Echocardiographic Evaluation of Aortic Valve Prosthesis

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Philadelphia, PA

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Pre Questions (1)

- Regarding Aortic Prosthetic Valves
  - A. A routine echocardiogram is required very two years after AVR
  - B. An elevated gradient with a decreased EOA is always suggestive of valvular stenosis
  - C. Transthoracic echocardiogram alone is always sufficient to diagnose valvular stenosis
  - D. It is more challenging to quantify para-valvular versus valvular aortic regurgitation.

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Pre Questions (2)

- Patients with Prosthesis-Patient Mismatch
  - A. Have abnormal prosthetic valve function
  - B. Progressively worsen with time
  - C. Have a small valve compared to the demands of their body and cardiac output
  - D. Have a benign condition

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GUIDELINES AND STANDARDS

Recommendations for Evaluation of Prosthetic Valves With Echocardiography and Doppler Ultrasound

A Report From the American Society of Echocardiography's Guidelines and Standards Committee and the Task Force on Prosthetic Valves, Developed in Conjunction With the American College of Cardiology Cardiovascular Imaging Committee, Cardiac Imaging Committee of the American Heart Association, the European Association of Echocardiography, a registered branch of the European Society of Cardiology, the Japanese Society of Echocardiography and the Canadian Society of Echocardiography, Endorsed by the American College of Cardiology Foundation, American Heart Association, European Association of Echocardiography, a registered branch of the European Society of Cardiology, the Japanese Society of Echocardiography, and Canadian Society of Echocardiography

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JASE September 2009

Topics of Discussion

- Types and Flow Profiles of Prosthetic Valves
- Echocardiographic Evaluation: Key Points
- Challenges for Evaluation
- Prosthetic Valves Evaluation
  - Elevated gradients
  - Regurgitation
  - Endocarditis
  - Thrombosis versus pannus

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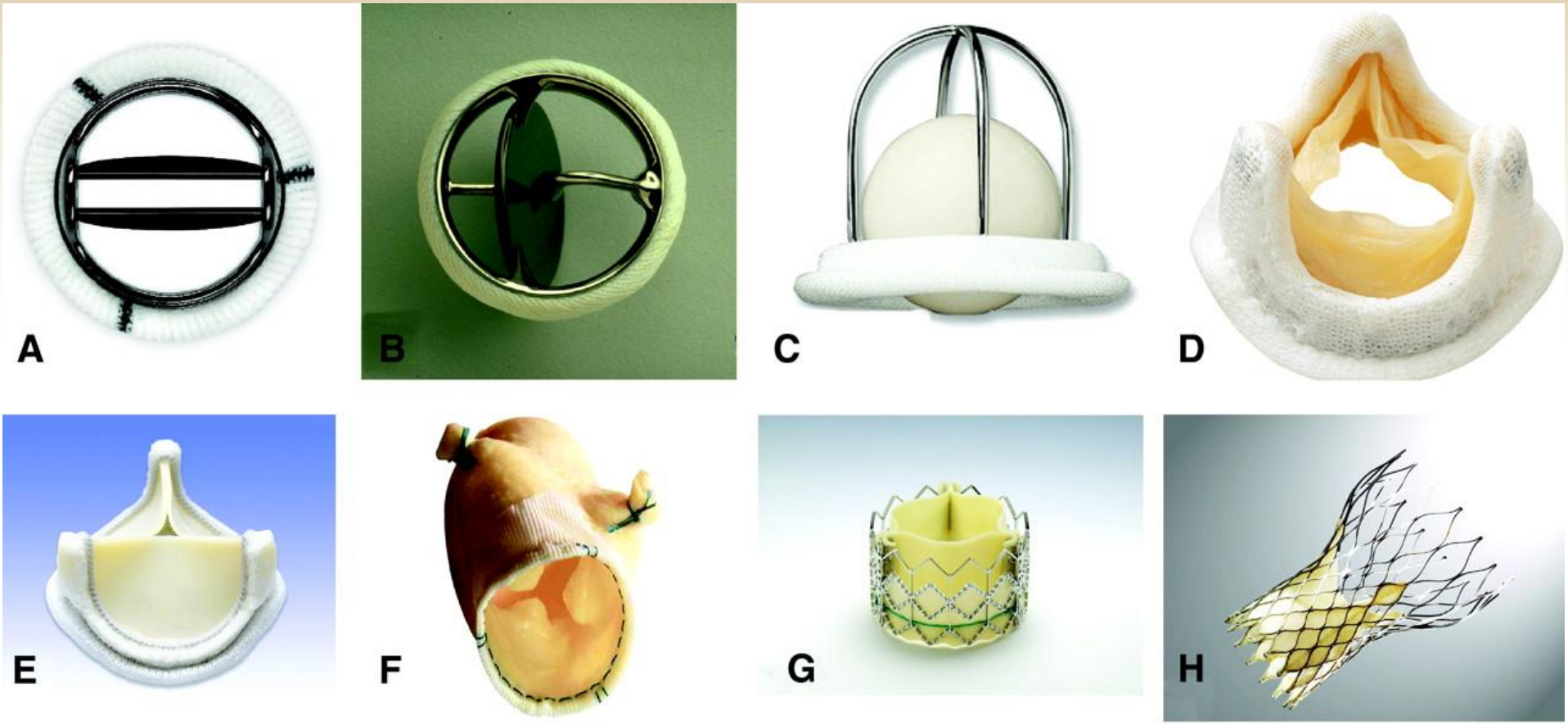
Types & Flow Profiles of Prosthetic Valves

Mechanical Vs. Bioprosthetic Vs. Autografts



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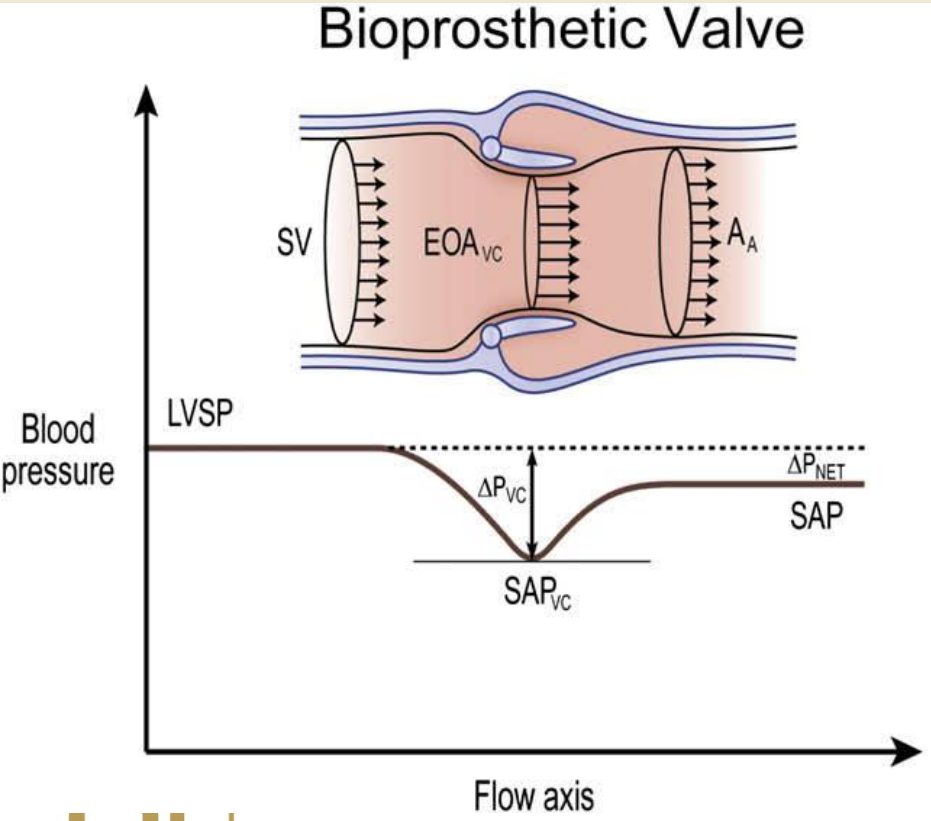
Pibarot P , Dumesnil J G Circulation 2009;119:1034-1048

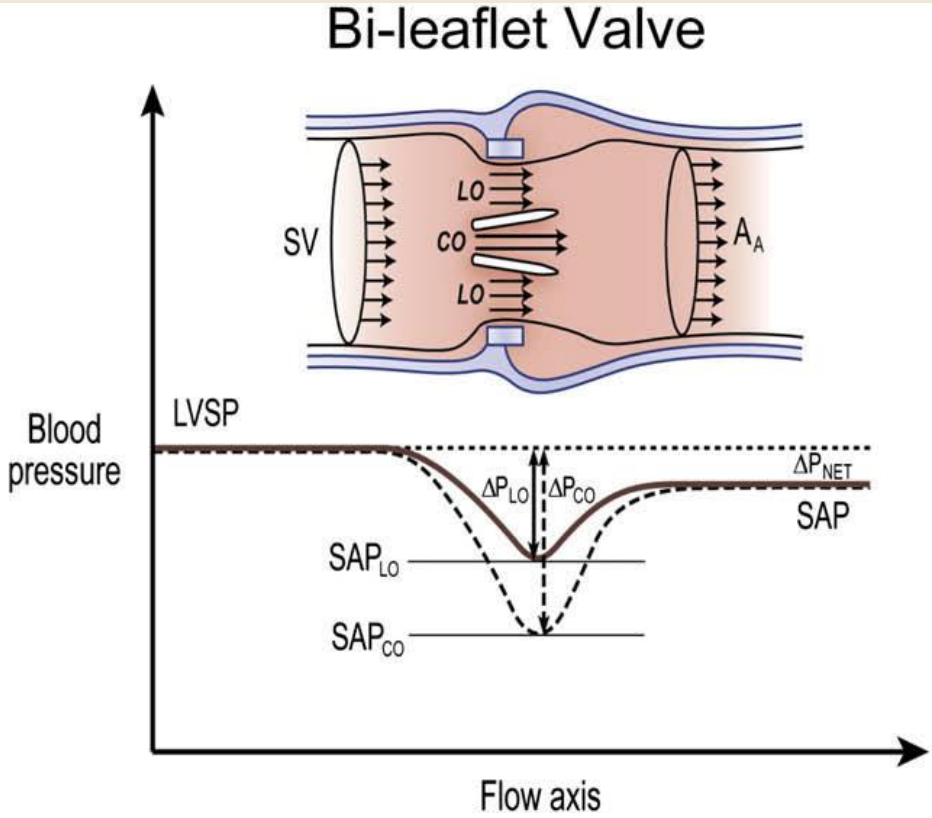
American Heart Association

Learn and Live

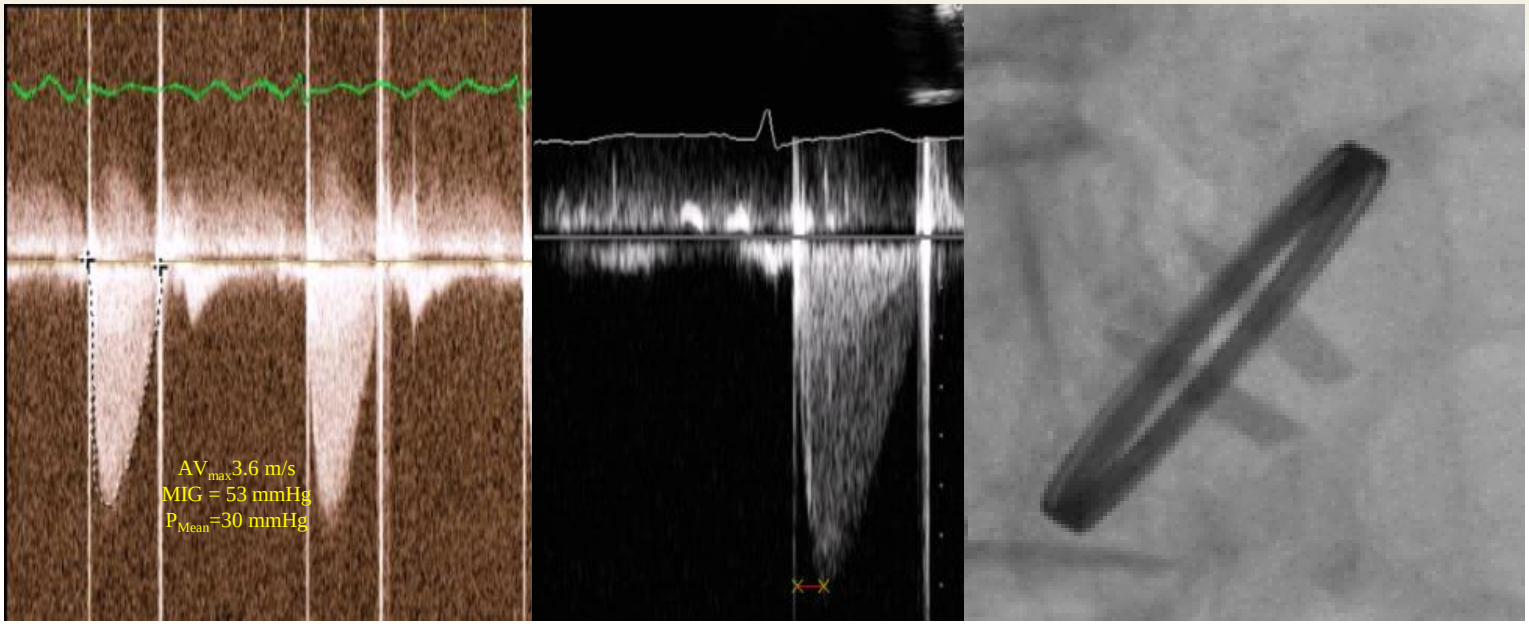
Types & Flow Profiles of Prosthetic Valves

Mechanical Vs. Bioprosthetic Flow





Localized Pressure Loss and High Gradient in Central Orifice of Bileaflet Mechanical Valve (?Pressure Recovery)



- **Fluoroscopy**

ECHO EVALUATION Guidelines

- CLASS I
  - Initial TTE after AVR (2-4 weeks or sooner if concern for follow up and transfer)
  - Repeat TTE for AVR if there is a change in clinical symptoms or signs suggesting dysfunction
  - TEE for AVR if there is a change in clinical symptoms or signs suggesting dysfunction
- CLASS II
  - Annual TTE in bioprosthetic valves after the first 10 years (5 years in prosthetic statement 2008) but not mechanical valves

Nishimura et al 2014

ECHO EVALUATION: Key Points

- Clinical picture
- Baseline study
- Type and size of valve
- LV chamber
- BP/HR
- Height/weight/BSA
- Exercise echo may be helpful
- Cinefluoroscopy, CT, MRI

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ECHO EVALUATION: Key Points

- Opening and Closing of leaflets or occluders
- Abnormal densities (calcium/mass/vegetation)
- Stability versus rocking motion
- May use Modified versus Simplified Bernoulli
  - $4V_2^2 - 4V_1^2$ Vs. $4V_2^2$
- Attention to flow states & adequate Doppler signals

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Echo Evaluation: Key Points

- Adequate Doppler Signals
  - LVOT obtained away from flow acceleration (0.5 to 1 cm below sewing ring)
  - Multiple planes
  - Off axis view in parasternal view to obtain LVOT diameter
  - Eccentric aortic regurgitant jets may require different angles to Doppler

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Evaluation of Prosthetic Valves: Challenges

- Large range in what is considered normal
- Mean Gradients produced depend on size and type of valve.
- For any particular patient… it is difficult to differentiate normal from abnormal, hence the need for comparison to older studies
- Shadowing may interfere with assessment of location and amount of regurgitation

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Bioprosthetic Valve Abnormalities

- Elevated Gradients
- Regurgitation
- Endocarditis
- Thrombosis
- Pannus

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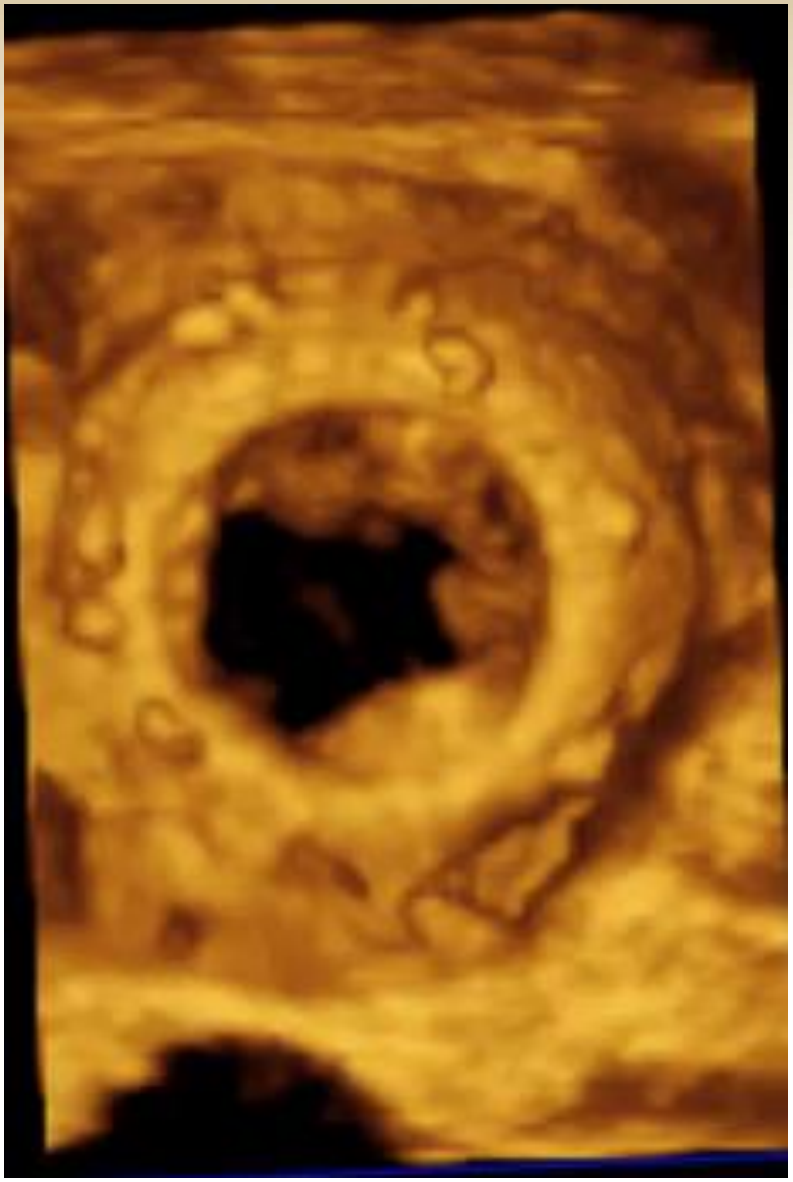
3D Echocardiography



