A Practical Approach to Prosthetic Valves

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Disclosures

- None

1 Know the Product

- Design type & size
- Flow characteristics
- Age of valve

2 Know the Look

- Structural appearance
- Mobility & seating
- Artifacts

3 Know the Flow

- Maximum & mean gradients
- Effective orifice area (EOA)
- Normal regurgitation

4 Know the Problems

- Patient-prosthesis mismatch
- Obstruction/stenosis
- Abnormal regurgitation

1 Know the Product

1

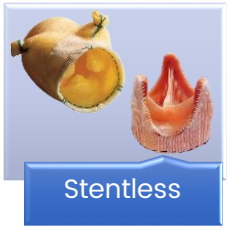
Each valve differs in it's design & flow characteristics

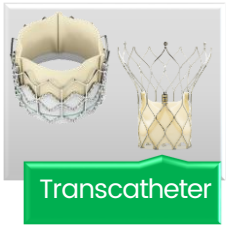

Bileaflet titling disk


Single tilting disk


Ball-Cage


Stented


Stentless


Transcatheter


Surgical Hybrid

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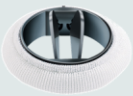
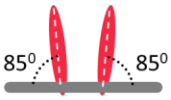
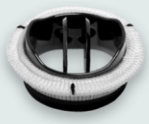
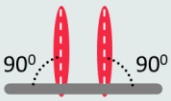
Valve Design

Bileaflet Mechanical Valves

Valve	Opening angle	Closing angle
 CarboMedics	 78⁰ 78⁰	 25⁰ 25⁰
 ATS Open Pivot	 85⁰ 85⁰	 25⁰ 25⁰
 On-X	 90⁰ 90⁰	 40⁰ 40⁰

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Flow Characteristics
Mechanical Valves - Inflow

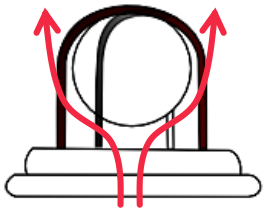
Bileaflet

2 large lateral orifices
1 smaller central orifice

Single disk

1 major orifice
1 minor orifice

Ball-cage



Flow diverges around the ball

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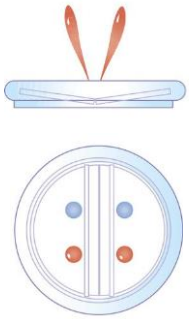
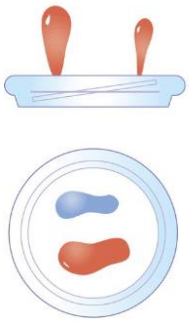
Flow Characteristics
Mechanical Valves - Regurgitation

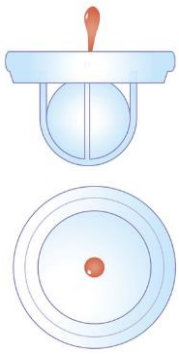
Bileaflet



Single disk (Björk-Shiley)



Ball-cage



From John B Chambers Echo Res Pract 2016;3:R35-R43

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2. Know the Look

Prosthetic valves do not have the same look

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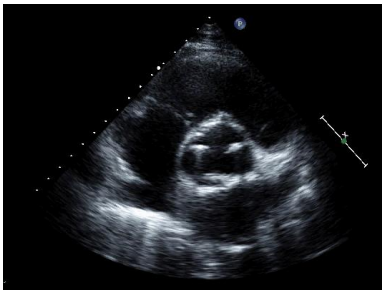
2. Know the Look

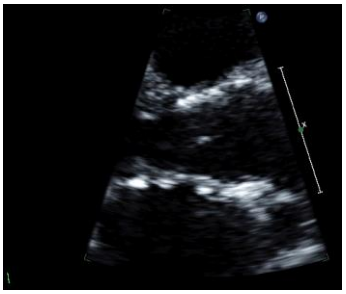
Design influences 2D appearance

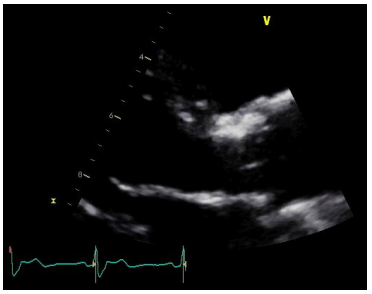
CE AVR
Stented

CLOB AVR
Stentless

SAPIEN
Transcatheter







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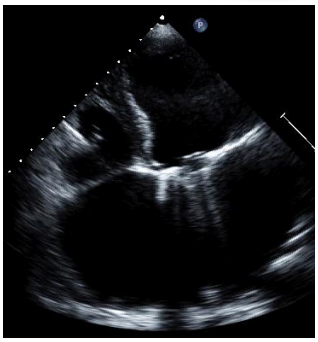
2 Know the Look

Design influences 2D appearance

Mosaic Stented

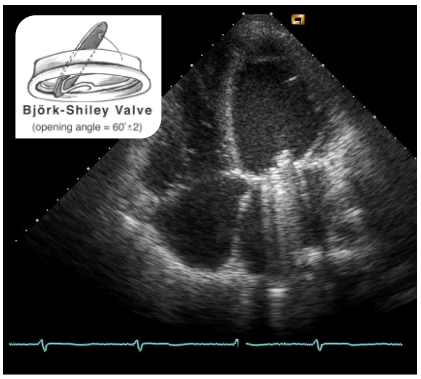
St Jude Bileaflet

Starr-Edwards Ball-cage

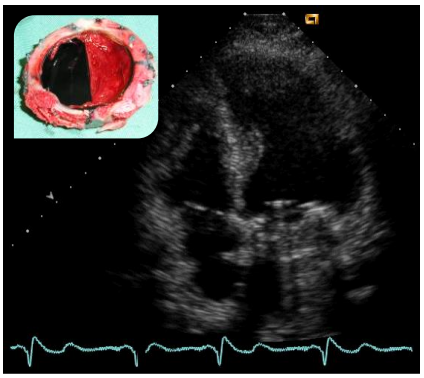


2 Know the Look

Normal or Abnormal?



