications
  - Not valid for multiple jets, less accurate in eccentric jets
  - Limited experience
  - Small errors in radius measurement can lead to substantial errors in EROA due to squaring of error.

---

**Flow Convergence Method**

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<th>Example</th>
<th>Advantages</th>
<th>Pitfalls</th>
</tr>
</thead>
</table>
| Quantitative Doppler: EROA, regurgitation volume and fraction | Align ionization beam with the flow
  - Look for the hemispheric shape to guide the best lower Nyquist limit
  - CWD of regurgitant jet for peak velocity and VTI | | | |
| Flow Convergence Method: \[ 2\pi r^2 = 6.28r^2 \] | | | | |

**Flow 1:**

- $A_1 \cdot V_1 = A_2 \cdot V_2$
- $2\pi r^2 \cdot V_a = \text{EROA} \cdot PkV$_{\text{max}}$

---

**Flow Convergence & PISA Example**

- **Example:**
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Stroke Volume (SV) Method

- Volume through mitral valve is representative of “full” amount
- Volume through LVOT will include regurgitant volume
  \[SV_{\text{mitral}} + Rvol = SV_{\text{lvot}}\]
  \[Rvol = SV_{\text{lvot}} - SV_{\text{mitral}}\]
- \[SV = \pi r^2 \times \text{stroke distance}\]
  \[\pi r^2 = \pi (d/2)^2 = \pi (d^2/4) = 0.785 d^2\]

Via PISA method

- LVOT diameter measured at the annulus in diastole and pulsed Doppler from apical views at same site
- Mitral annulus measured at mid-esophageal pulsed Doppler at the annulus level in diastole
- LV stroke volume can also be measured by the difference between LV end-diastolic volume and end-systolic volume.
- LV volumes are best measured by 3D. Contrast may be needed to better trace endocardial borders. If 3D not feasible, use 3D method of tricus

- AR volume is regurgitant volume, then divided by outflow stroke volume
Left Ventricular End Diastolic Pressure

Pressure originating chamber_{aorta} = 4v^2 + Pressure receiving chamber_{left ventricle}

\[\Delta P = 4v^2\]
\[\Delta P = DBP - LVEDP\]
\[DBP - LVEDP = 4(AR_{end-diastolic peak velocity})^2\]
\[LVEDP = DBP - 4(AR_{end-diastolic peak velocity})^2\]

If BP is 130/40:
\[4(AR velocity)^2 = DBP - LVEDP\]
\[LVEDP = DBP - 4(AR velocity)^2\]
\[LVEDP = 40 - 4(1.5)^2\]
\[LVEDP = 40 - 9\]
\[LVEDP = 31 \text{ mmHg}\]
Aortic Valve Interventions

Aortic Regurgitation

- Severe AR (Stage D)
  - Vena contracta >6 mm
  - HOB: aortic flow reversal
  - RVol <60 mL, mean RVH >50 mmHg
  - ERO >0.3 cm²

- Asymptomatic (Stage C)
  - LV EF >50%
  - LV ESVD >30 mm

- Symptomatic (Stage B)
  - LV EF <50%
  - LV ESVD >50 mm

- Other cardiac surgery

- Prognostic AR (Stage B)
  - Vena contracta >6 mm
  - RVol <60 mL, mean RVH >50 mmHg
  - ERO >0.3 cm²

- Other cardiac surgery

- Moderate AR

Aortic Regurgitation

- LV EF <50%
  - LV ESVD >30 mm
  - Low surgical risk

- Other cardiac surgery

- LV EF <50%
  - LV ESVD >50 mm
  - Increase in LVEDD to >45 mm or at least 3 studies

- Progressive decrease in LVSF to <55%–60% or increase in LVEDD to >45 mm or at least 3 studies

- Low surgical risk

- Aortic Regurgitation

NISHIMURA 2014;
OTTO ET AL 2020
Mechanical Aortic Valve

Bioprosthetic Aortic Valve

Components of stented bioprosthesis

<p>| | | |</p>
<table>
<thead>
<tr>
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<tbody>
<tr>
<td>Stent posts</td>
<td>Base ring</td>
<td>Prosthesis</td>
</tr>
<tr>
<td>Elgiloy wireform</td>
<td>Elgiloy and Polyester</td>
<td></td>
</tr>
<tr>
<td>stent</td>
<td>ring and stent posts</td>
<td></td>
</tr>
<tr>
<td>Elgiloy</td>
<td></td>
<td></td>
</tr>
<tr>
<td>PERIMOUNT Magna</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Image adapted from Piazza et al. BMJ 2012
Teaching points