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Echocardiographic Evaluation of Elevated Prosthetic Valve Gradients

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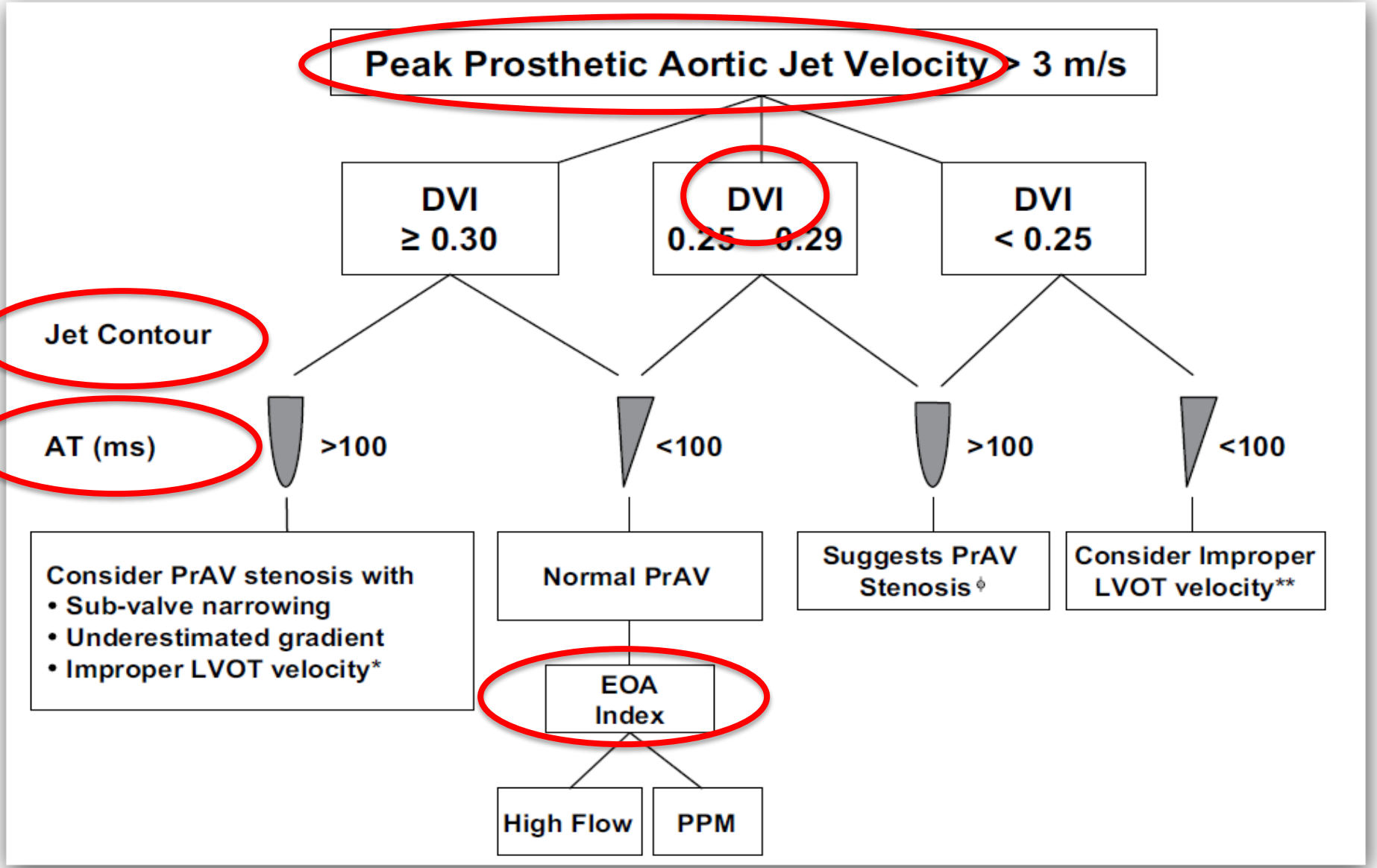
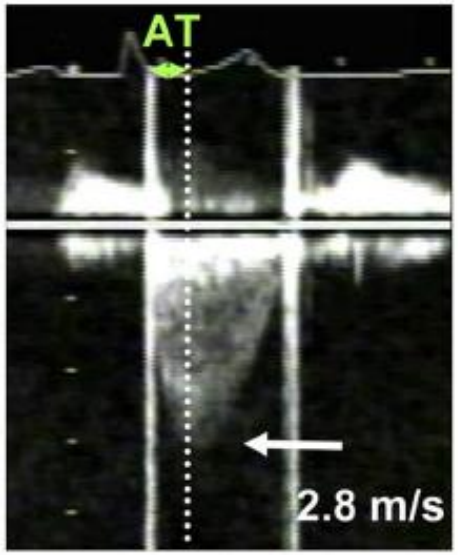
Echocardiographic Approach

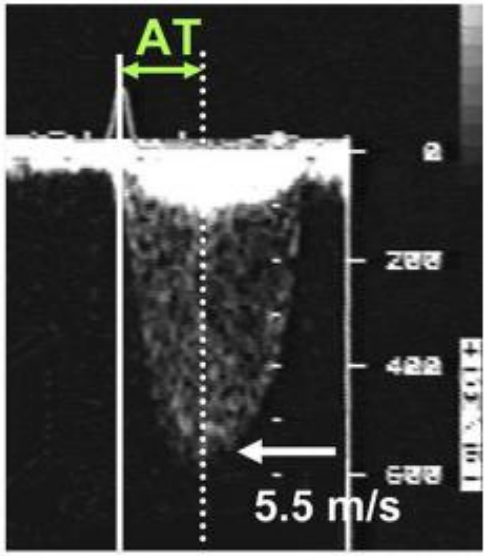


Parameters Utilized

- Peak prosthetic aortic velocity

CW Doppler
Prosthetic AV





Normal < 3 m/sec

Abnormal > 3 m/sec

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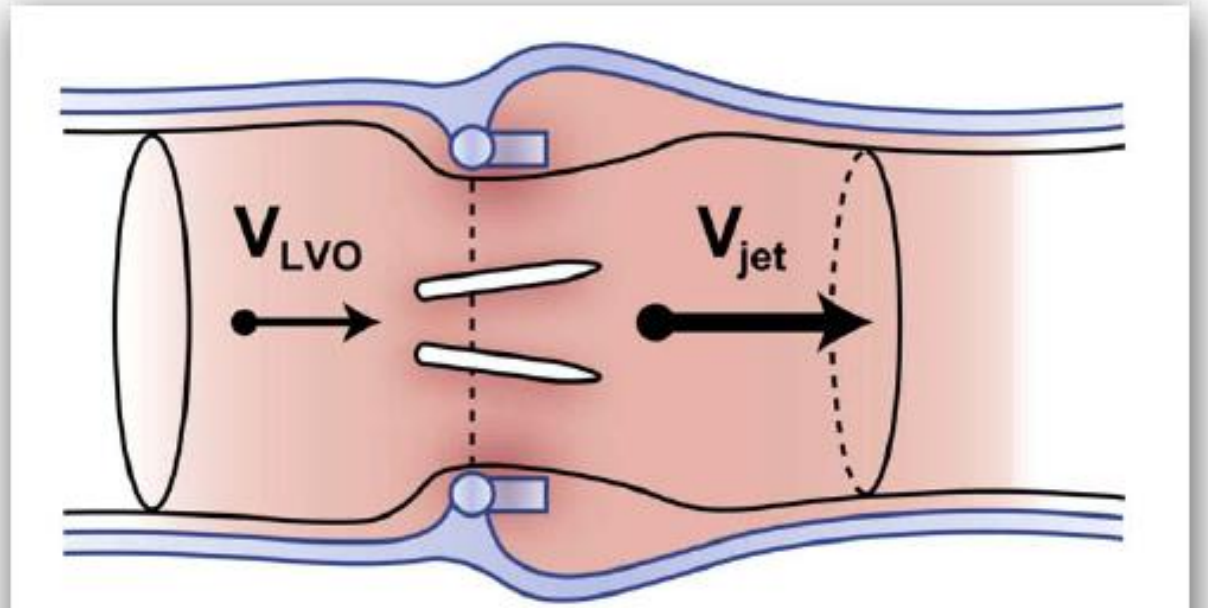
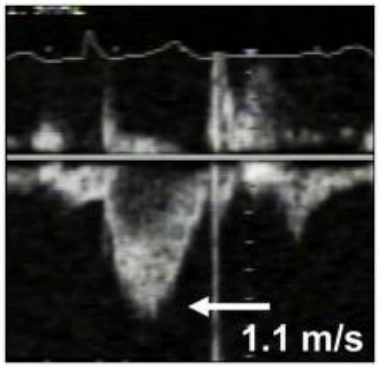
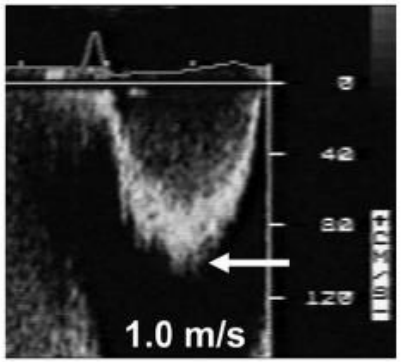
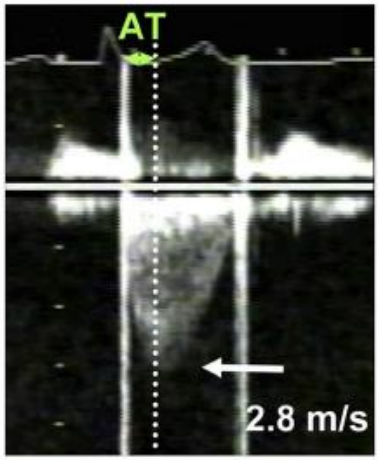
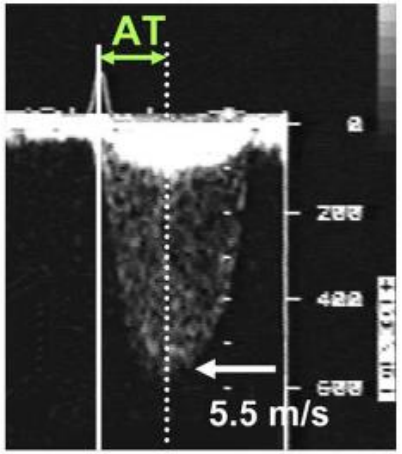
Parameters Utilized

- Doppler Velocity Index



$$\text{Doppler Velocity Index} = \frac{\text{Velocity}_{LVO}}{\text{Velocity}_{jet}}$$

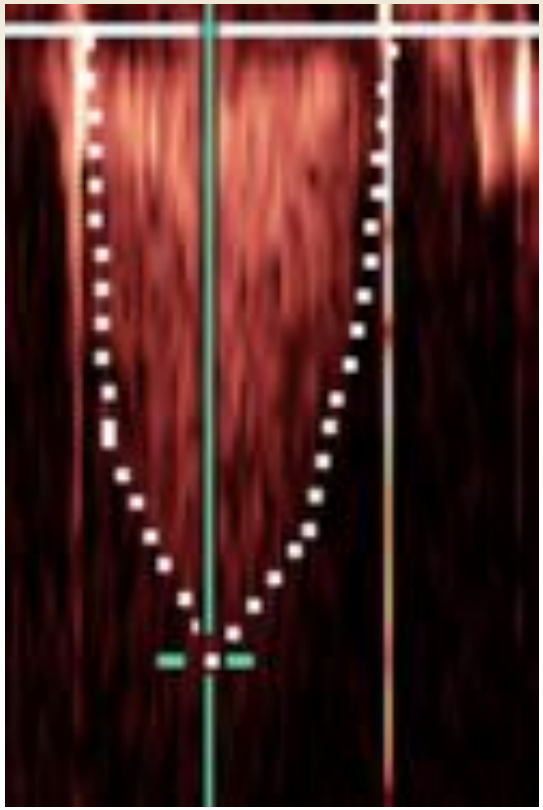
Doppler Velocity Index

	Normal	Obstructed
Pulsed Doppler LVO		
CW Doppler Prosthetic AV		
	1.1/2.8 = 0.39 **Normal > 0.3**	**1/5.5 = 0.18** **Abnormal < 0.25**

Parameters Utilized

- Jet Contour

Triangular

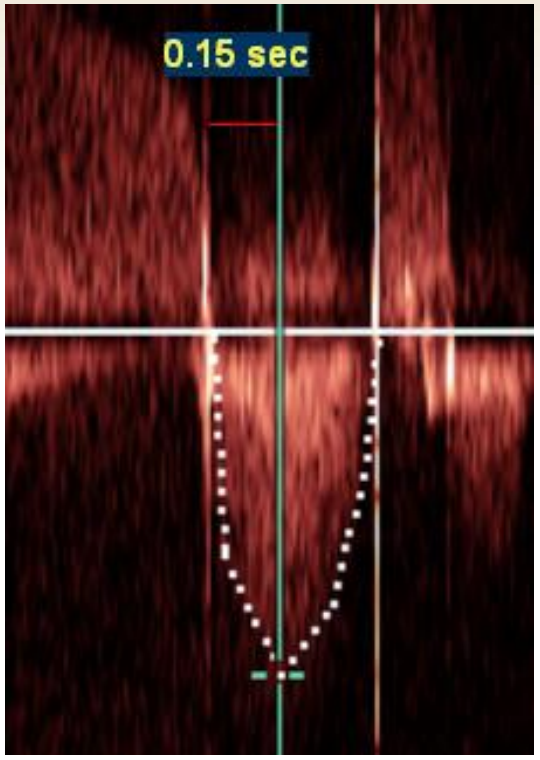


Rounded

Parameters Utilized

- Acceleration Time

90 msec
Normal < 100 msec



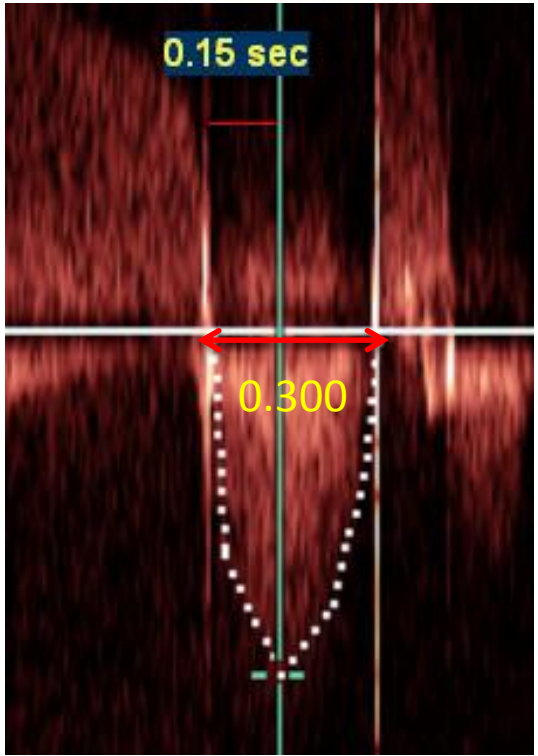
150 msec
Abnormal > 100 msec

Parameters Utilized

- Acceleration time/ ejection time
- AT/ET > 0.4: Prosthetic valve obstruction

No Obstruction:0.31

Obstruction: 0.5



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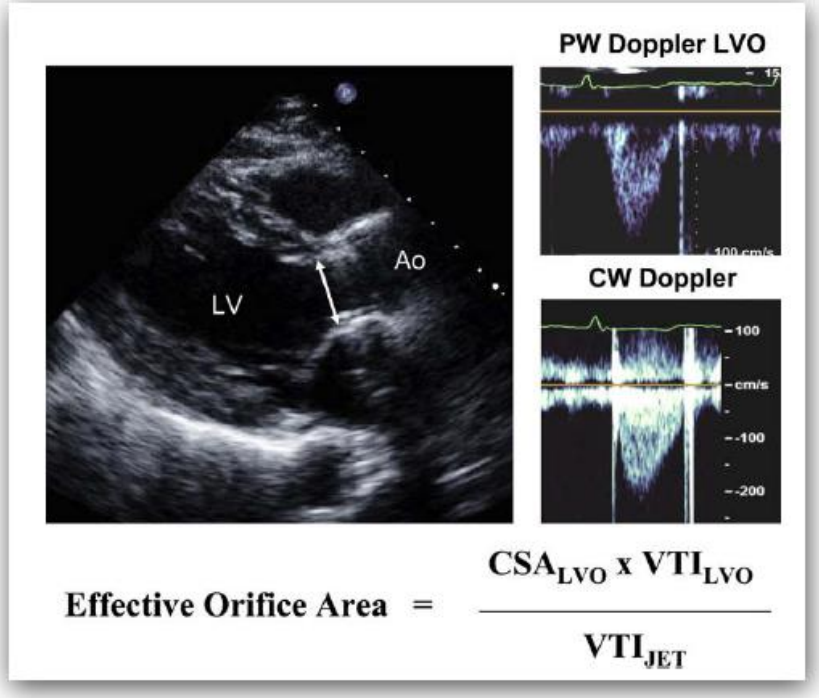
Parameters Utilized