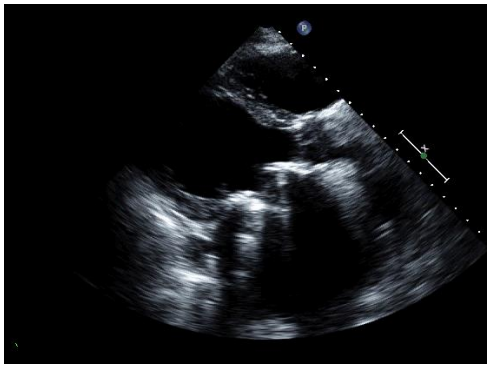
Normal Björk-Shiley



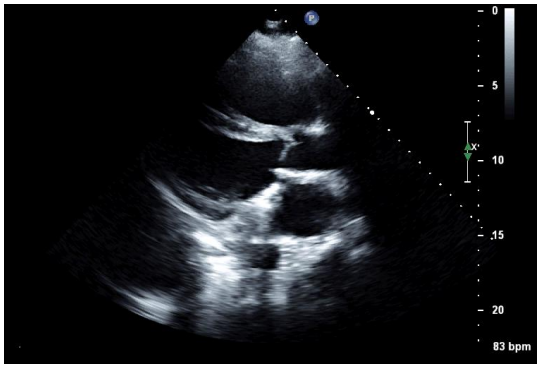
Abnormal ATS

2. Know the Look

Check the valve bed & stability of valve



Good: Stable



Bad: 'Rocking' ≈ Dehiscence

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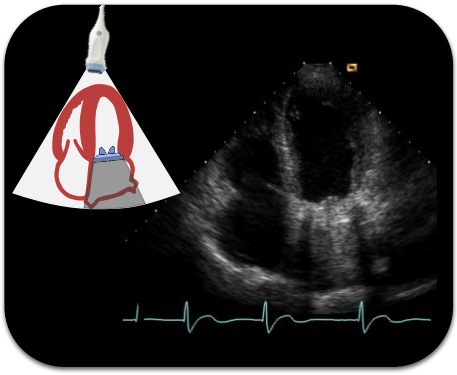
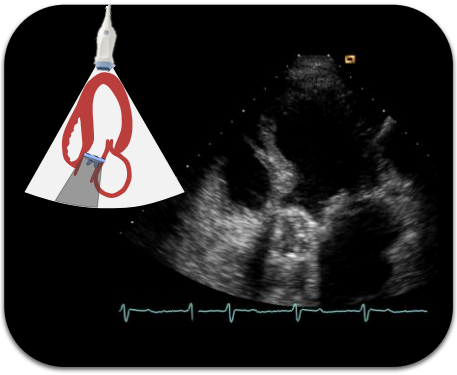
2. Know the Look

Artifacts: awareness avoids missing a diagnosis





Acoustic shadow & reverberation artifacts
Decreased resolution in far-field with reduced diagnostic accuracy

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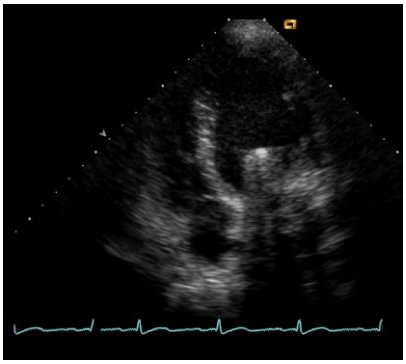
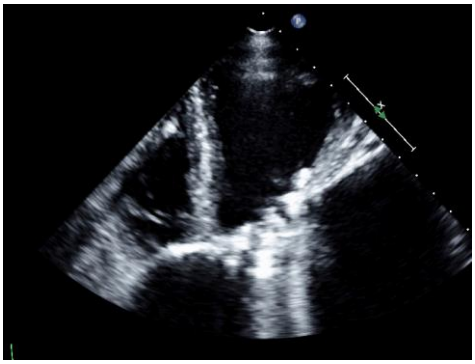
2 Know the Look

Artifacts: awareness avoids over-diagnosis



Beam path artifact in SE MVR (Normal)



Microbubbles in St Jude MVR (Normal)

3 Know the Flow

3 Know the Flow

Appendix A. Normal Doppler Echocardiographic Values for Prosthetic Aortic Valves*

Valve	Size	Peak gradient (mm Hg)	Mean gradient (mmHg)	Effective orifice area (cm^2)
St. Jude Medical	19	28.5± 10.7	17.0± 7.8	1.9± 0.1
Haem Plus	21	16.3± 17.0	10.6± 5.1)	1.8± 0.5
Bileaflet	23	16.8± 7.3	12.1± 4.2	1.7± 0.5
	19	20.6± 12	11.0± 4.9	1.6± 0.4
St Jude Medical Regent	21	15.6± 9.4	8.0± 4.8	2.0± 0.7
Bileaflet	23	12.8± 6.8	6.9± 3.5	2.3± 0.9
	25	11.7± 6.8	5.6± 3.2	2.5± 0.8
	27	7.9± 5.5	3.5± 1.7	3.6± 0.5
	19	42.0± 10.0	24.5± 5.8	1.5± 0.1
	21	25.7± 9.5	15.2± 5.0	1.4± 0.4
St Jude Medical Standard	23	21.8± 7.5	13.4± 5.6	1.6± 0.4
Bileaflet	25	18.9± 7.3	11.0± 5.3	1.9± 0.5
	27	13.7± 4.2	8.4± 3.4	2.5± 0.4
	29	13.5± 5.8	7.0± 1.7	2.8± 0.5
	21	22.6± 14.5	10.7± 7.2	1.3± 0.6
St Jude Medical	23	16.2± 9.0	8.2± 4.7	1.6± 0.6
Stentless	25	12.7± 8.2	6.3± 4.1	1.8± 0.5
	27	10.1± 5.8	5.0± 2.9	2.0± 0.3
	29	7.7± 4.4	4.1± 2.4	2.4± 0.6

Zoghbi WA, et al. J Am Soc Echocardiogr. 2009 Sep;22(9):975-1014

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3 Know the Flow

Simplified

Valve	Parameter	Normal
AVR	Peak velocity	< 3 m/s
	Mean gradient	< 20 mmHg
	Doppler velocity Index (DVI)	≥ 0.30
	Effective orifice area (EOA)	> 1.2 cm^2
	Contour of the jet velocity	Triangular, early peaking
	Acceleration time (AT)	< 80 ms
MVR	Peak velocity	< 1.9 m/s
	Mean gradient	≤ 5 mmHg
	Doppler velocity Index (DVI)	< 2.2
	Effective orifice area (EOA)	≥ 2.0 cm^2
	Pressure half-time (PHT)	< 130 ms