- The non-coronary cusp is adjacent to the interatrial septum.
- The right coronary cusp is the most anterior cusp (farthest from the transducer on TEE)

Teaching points

- Papillary fibroelastomas are benign tumors
- Seen on aortic valve
- Small, well-delineated, pedunculated masses
- Small <20 mm
- Half have stalks
- Highly mobile
- High embolic risk
Question 2

Teaching points
- Subaortic stenosis is treated surgically
- Most common associated lesion are PDA, pulmonary valve stenosis, coarctation of the aorta, VSD

5. A 30-year-old woman is referred for management of a newly diagnosed subaortic stenosis. She is asymptomatic, but during a routine physical examination a loud systolic murmur was heard. An echocardiogram demonstrated a subaortic membrane with a gradient of 44 mm Hg and concomitant presence of moderate aortic valve regurgitation. The left ventricle is borderline enlarged, with an LVEF of 57%. At TEE, the aortic valve does not appear to be calcified. Which of the following statements are correct?

A. This type of lesion responds well to balloon dilatation.
B. The patient should undergo resection of the subaortic membrane and aortic valve replacement.
C. Careful inspection of the pulmonary valve and pulmonary artery should be carried out during TEE.
D. Doppler interrogation of the abdominal aorta provides no information in this case.

Question 3

Teaching points
- Watch units!!!

6. Which of the following statements regarding aortic regurgitation (AR) is correct?

A. A PISA radius of 0.8 cm with an aliasing velocity of 40 cm/s and a peak aortic regurgitant velocity of 4 m/s is consistent with severe AR.
B. A pressure half-time greater than 250 ms is consistent with severe AR.
C. Vena contracta is best evaluated from the apical long-axis view.
D. The use of the suprasternal notch window is not useful in the assessment of AR.

continuity equation as
Isovelocity flow = regurgitant flow
Isovelocity area × aliasing velocity
= EROA × Regurgitant velocity
2 × π × R^2 × aliasing velocity
= EROA × regurgitant velocity
EROA = \frac{2 \times \pi \times R^2 \times aliasing velocity}{Regurgitant velocity}
Replacing the numbers, this becomes:
EROA = \frac{2 \times \pi \times 0.8^2 \times 40}{400} = 0.48 \text{ cm}^2,
Question 4

8. A 67-year-old man with aortic regurgitation underwent transthoracic echocardiographic examination. There was no mitral stenosis or regurgitation. The following values were obtained:

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<tr>
<td>Peak aortic antegrade flow velocity</td>
</tr>
<tr>
<td>Blood pressure</td>
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</table>

Based on the aforementioned data, one can conclude that:

A. Pressure half-time is consistent with severe aortic regurgitation.
B. Aortic valve area can be estimated as 220 divided by pressure half-time.
C. Peak left ventricular systolic pressure (LVSP) is lower than the systolic blood pressure (SBP).
D. Left ventricular end-diastolic pressure (LVEDP) is estimated at 10 mm Hg.
E. Aortic valve area cannot be calculated using continuity equation because there is aortic regurgitation.

Using the end-diastolic velocity \( V \) of the aortic regurgitant jet, one can calculate the pressure gradient \( \Delta P \) between the diastolic blood pressure (DBP) and the LVEDP:

\[ \Delta P = DBP - LVEDP = 4 \times V^2 \]  \hspace{1cm} (1)

Rearranging Eq. 1, LVEDP can be calculated in the following manner if the DBP is known:

\[ \text{LVEDP} = DBP - 4 \times V^2 \]  \hspace{1cm} (2)

In our patient:

\[ \text{LVEDP} = 85 \text{ mm Hg} - 4 \times (3.7 \text{ m/s})^2 = 10 \text{ mm Hg} \]

Therefore, answer D is correct.

Thank You and Good Luck!