- Effective Orifice Area and iEOA

$$A_2\ (EOA) = \frac{A_1 \times V_1}{V_2}$$

iEOA = AVA/BSA

Normal > 1.2 cm²
Abnormal < 0.8 cm²
Abnormal < 0.6 cm²/m²



Cause of Elevated Gradients Across Aortic Prosthesis

- Errors in Measurement
  - Improper LVOT Velocity
    - Taken too far from flow acceleration
  - Improper AV Velocity (Gradient) Assessment
- Increased Flow
- Pressure Recovery
- Prosthesis patient mismatch
- Prosthesis stenosis

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NORMAL PROSTHESIS FUNCTION

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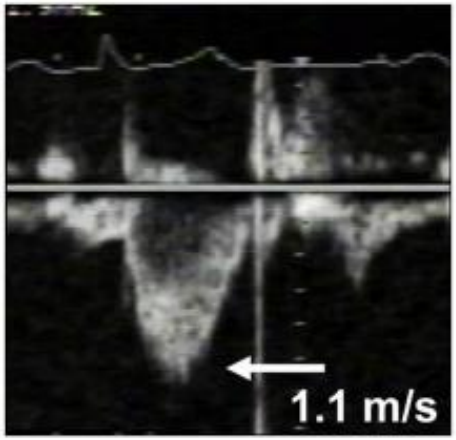
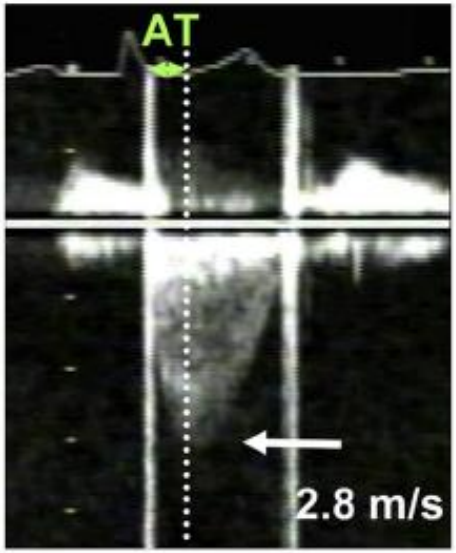
Normal

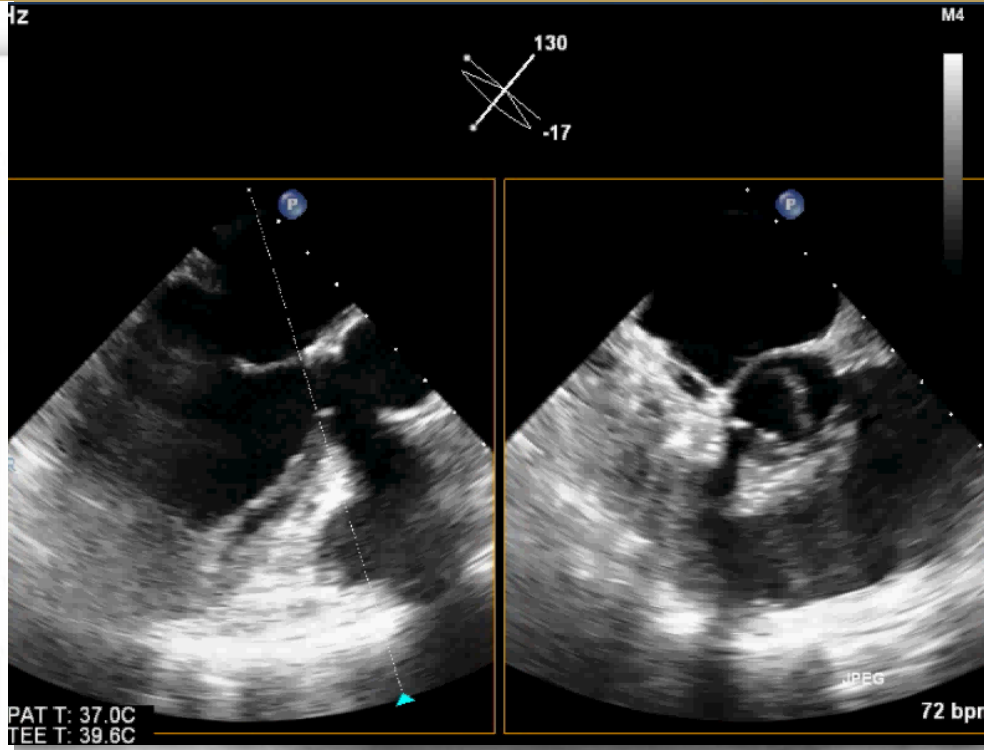
Pulsed Doppler LVO

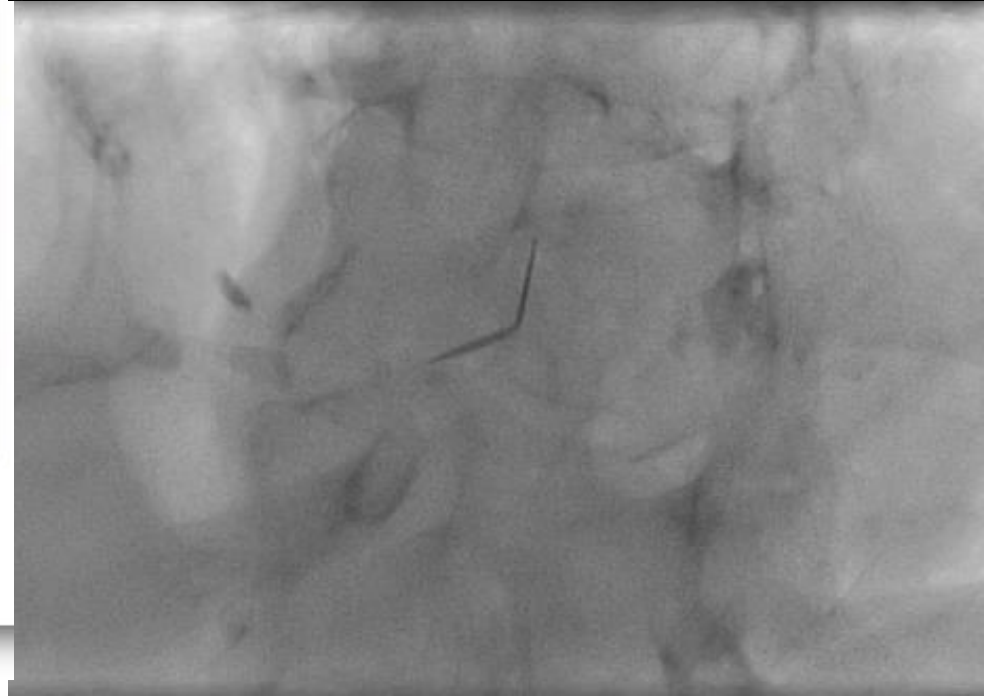


CW Doppler Prosthetic AV



MG = 22 mmHg
DVI = 0.4
AT = 75 ms





PROSTHETIC STENOSIS

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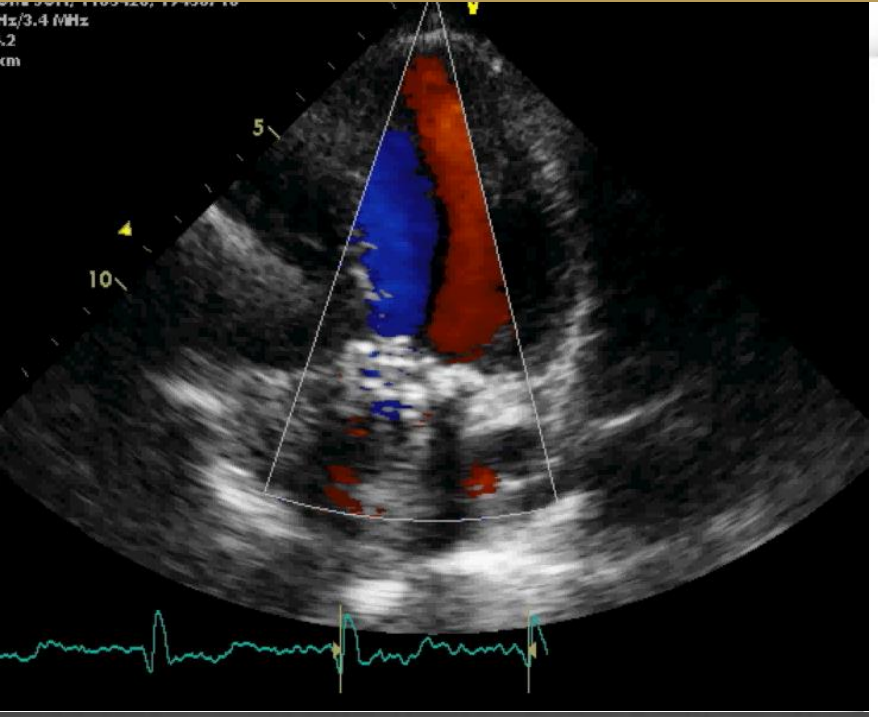
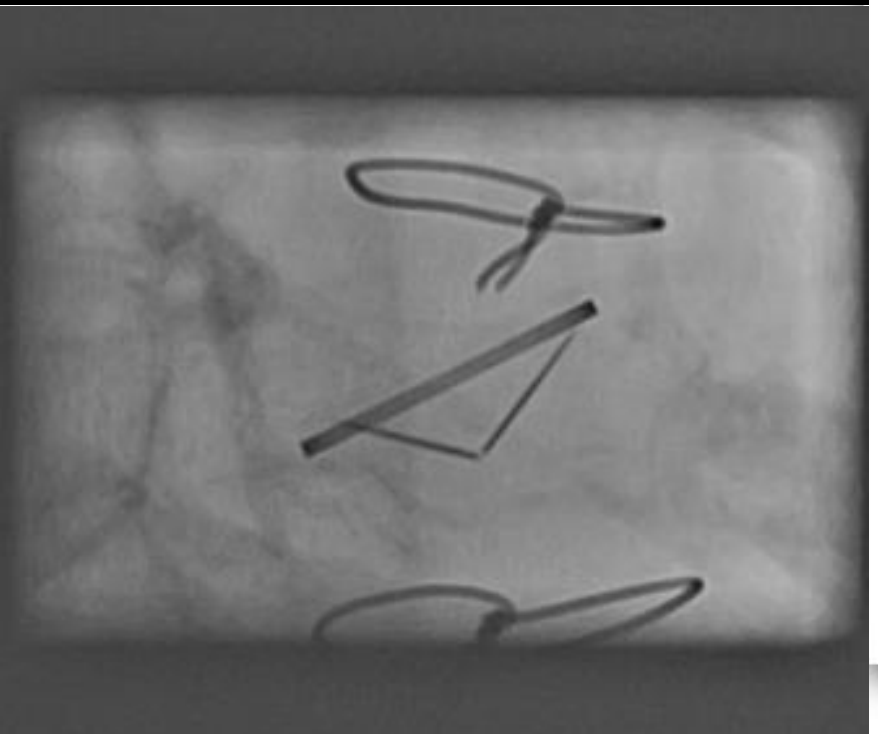
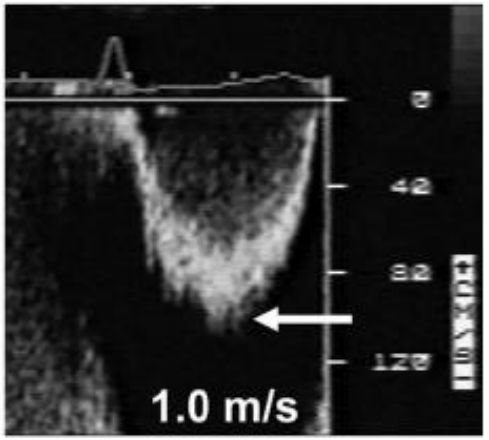


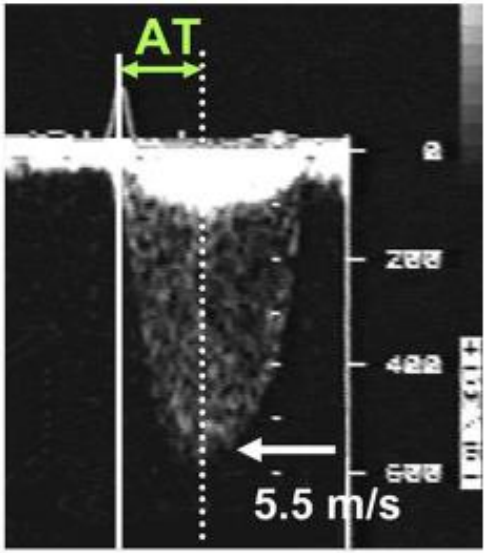


Obstructed

Pulsed Doppler
LVO



CW Doppler
Prosthetic AV

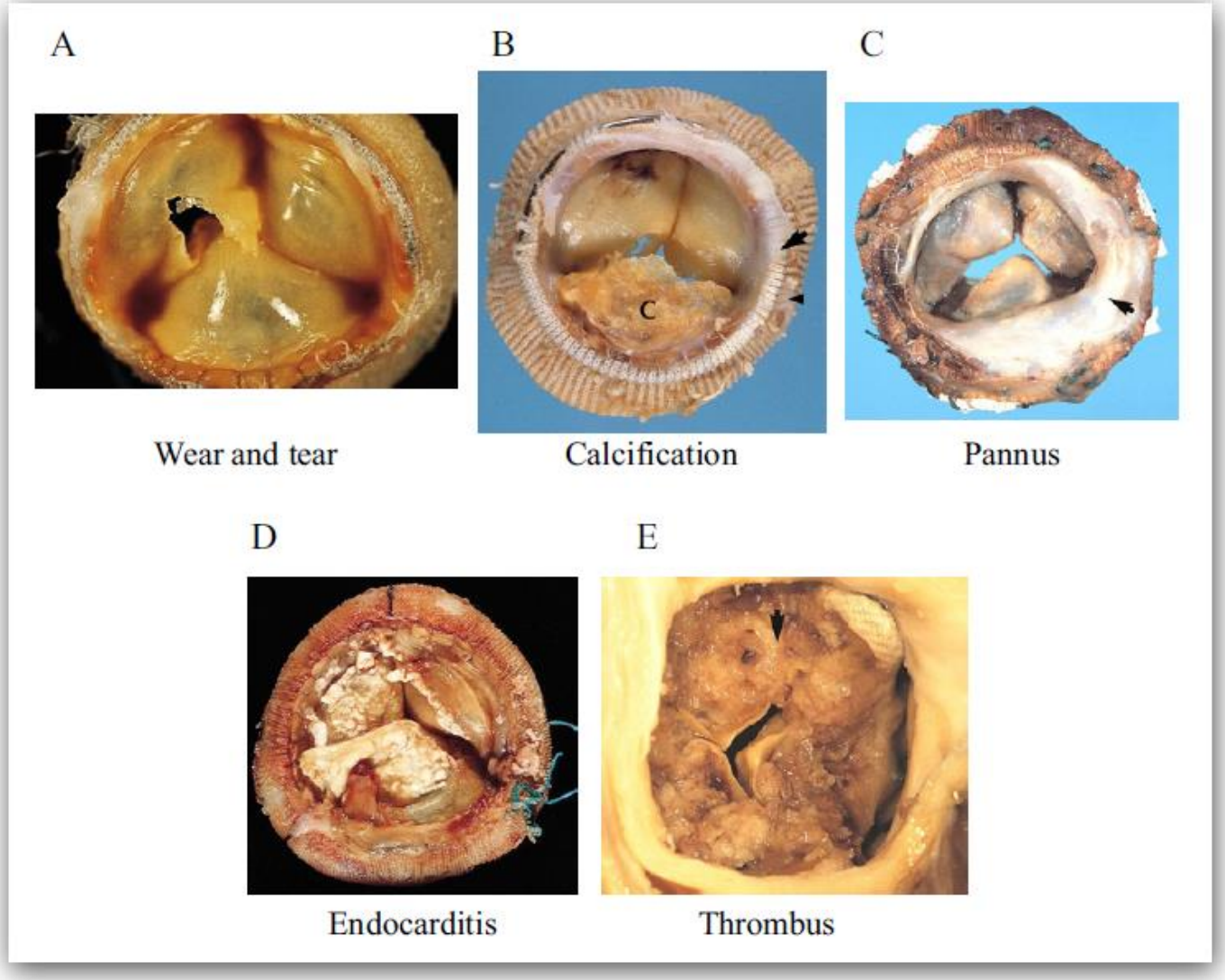


MG = 80 mmHg
DVI = 0.18
AT = 180 ms

Doppler Parameters of Prosthetic Aortic Valve Function

	Normal	Suggests Stenosis
Peak Velocity	< 3 m/s	> 4 m/s
Mean Gradient	< 20 mmhg	> 35 mmhg
Doppler Velocity Index	>= 0.3	< 0.25
Effective Orifice area	> 1.2 cm2	< 0.8 cm2
Contour of Jet	Triangular Early Peaking	Rounded Symmetrical contour
Acceleration Time	< 80 ms	> 100 ms