Zoghbi WA, et al. J Am Soc Echocardiogr. 2009 Sep;22(9):975-1014

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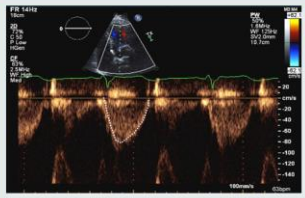
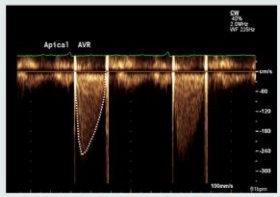
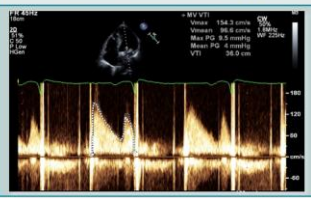
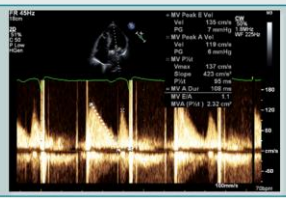
3 Know the Flow

Baseline study early post-op/post-procedure strongly recommended

23 mm ATS AVR			• Vmax = 2.4 m/s • mPG = 13 mmHg • DVI = 0.33 • EOA = 1.5 cm^2
31 mm ATS AVR			• mPG = 4 mmHg • DVI = 1.5 • EOA = 2.8 cm^2 • PHT = 95 ms

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4 Know the Potential Problems

Path	Thrombosis	Pannus	Structural Degeneration	Endocarditis	PPM	Mal-deployment (TAVR)
Type of dysfunction	Obstruction	Obstruction	Stenosis / Regurgitation	Regurgitation / Shunts / stenosis	Non-structural dysfunction	Regurgitation/ Stenosis
Clinical presentation	Echo CHF Shock	Echo CHF Shock	Echo CHF Shock	Echo CHF Shock Sepsis	Echo CHF	Echo CHF Shock

Courtesy Dr Darryl Burstow, The Prince Charles Hospital

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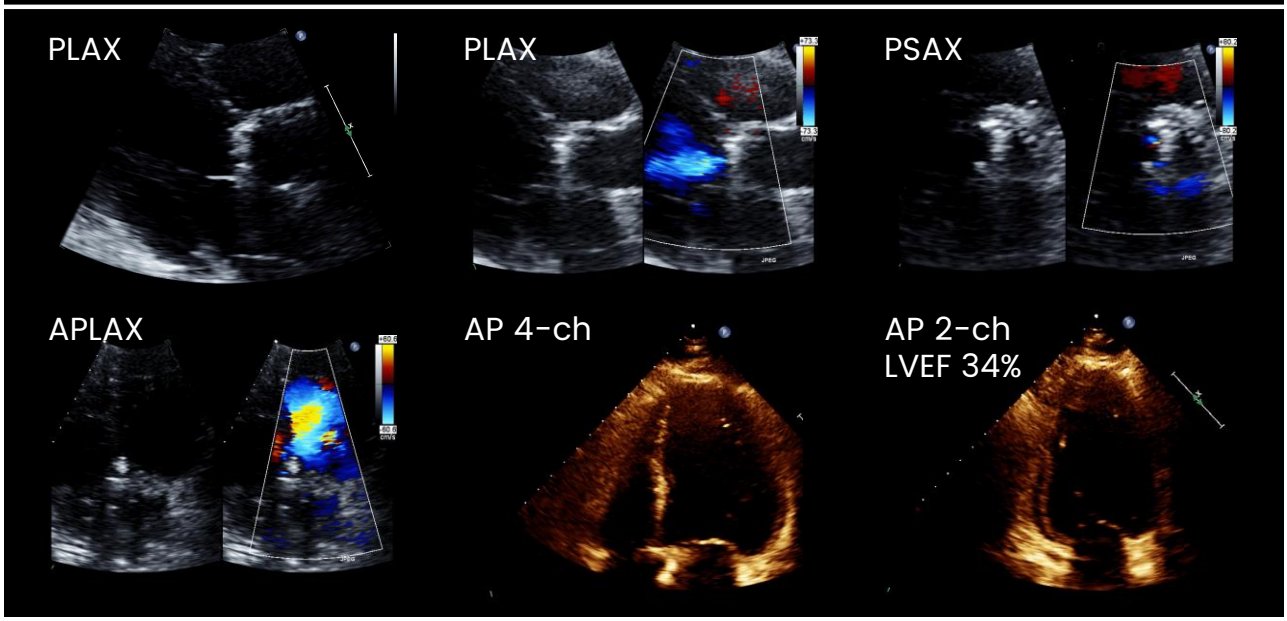
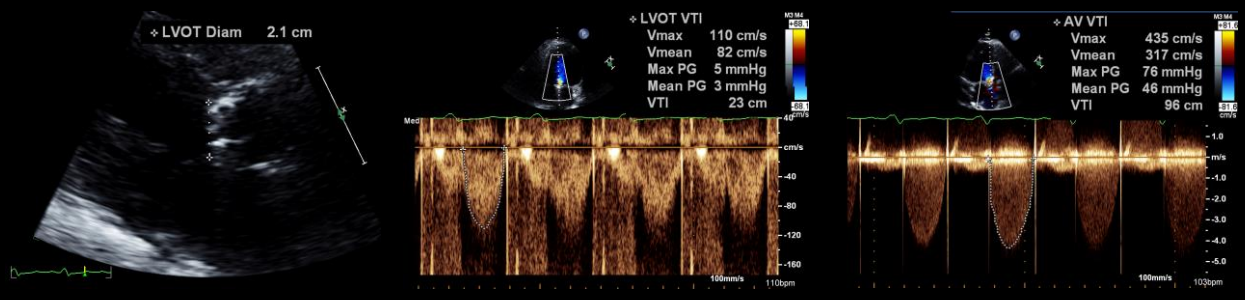
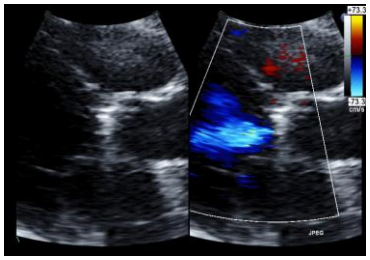
50 yo female, 21 mm St Jude AVR, presents with CCF

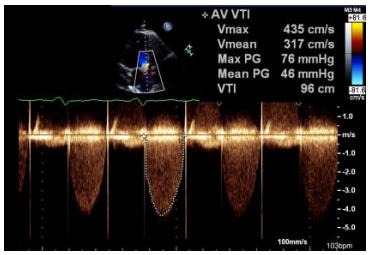


50 yo female, 21 mm St Jude AVR, presents with CCF



- Peak PG 76 mmHg (normal 25.7 ± 9.5 mmHg)
- mPG 46 mmHg (normal 15.2 ± 5.0 mmHg)
- EOA 0.83 cm^2 (normal 1.4 ± 0.4 cm^2)
- IEOA 0.40 cm^2/m^2 (abnormal ≤ 0.85 cm^2/m^2)
- DVI 0.24 (normal ≥ 0.3)





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Question

What is the likely cause for increased gradients in this AVR?

1. Prosthesis-patient mismatch
2. LV flow acceleration
3. True obstruction
4. High flow rate due to significant AR

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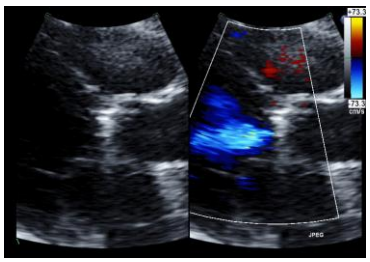

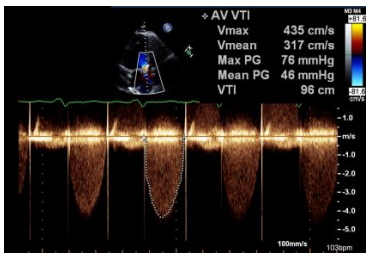

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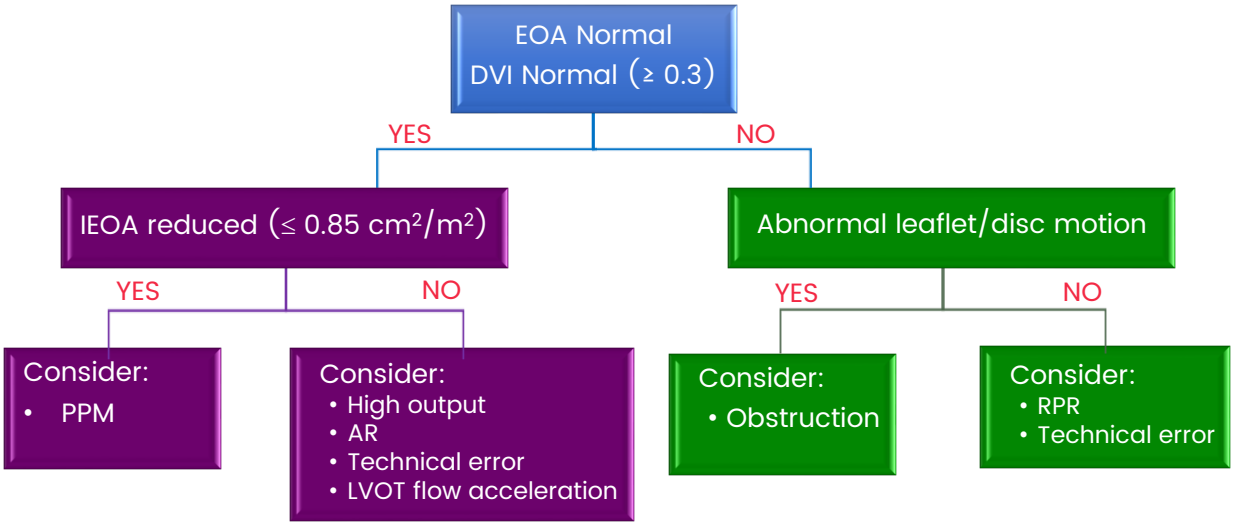
A Diagnostic Pathway for Elevated AVR Gradients



Adapted from 'A Sonographer's Guide to the Assessment of Heart Disease.' B. Anderson; 2014 Echotext Pty Ltd

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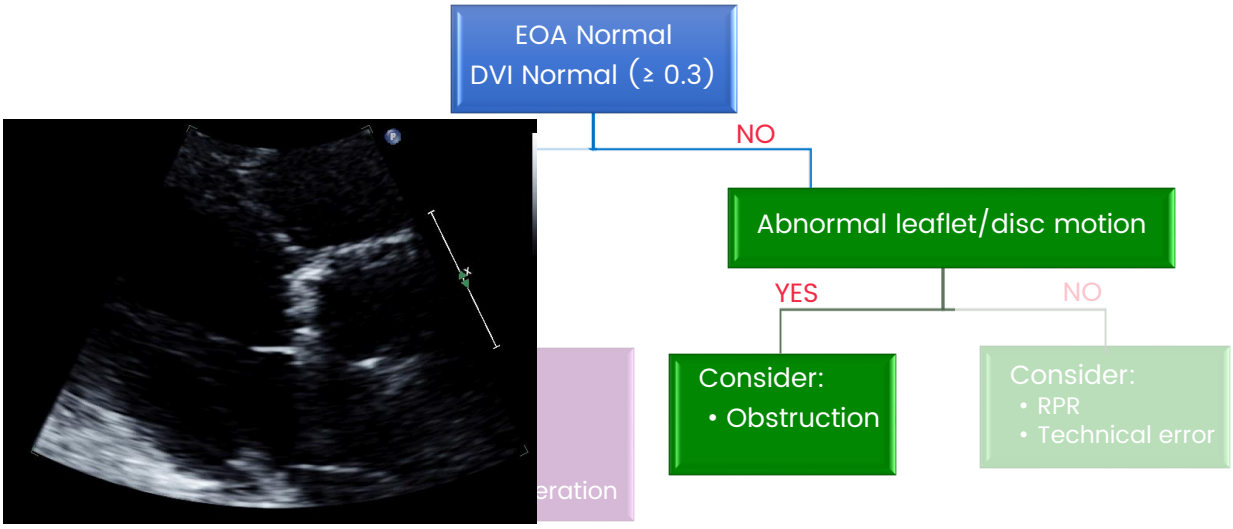
Our patient: EOA 0.83 cm² (normal 1.4±0.4 cm²)
DVI 0.24