Mechanisms of Prosthetic Valve Dysfunction



CASE PRESENTATIONS

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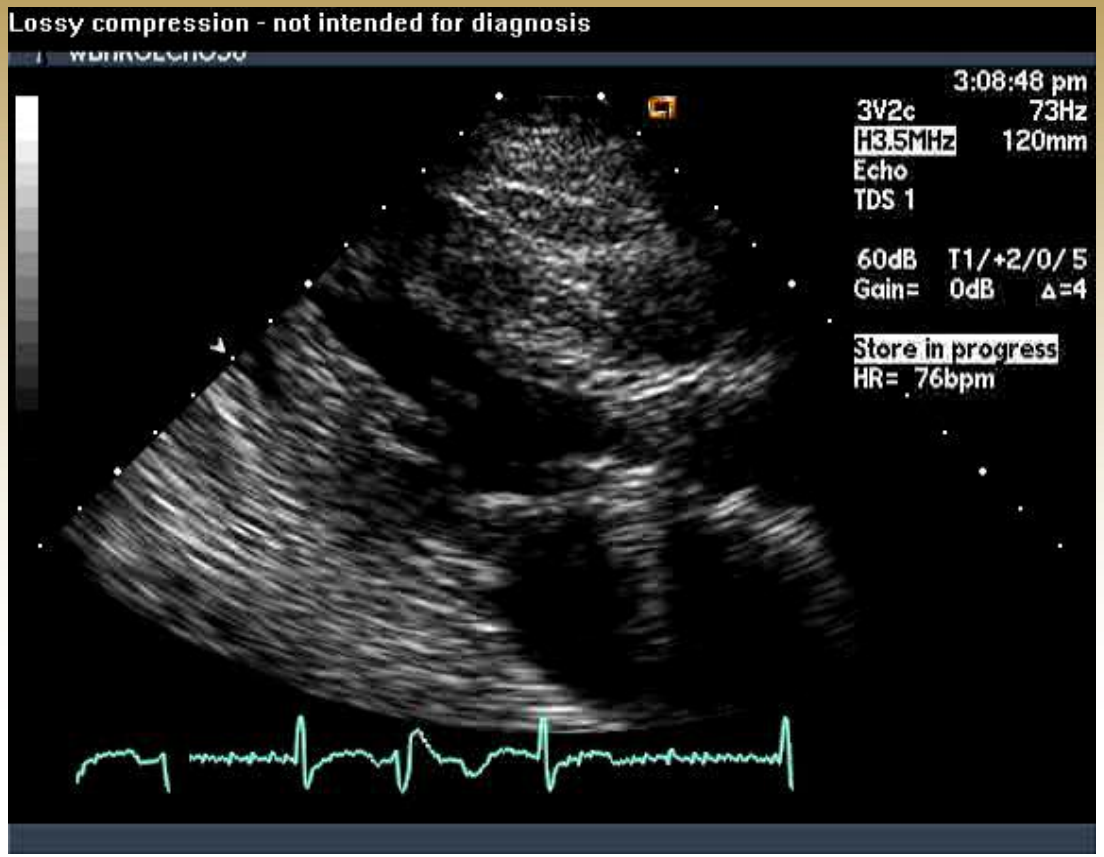

- CASE PRESENTATION (1):
- 81 Y/O with progressive DOE
- PMHx: Rheumatic valve disease, CABG + Mechanical AVR 2003 (19 St Jude Regent Valve)
- TTE: Difficult to visualize mechanical AV

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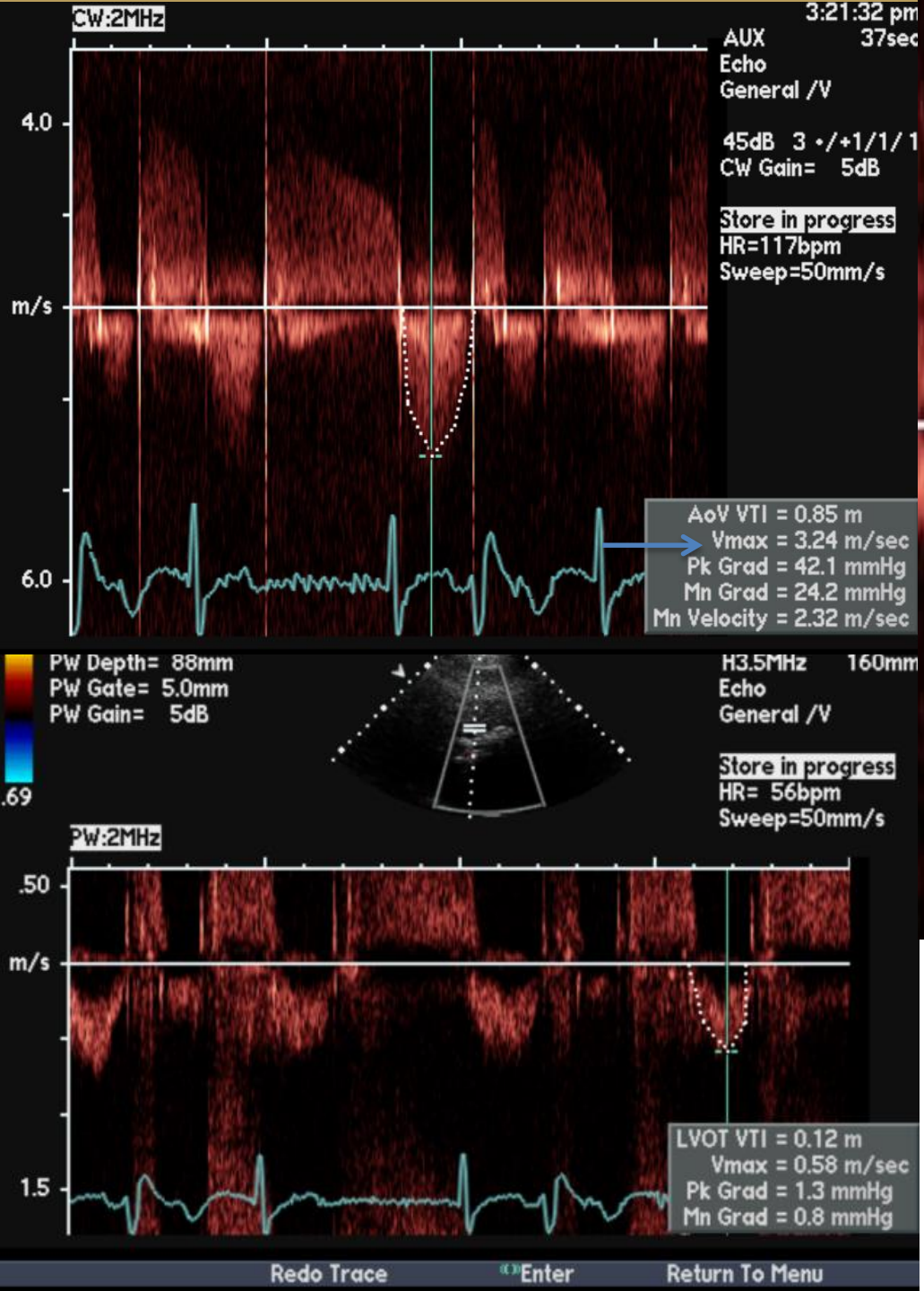
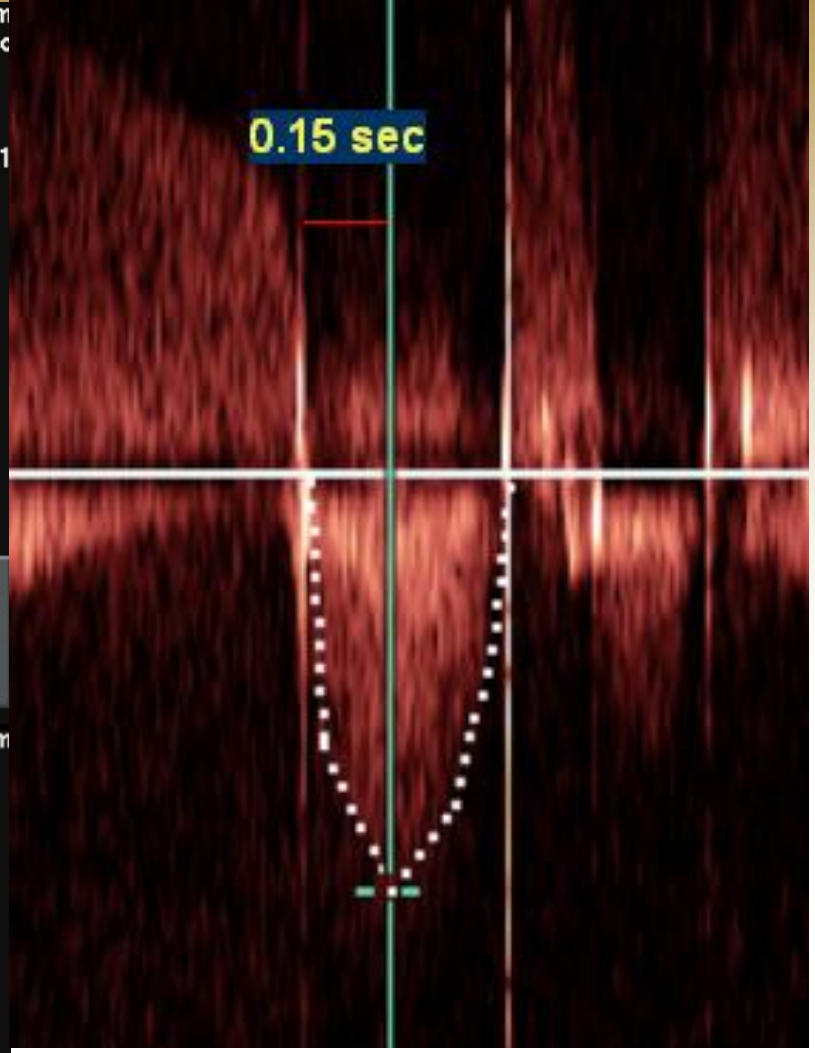




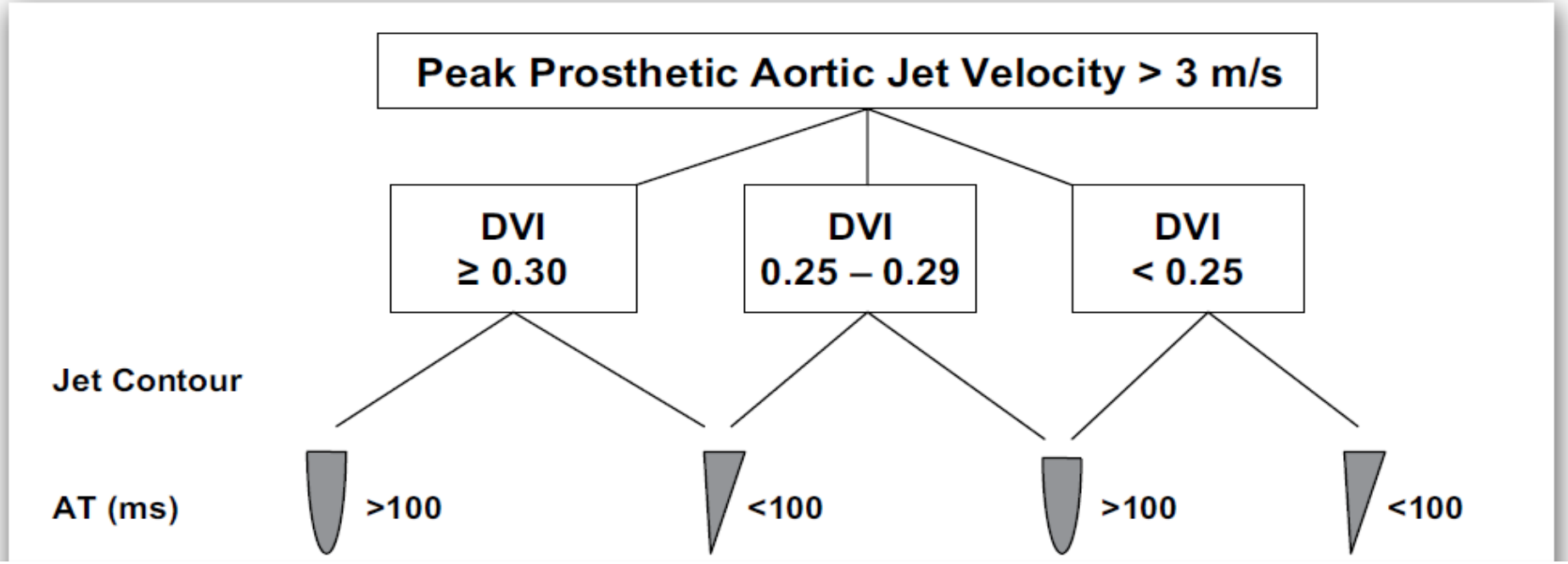
AV VEL=3.2

DI=0.58/3.2=0.18

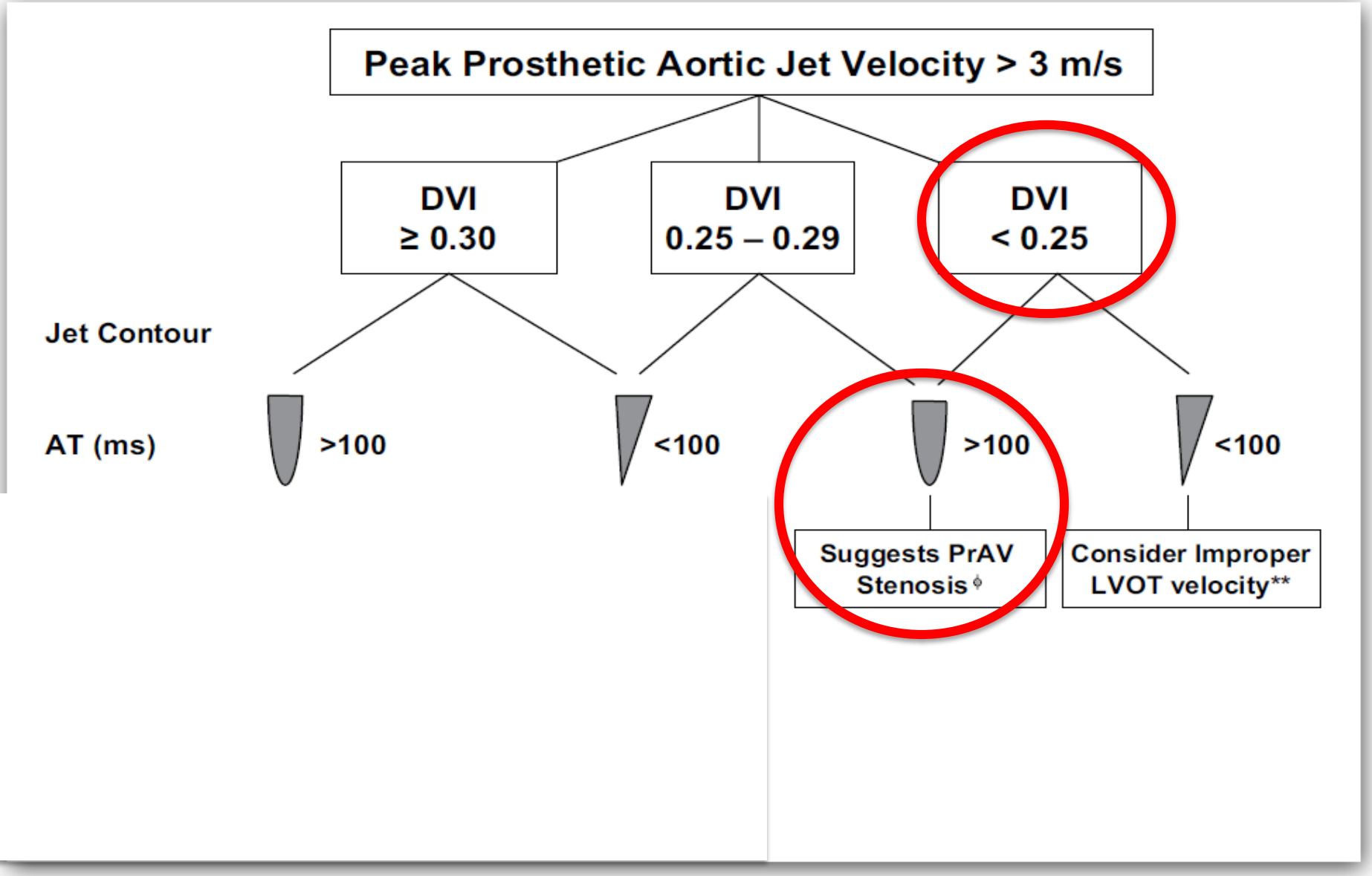
AT=150msec

Jet Contour: Circular

An approach to prosthetic AV stenosis



An approach to prosthetic AV stenosis



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Contour of Jet	Triangular Early Peaking	Rounded Symmetrical contour
Acceleration Time	< 80 ms	> 100 ms

3.2

24

0.18

150 ms

What is your diagnosis?

- A) Normal Prosthetic Valve Function
- B) Prosthesis – Patient Mismatch
- C) High Flow State
- D) **Prosthetic Valve Stenosis**
- E) Errors of Measurement: Improper LVOT Velocity

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Additional Studies Needed?