Adapted from 'A Sonographer's Guide to the Assessment of Heart Disease.' B. Anderson; 2014 Echotext Pty Ltd

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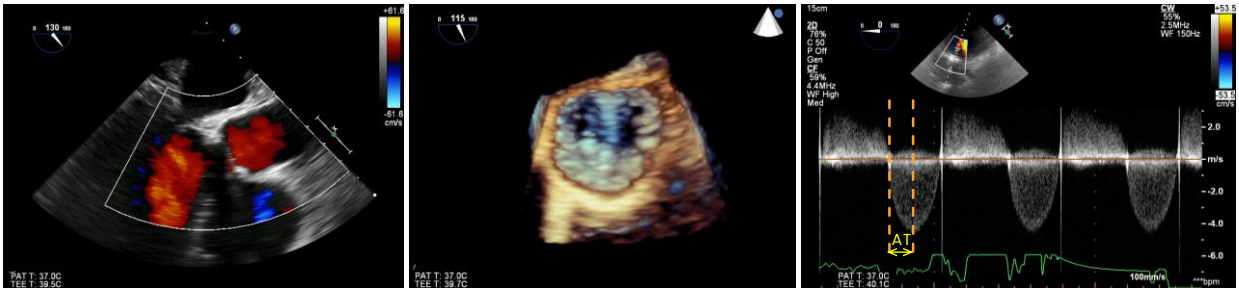
Case #1: Follow-up



There is a St Jude 21mm aortic valve replacement, which is well seated with abnormal occluder motion. The anterior occluder motion is severely restricted. There is a soft echogenic linear mass attached to the aortic surface of the anterior occluder which may represent thrombus or pannus (thrombus more likely but appearances non-diagnostic). Its exact size cannot be accurately measured but appears of moderate size. The peak velocity is 4.1 m/s, (normal 2.5 - 3.2m/s). The mean gradient is 47.5 mmHg , (normal 13 - 23mmHg). Dimensionless Performance Index is 0.2, (normal 0.33 - 0.41). There is grade 3/4 valvular AR. AV Acceleration time 148ms.

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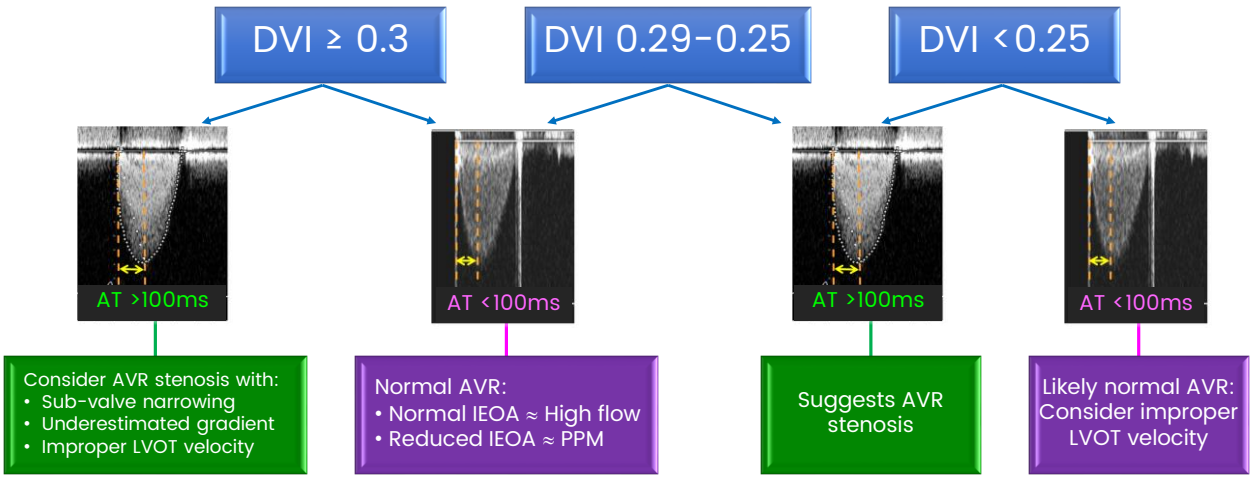
Value of AVR Acceleration Time (AT) for Elevated AVR Gradients



Adapted from Zoghbi WA, et al. J Am Soc Echocardiogr. 2009 Sep;22(9):975-1014

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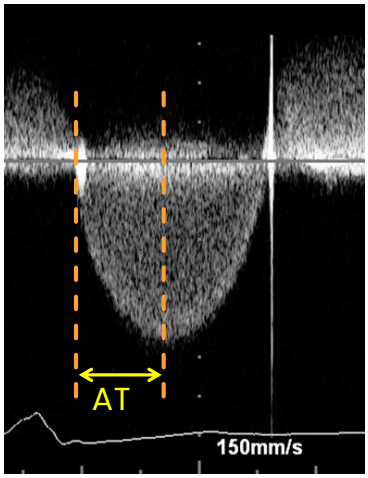

JACC: CARDIOVASCULAR IMAGING
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ORIGINAL RESEARCH

Flow Acceleration Time and Ratio of Acceleration Time to Ejection Time for Prosthetic Aortic Valve Function

Sagit Ben Zekry, MD,* Robert M. Saad, MD,* Mehmet Özkan, MD,†
Maie S. Al Shahid, MD,‡ Mauro Pepi, MD,§ Manuela Muratori, MD,§ Jiaqiong Xu, PHD,‖
Stephen H. Little, MD,* William A. Zoghbi, MD*
Houston, Texas; Istanbul, Turkey; Riyadh, Saudi Arabia; and Milan, Italy

Cut-off AT = 100 ms for identifying AVR stenosis:

- Sens. 86%
- Spec. 86%
- PPV 66%
- NPV 95%

Ben Zekry S, et al. JACC Cardiovasc Imaging. 2011 Nov;4(11):1161-70.

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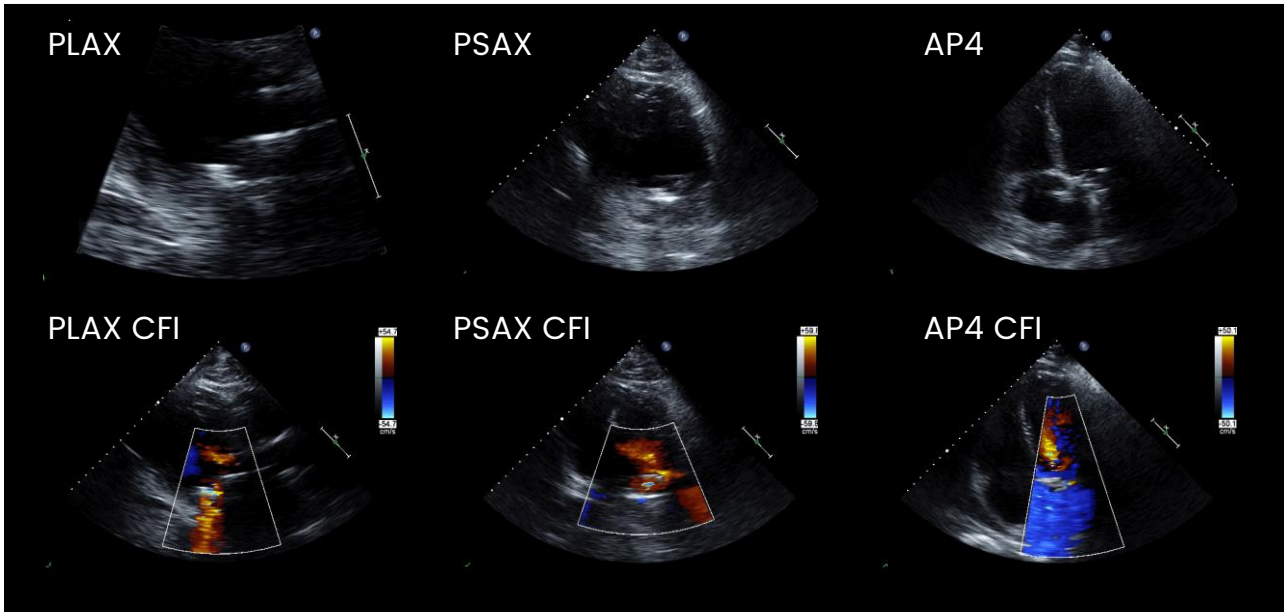
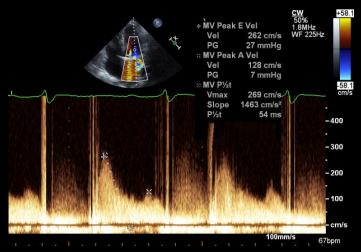
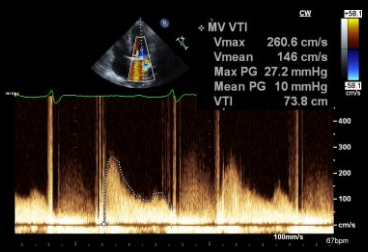
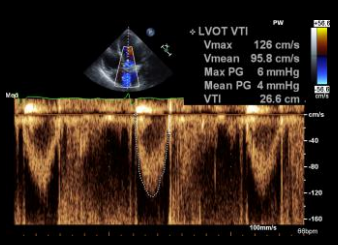
61 yo male, 31mm ATS MVR, 27mm ATS AVR, SOBOE



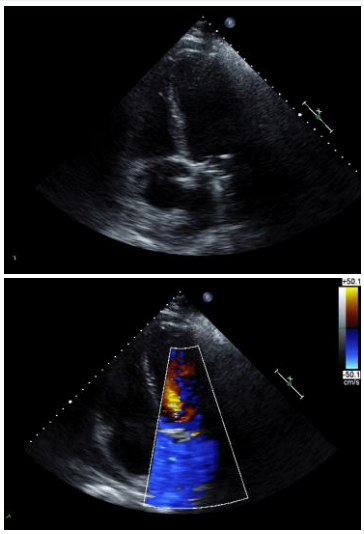
61 yo male, 31mm ATS MVR, 27mm ATS AVR, SOBOE







- Peak E velocity 2.6 m/s
- mPG 10 mmHg (normal 3.1 ± 0.2 mmHg)
- PHT 54 ms
- EOA 2.1 cm^2 (normal 2.9 ± 0.2 cm^2)
- IEOA 0.83 cm^2/m^2 (abnormal ≤ 1.2 cm^2/m^2)
- DVI 2.8 (normal ≤ 1.8)



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Question

What is the likely cause for increased gradients in this MVR?

1. Technical error
2. Significant MR
3. True obstruction
4. Prosthesis-patient mismatch

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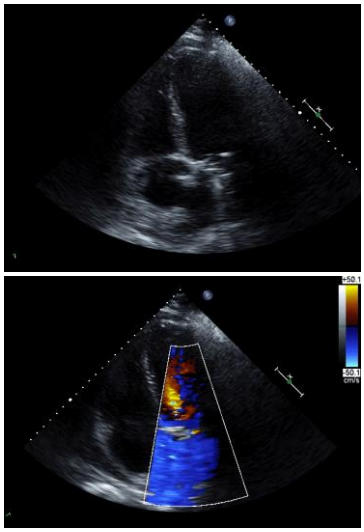

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Question

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2. Significant MR
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4. Prosthesis-patient mismatch