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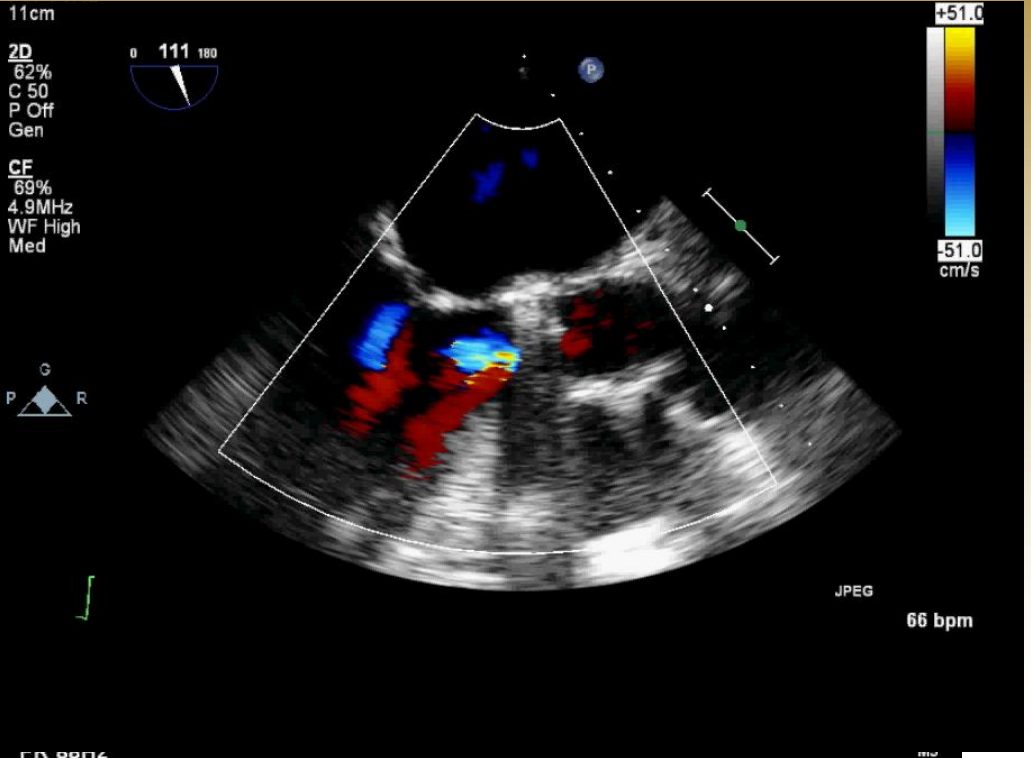
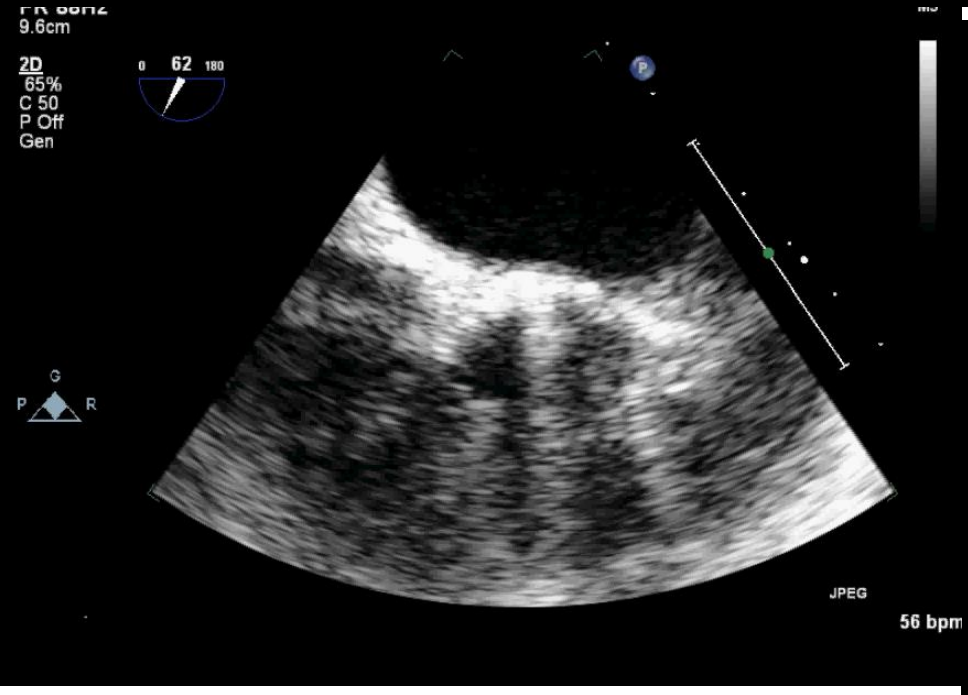
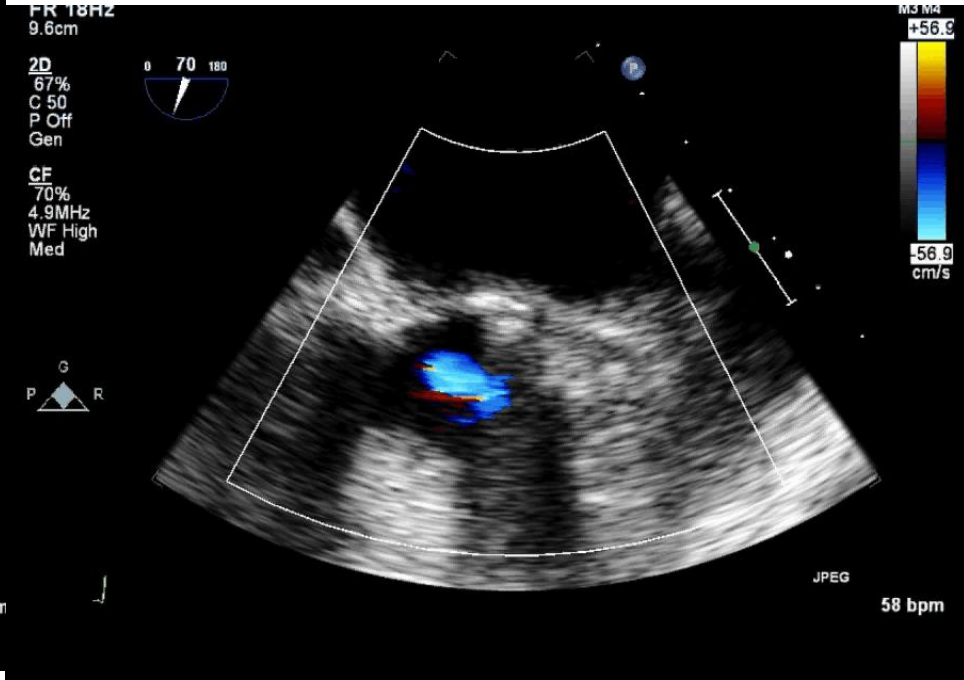
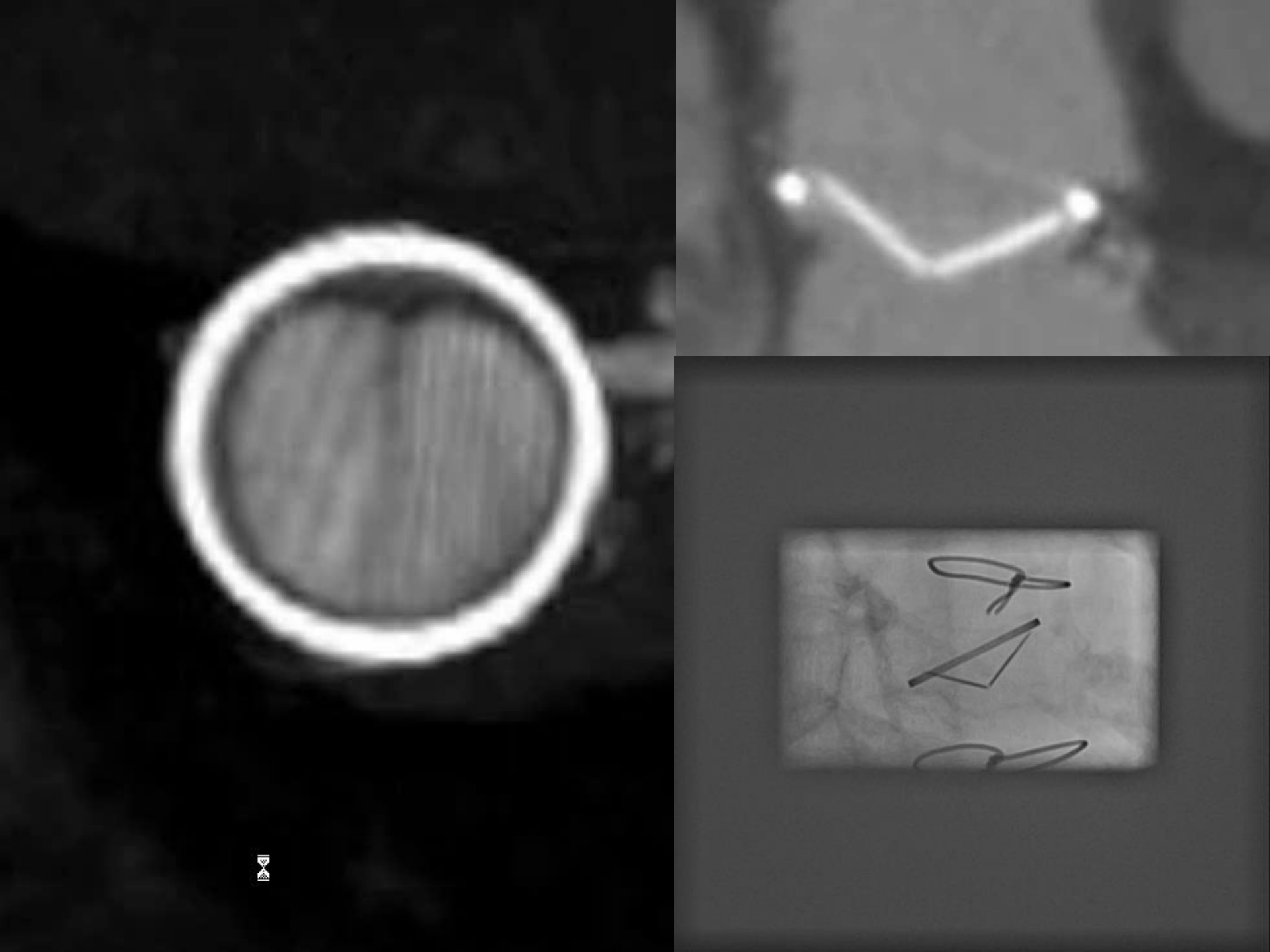
TEE

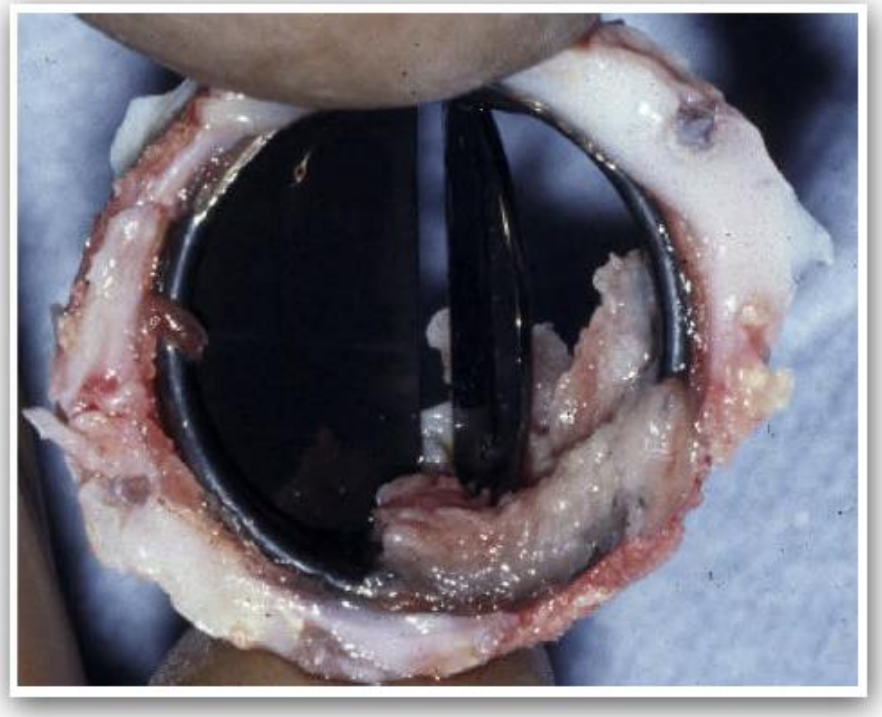
Helpful with high gradients and normal motion by Fluoro

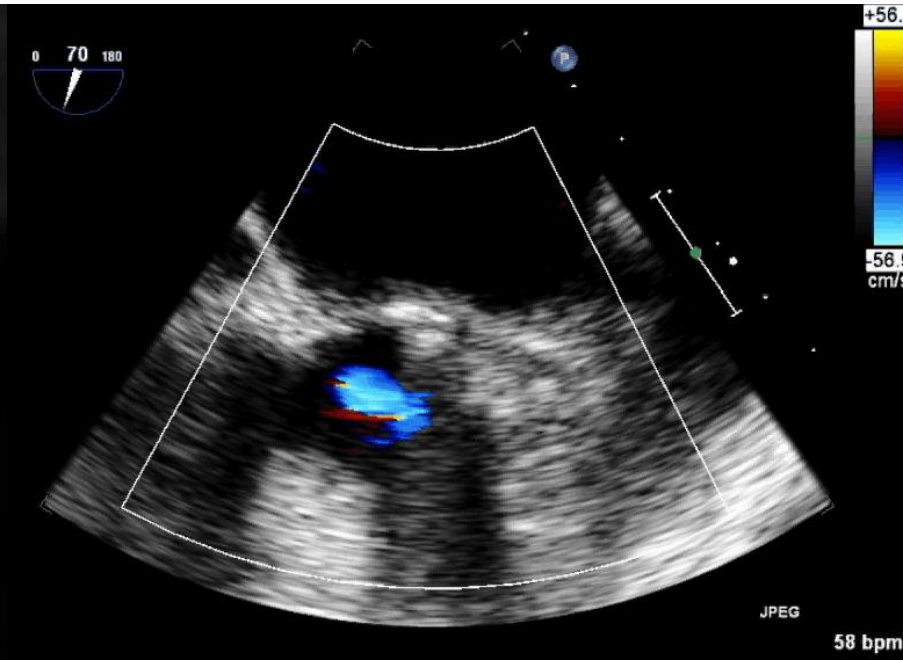


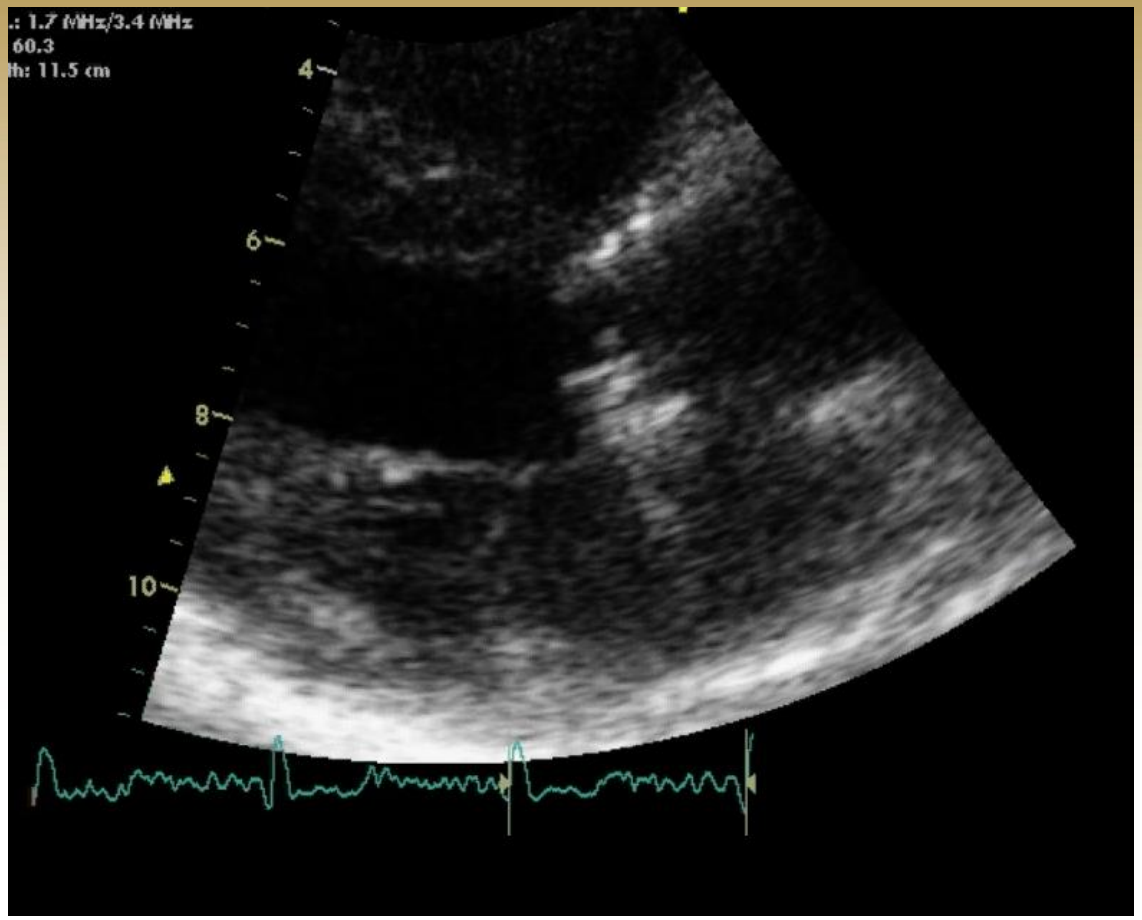









0
70
180
+56.
-56.
cm/
JPEG
58 bpm



- CASE PRESENTATION (2):
- 67 Y/O F Hx AVR (Bi-Leaflet Mechanical Valve 1998)
- On Coumadin, difficulty maintaining therapeutic INR
- Progressive DOE 6 mos

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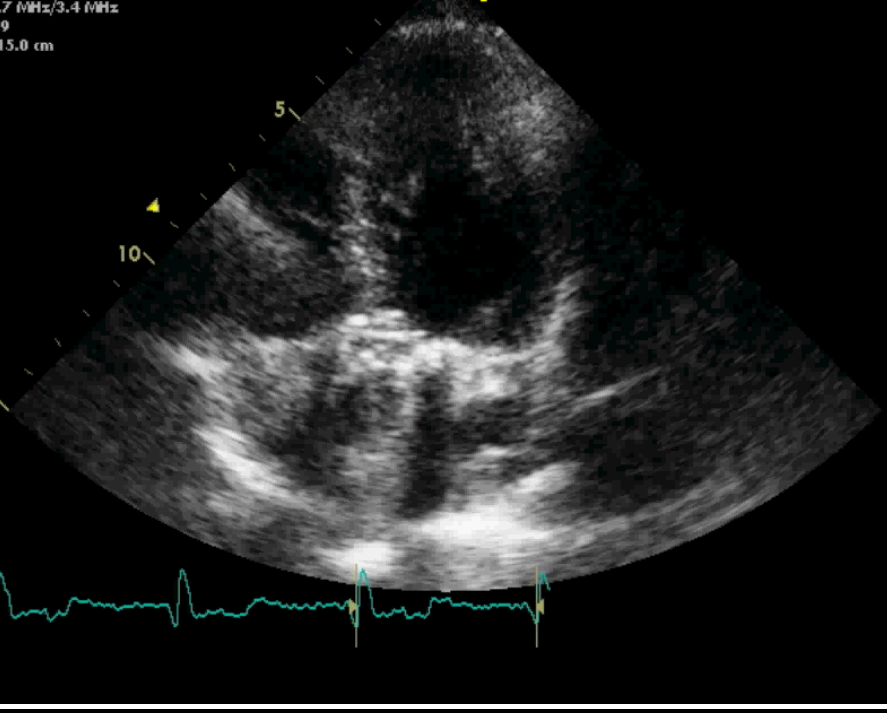
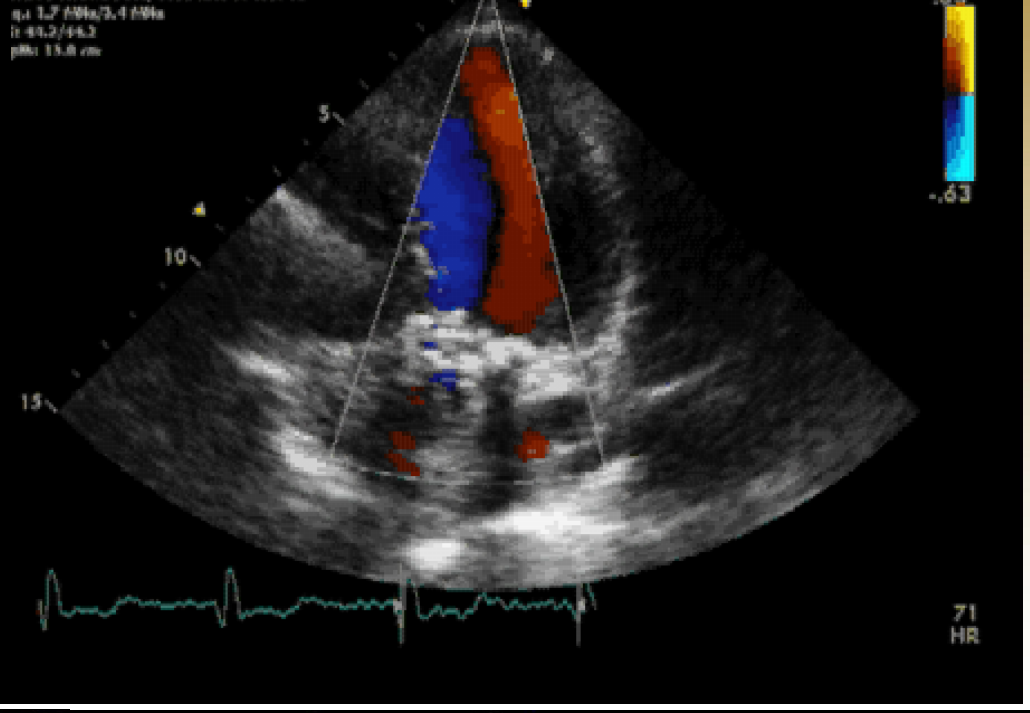
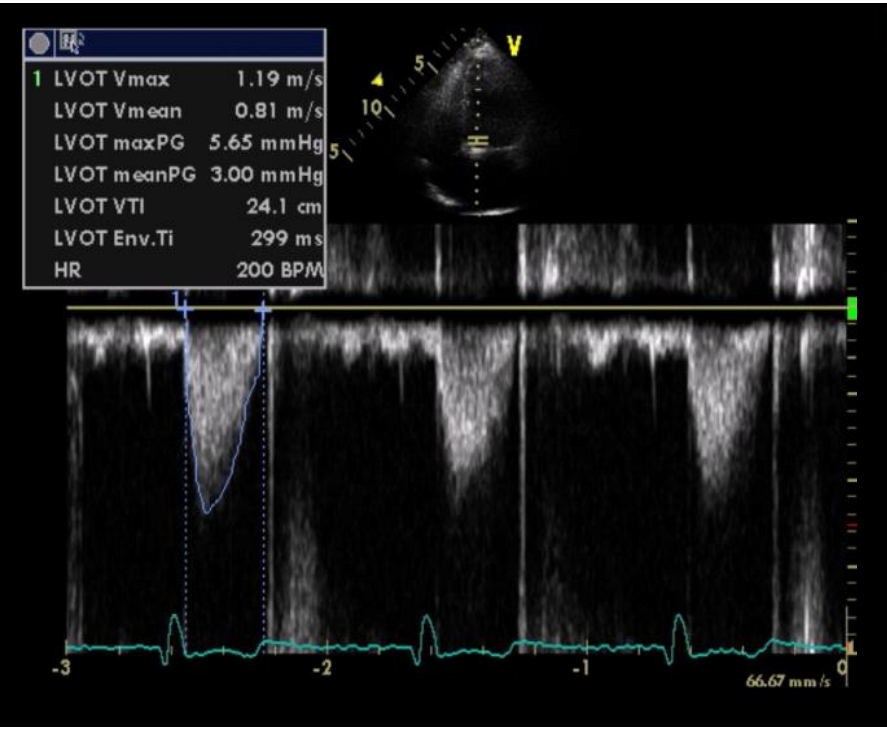
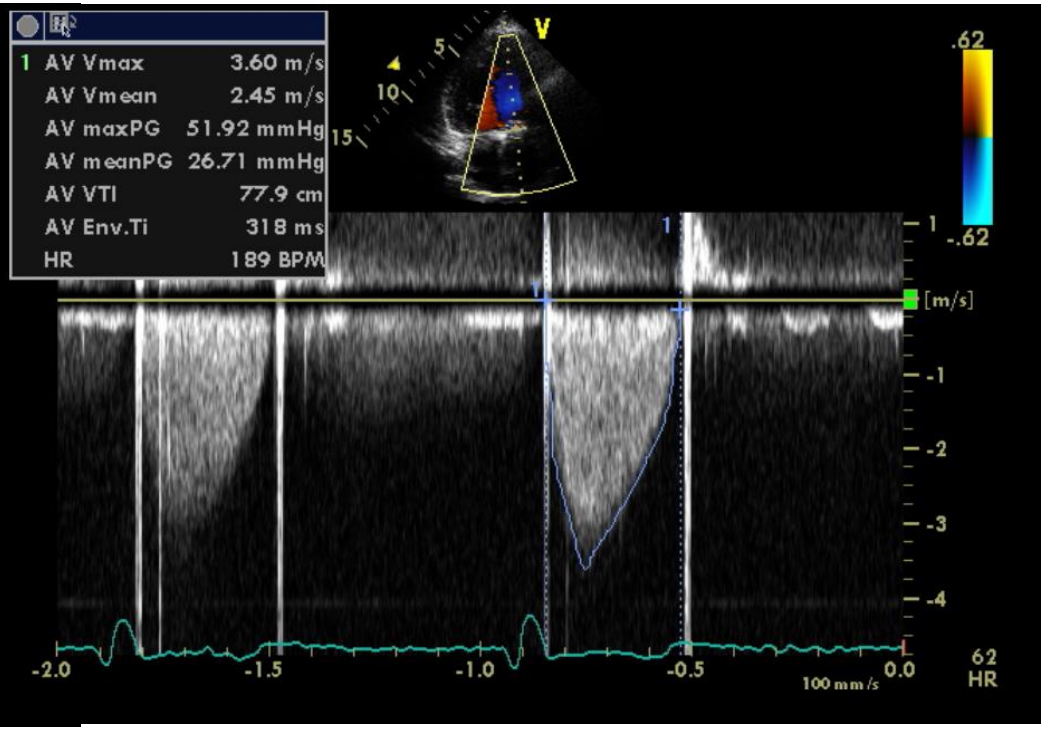



71
HR


1 LVOT Vmax 1.19 m/s
LVOT Vmean 0.81 m/s
LVOT maxPG 5.65 mmHg
LVOT meanPG 3.00 mmHg
LVOT VTI 24.1 cm
LVOT Env.Ti 299 ms
HR 200 BPM
66.67 mm/s

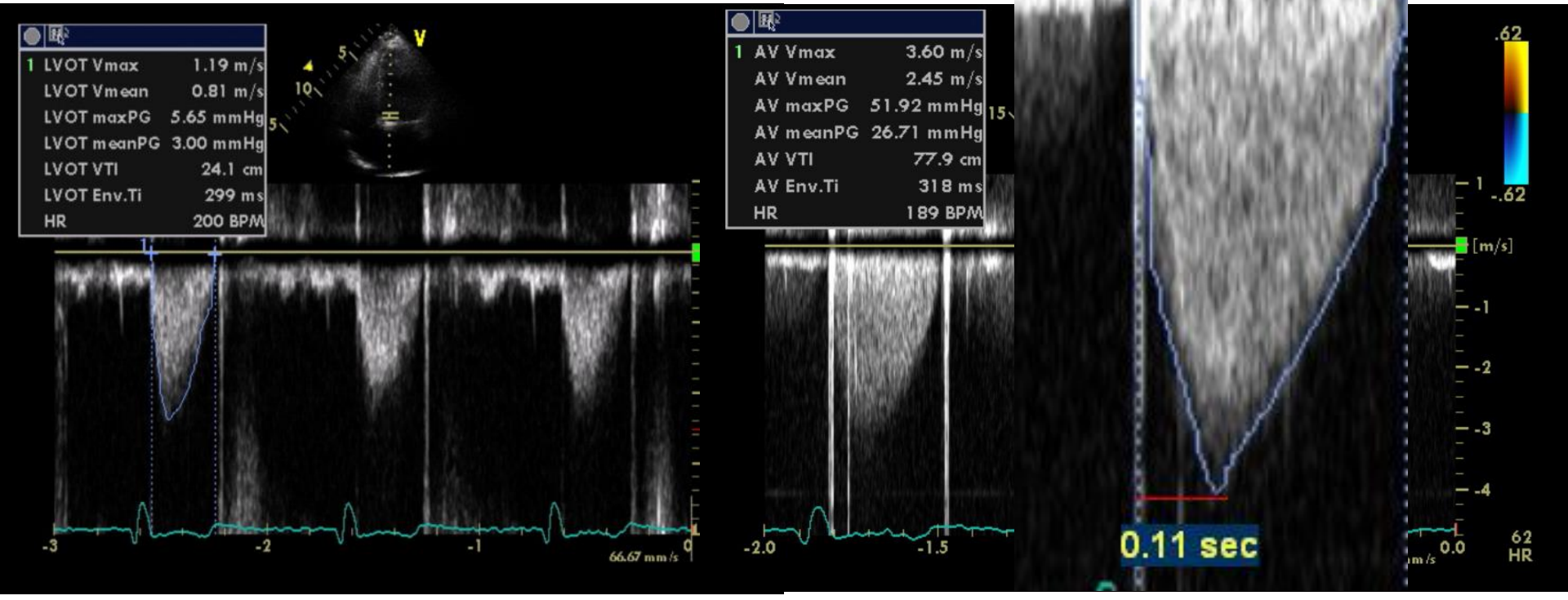

1 AV Vmax 3.60 m/s
AV Vmean 2.45 m/s
AV maxPG 51.92 mmHg
AV meanPG 26.71 mmHg
AV VTI 77.9 cm
AV Env.Ti 318 ms
HR 189 BPM
[m/s]
62
HR
100 mm/s