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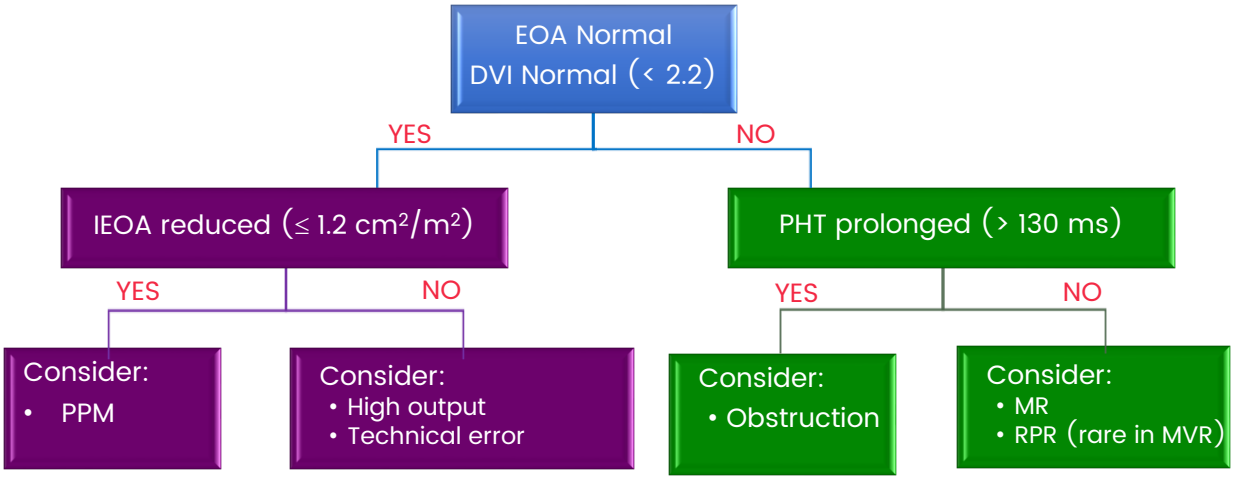
A Diagnostic Pathway for Elevated MVR Gradients



Adapted from 'A Sonographer's Guide to the Assessment of Heart Disease.' B. Anderson; 2014 Echotext Pty Ltd

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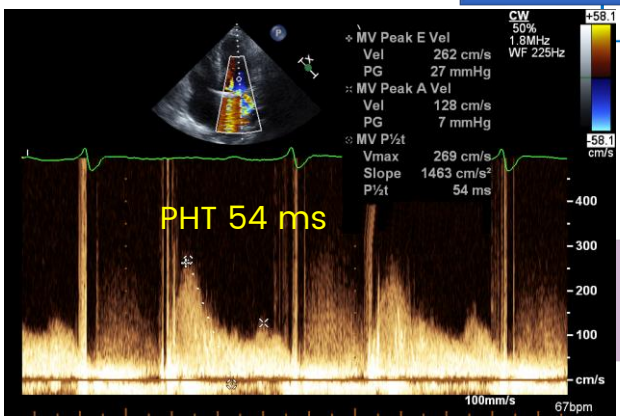
Our patient: EOA 2.1 cm^2 (normal 2.9 ± 0.2 cm^2)
DVI 2.8



EOA Normal
DVI Normal (< 2.2)

NO

PHT prolonged (> 130 ms)

YES

Consider:
• Obstruction

NO

Consider:
• MR
• RPR (rare in MVR)

Adapted from 'A Sonographer's Guide to the Assessment of Heart Disease.' B. Anderson; 2014 Echotext Pty Ltd

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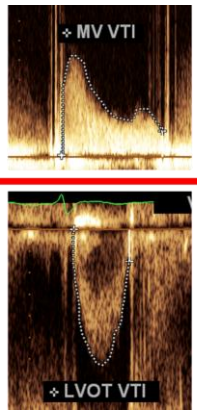
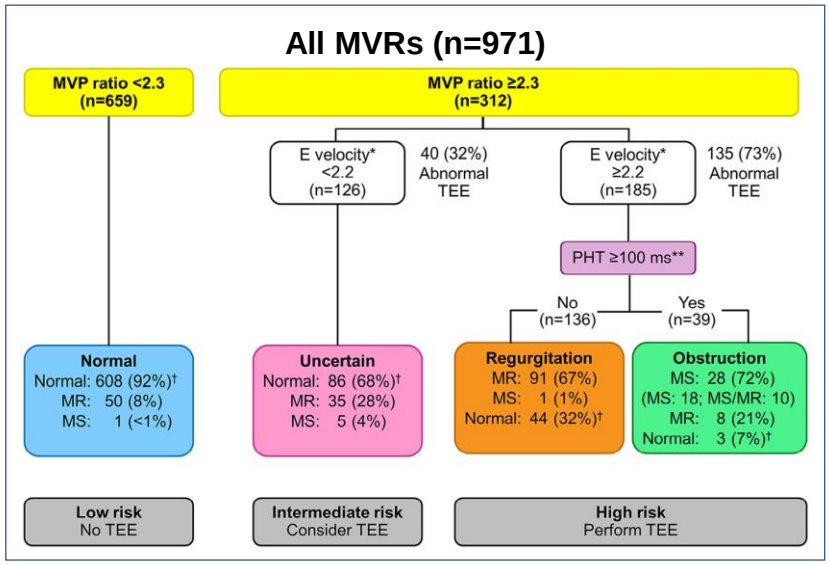
Value of Mitral Valve Prosthesis (MVP) Ratio (or DVI)

DVI = (MVP)





Luis SA, et al. Am J Cardiol 2017;120:1373–1380

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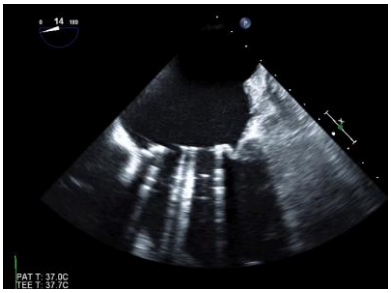
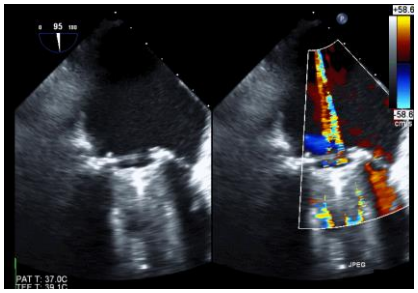
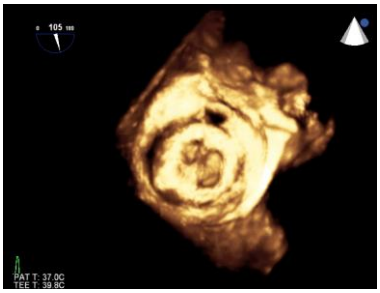
Case #2: Follow-up

There is a 31 mm ATS mitral valve replacement. The prosthetic occluder discs move normally. E velocity is 2.2 m/s, mean gradient is 8 mmHg (normal 2.5 - 4 mmHg). There is extensive anterolateral sewing ring dehiscence extending at least one-third of the circumference (extending between 30 to 160 degrees in the midoesophageal view). The defect measures up to 10 mm in width. There is abnormal rocking of the prosthesis adjacent to this defect consistent with significant dehiscence. There are small, mobile strand-like echodensities in this region, which are likely to represent suture material or fibrin. However, vegetations cannot be excluded and clinical correlation is recommended. There is severe, grade 4/4 paravalvular mitral regurgitation. The effective regurgitant orifice area is 80 mm² and the regurgitant volume is 105 ml.