AV VEL = 3.6

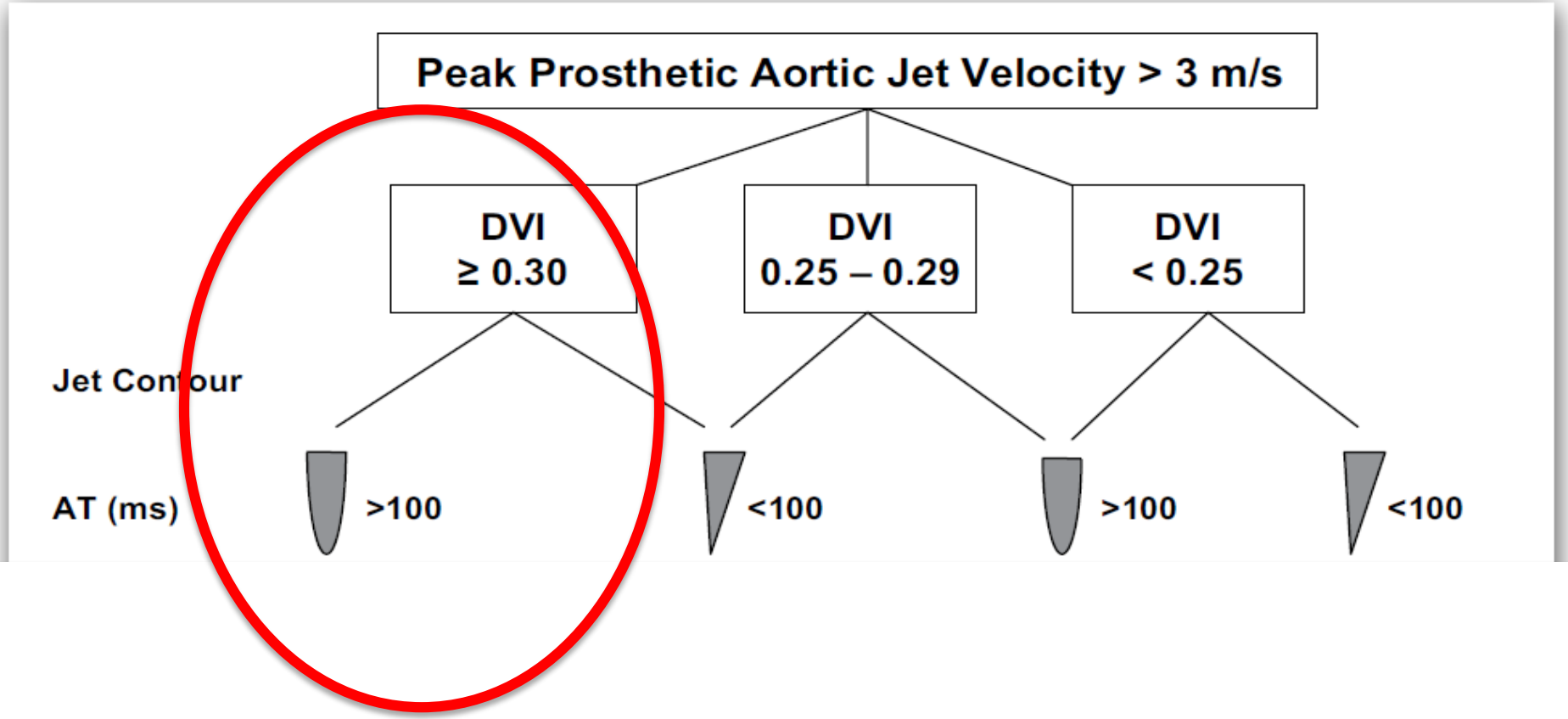
DVI = 1.19 / 3.60

DVI = 0.33

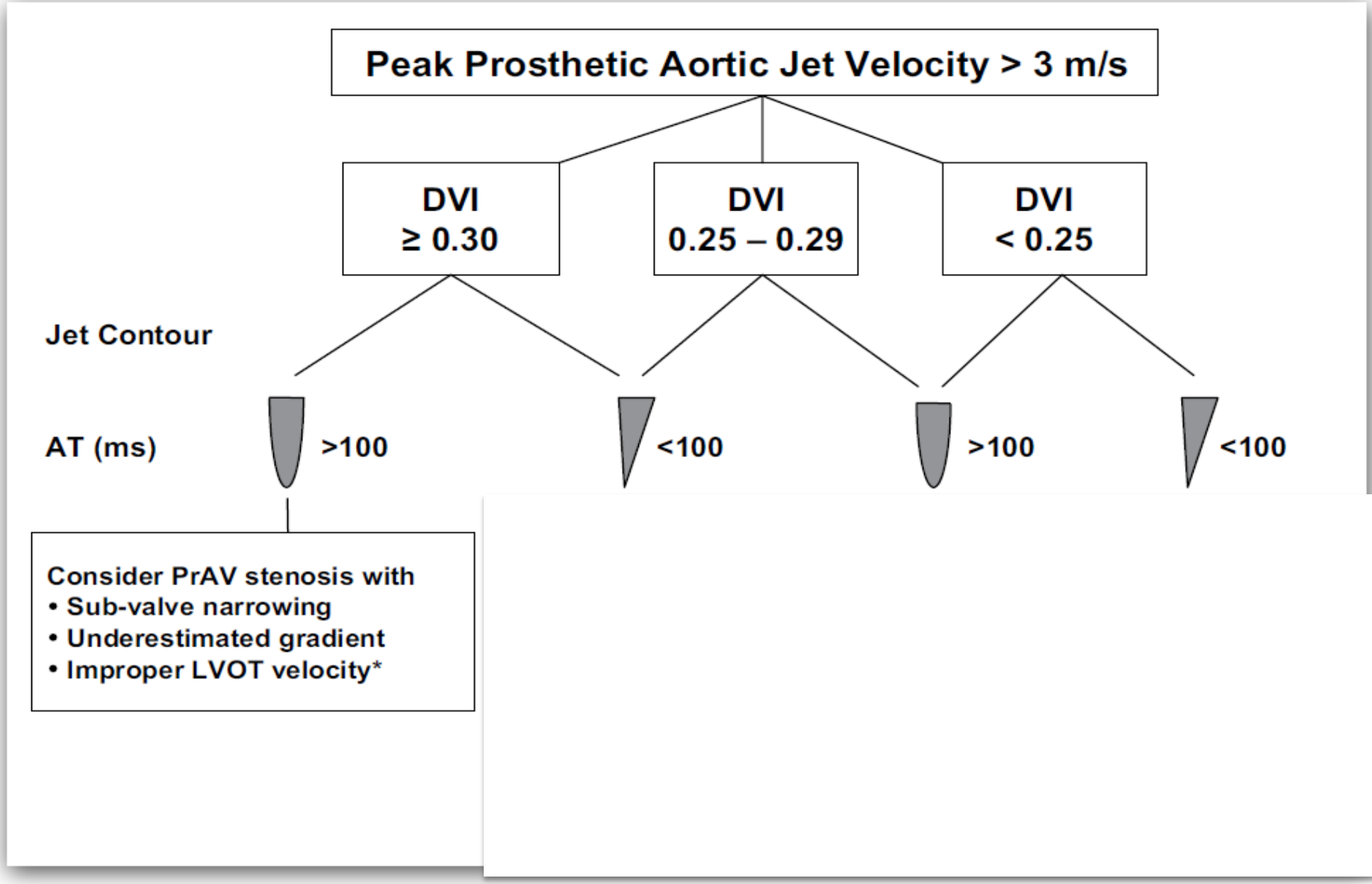
Acceleration Time 0.11 sec



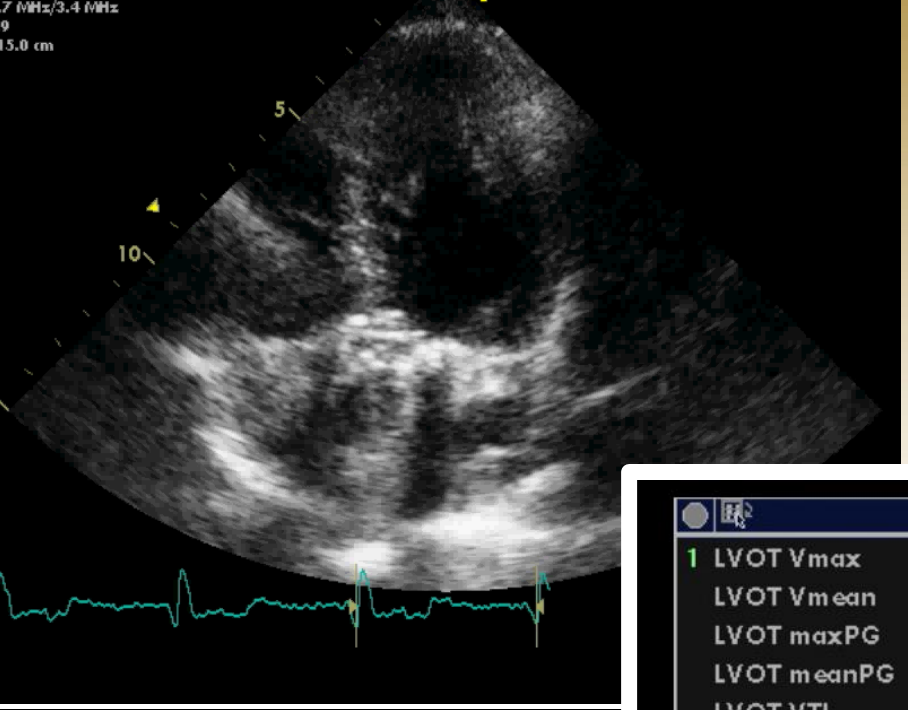
An approach to prosthetic AV stenosis

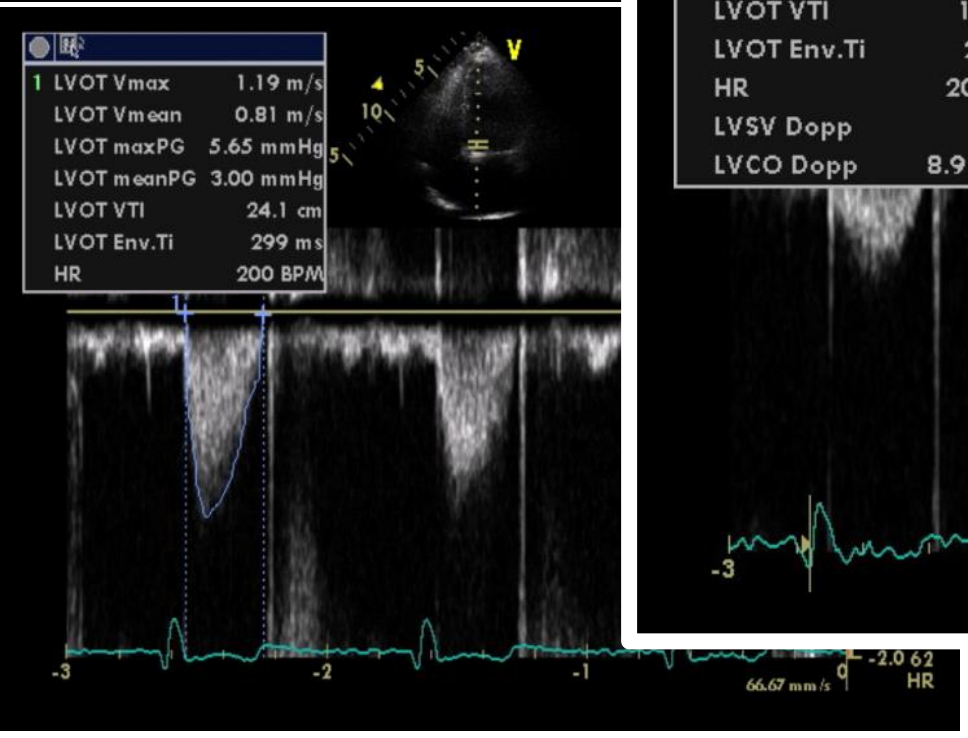


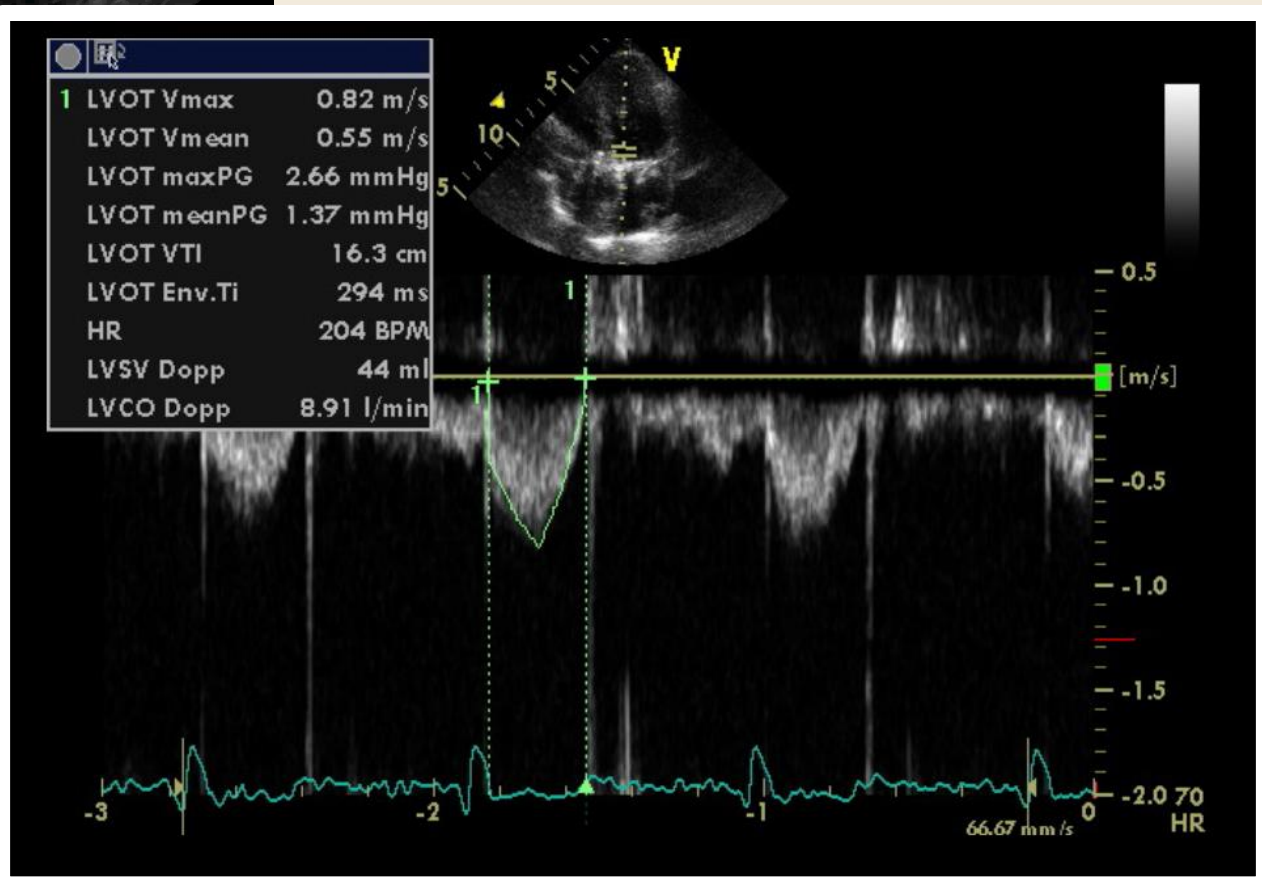
An approach to prosthetic AV stenosis



Original LVOT Velocity Taken Too Close to the AV Prosthesis *(region of sub-valvular acceleration)*