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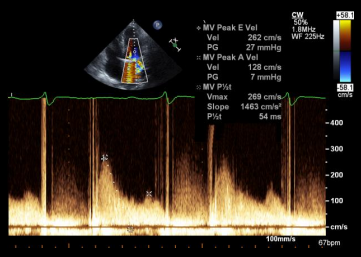
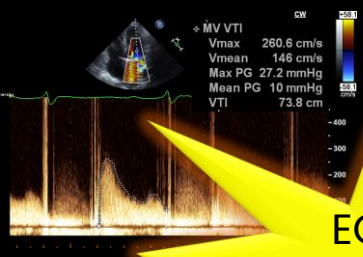
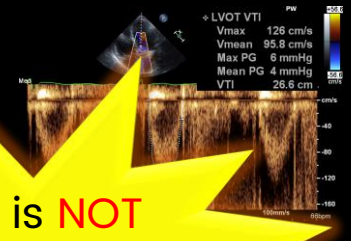
61 yo male, 31mm ATS MVR, 27mm ATS AVR, SOBOE







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- mPG 10 mmHg (normal
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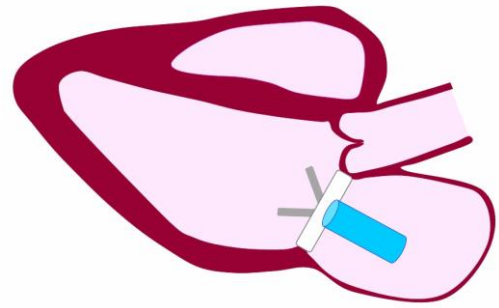
- DVI 2.8 (normal ≤ 1.8)

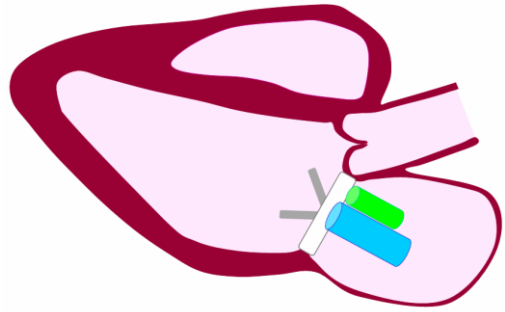
EOA is NOT accurate in this case due to MR

Continuity Equation for EOA*

$$EOA = \frac{SV_{LVOT}}{MVR_{VTI}}$$

$$\downarrow EOA = \frac{SV_{LVOT}}{\uparrow MVR_{VTI}}$$





* Assumes MVR stroke volume = LVOT stroke volume

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1 Know the Product

- Design type & size
- Flow characteristics
- Age of valve

2 Know the Look

- Structural appearance
- Mobility & seating
- Artifacts

3 Know the Flow

- Maximum & mean gradients
- Effective orifice area (EOA)
- Normal regurgitation

4 Know the Problems

- Patient-prosthesis mismatch
- Obstruction/stenosis
- Abnormal regurgitation

Thanks for your attention

http://www.tobacco-news.net/wp-content/uploads/2010/05/The-Smoking-Heart.-300x225.jpg

Extra: Pannus versus thrombus

Parameters	Thrombus	Pannus
Clinical	• shorter (≈ 2 months) • Symptom duration before reoperation shorter (< 1 month) • Inadequate anticoagulation *	• Time from valve surgery to valve malfunction longer (> 12 months) • Symptom duration before reoperation • longer (≈ 10 months) • Adequate anticoagulation*
Echocardiography	• Larger • Soft tissue appearance (similar to myocardium) • Mobile • Extension of mass beyond limits of prosthetic valve ring to adjacent cardiac structures • More common in MVR than AVR	• Smaller • Echo dense appearance • Firmly fixed • Annular location (along valvular plane) • More common in AVR than MVR

* Adequate anticoagulation defined as International Normalized Ratio (INR) ≥ 2.5 at the time of diagnosis

Barbetseas J, et al. *J Am Coll Cardiol.* 1998 Nov;32(5):1410-7.

Extra: Calculation of the EOA

EOA

= (CSA LVOT*) X (LVOT VTI) ← LVOT Stroke Volume

÷ (AVR VTI) or (MVR VTI)

For MVR, ≤ grade 1/4 AR or MR

* CSA LVOT = LVOT diameter^2 x 0.785

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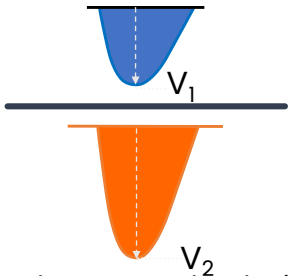
Extra: DVI for AVR & MVR

DVI (AVR) = $V_1 \div V_2$

PW Doppler LVOT peak velocity (V_1)

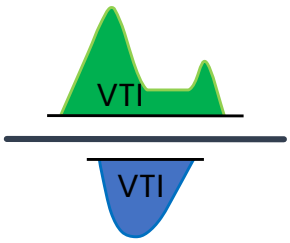


CW Doppler AVR peak velocity (V_2)

Normal ≥ 0.30 Abnormal ≤ 0.25

DVI (MVR) = $MVR_{VTI} \div LVOT_{VTI}$

CW Doppler MVR VTI



PW Doppler LVOT VTI

Normal ≤ 1.8 Abnormal ≥ 2.2

ECHO HAWAII