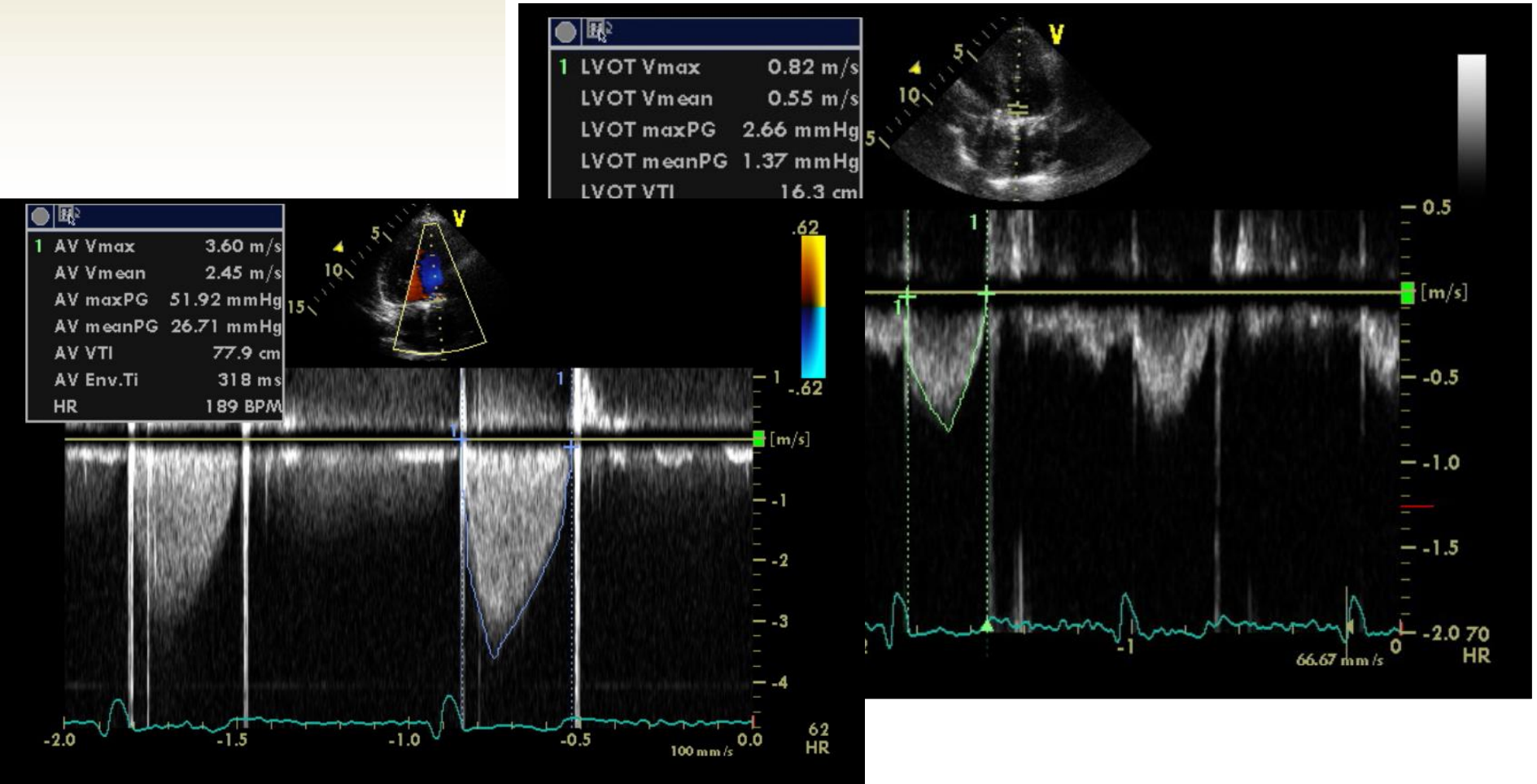


DVI = **Velocity** LVO / AV Jet

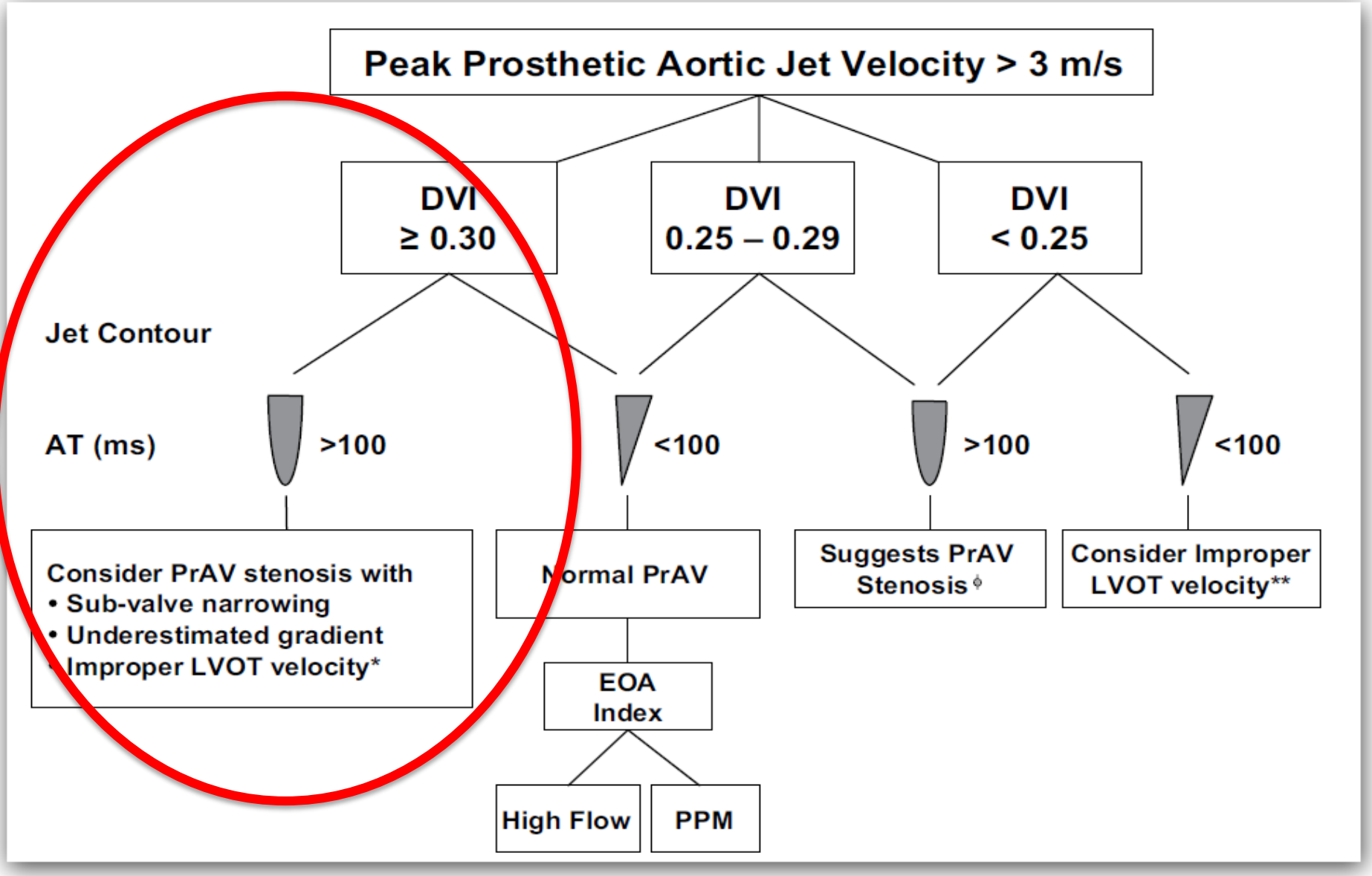
DVI = 0.82 / 3.60

DVI = 0.22

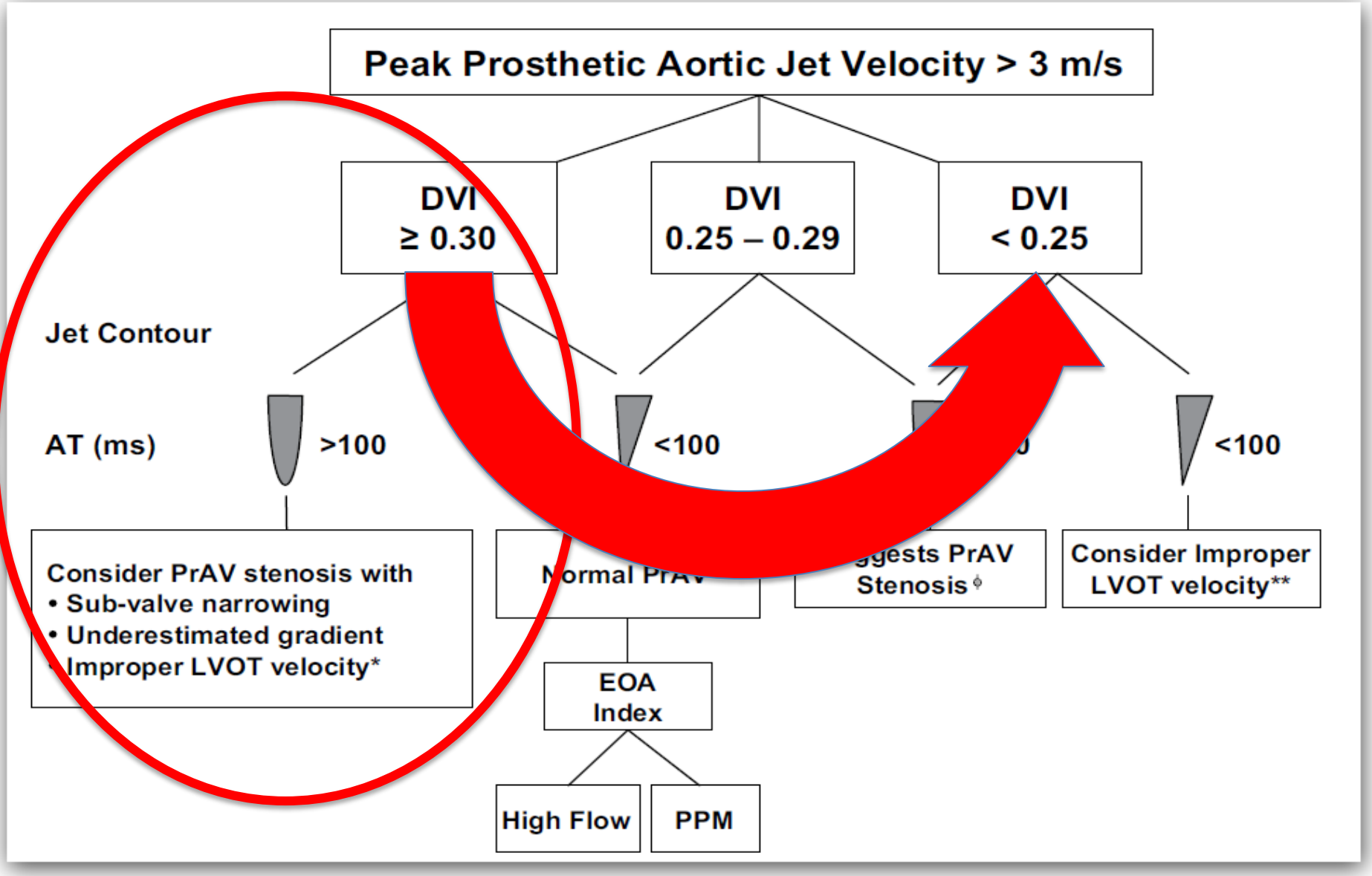
Original LVOT Velocity Taken Too Close to the AV Prosthesis



An approach to prosthetic AV stenosis

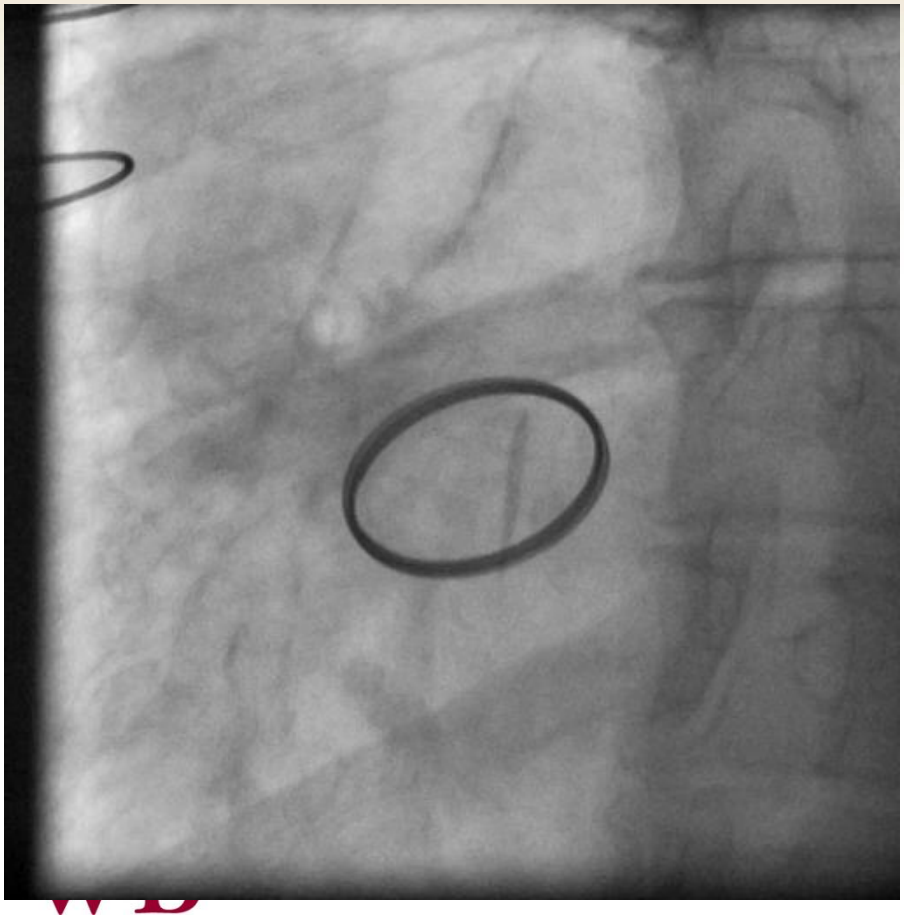


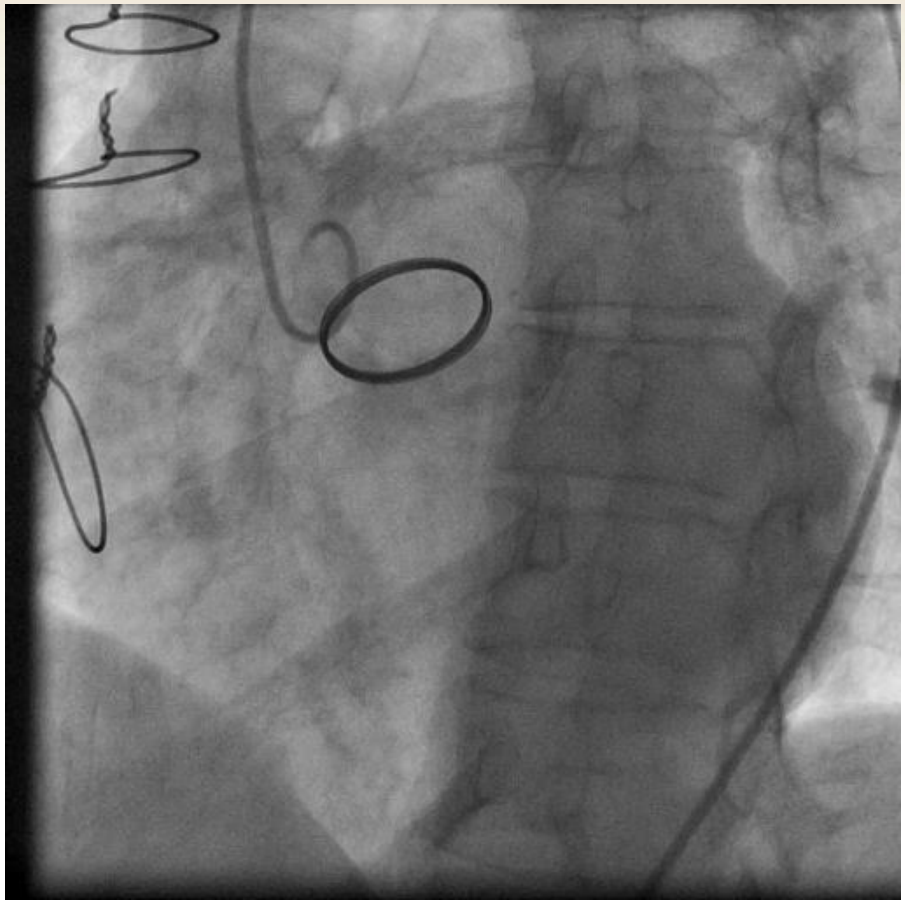
An approach to prosthetic AV stenosis



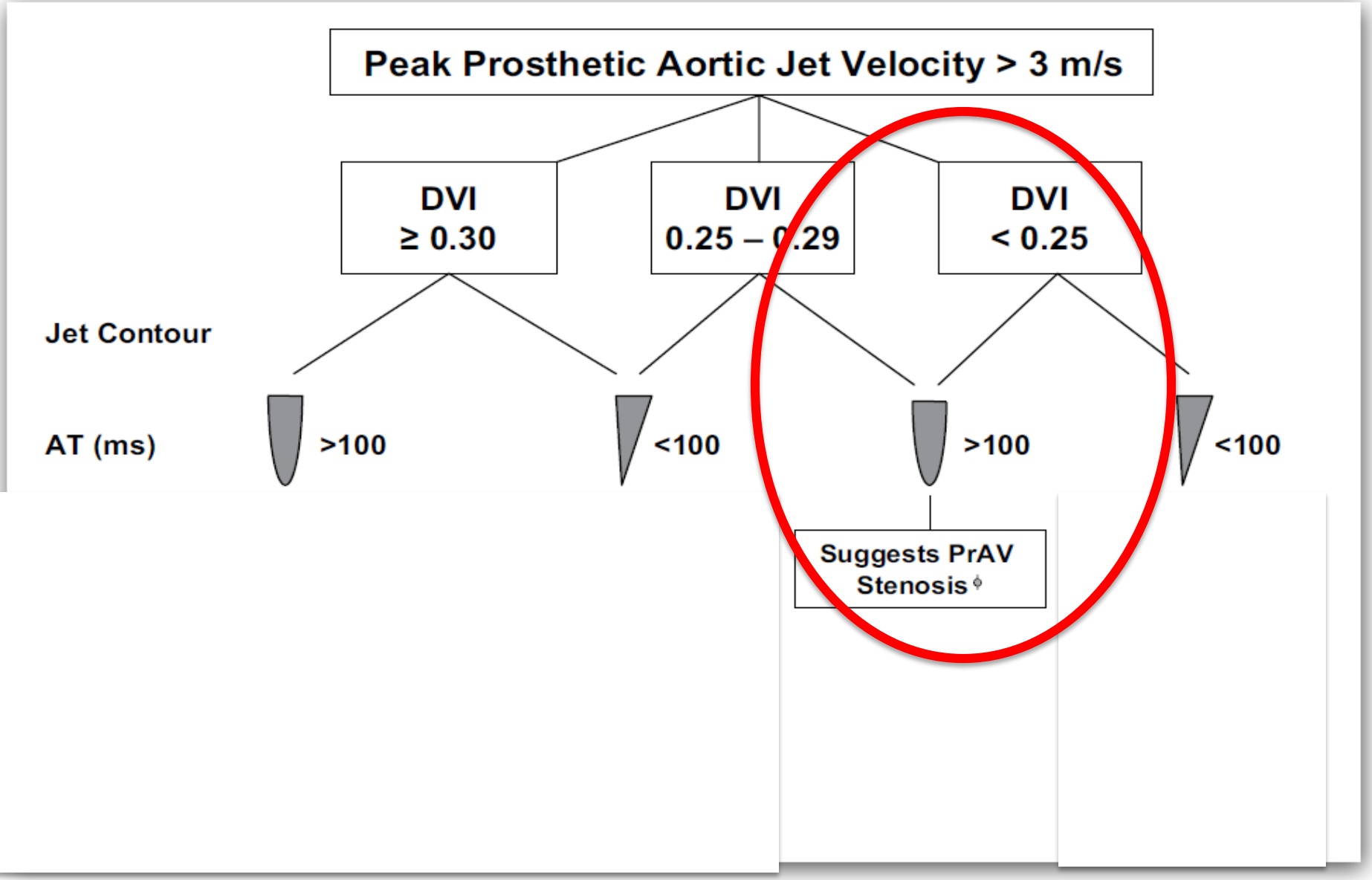
Surgical Findings

Well seated valve with a large amount of tissue ingrowth beneath the valve resulting in a frozen leaflet





An approach to prosthetic AV stenosis



What is your diagnosis?

- A) Patient – Prosthesis Mismatch
- B) Normal Prosthetic Valve Function
- C) High Flow State
- D) Prosthetic Valve Stenosis
- E) Improper LVOT Velocity

OU WB

What is your diagnosis?

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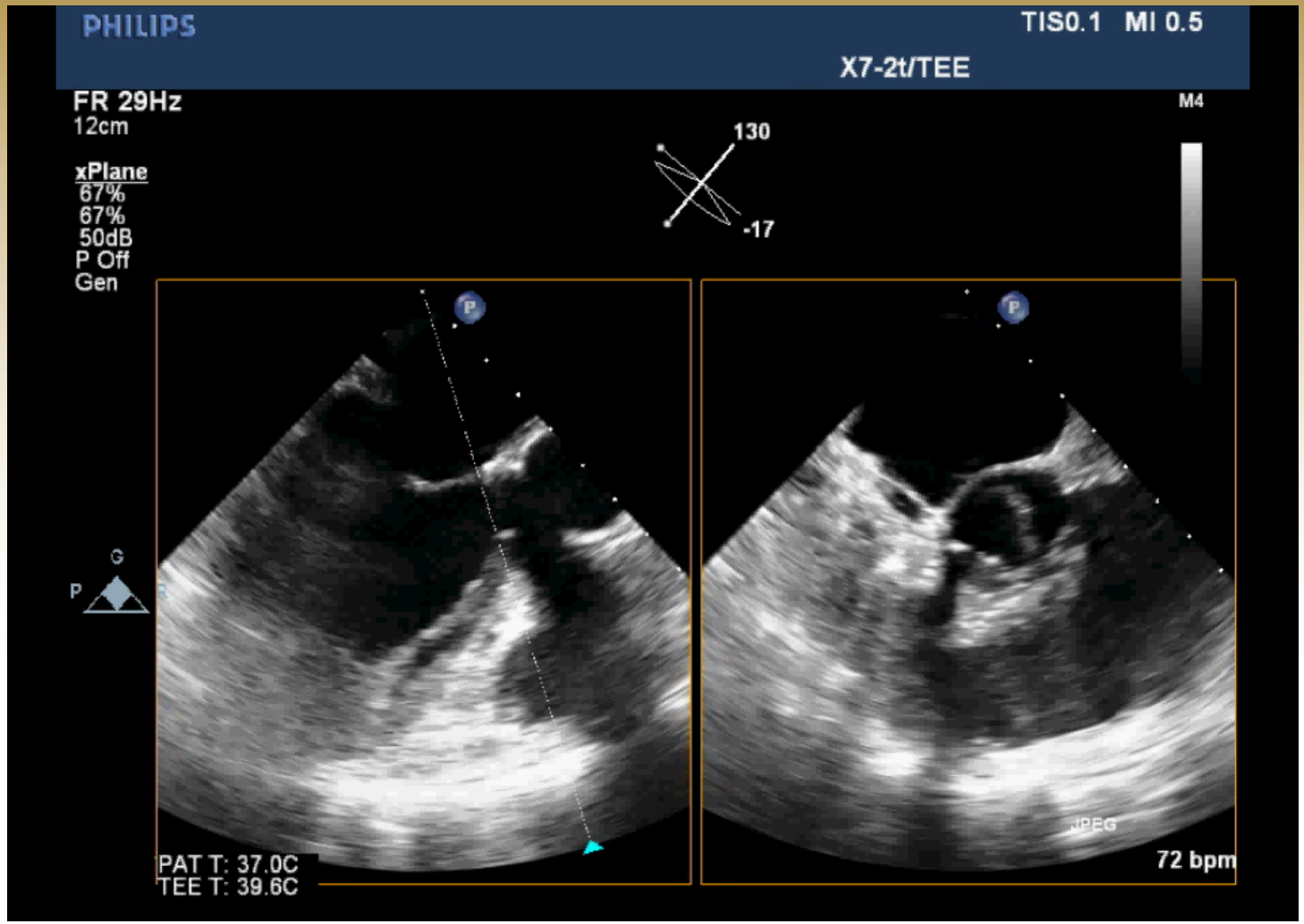
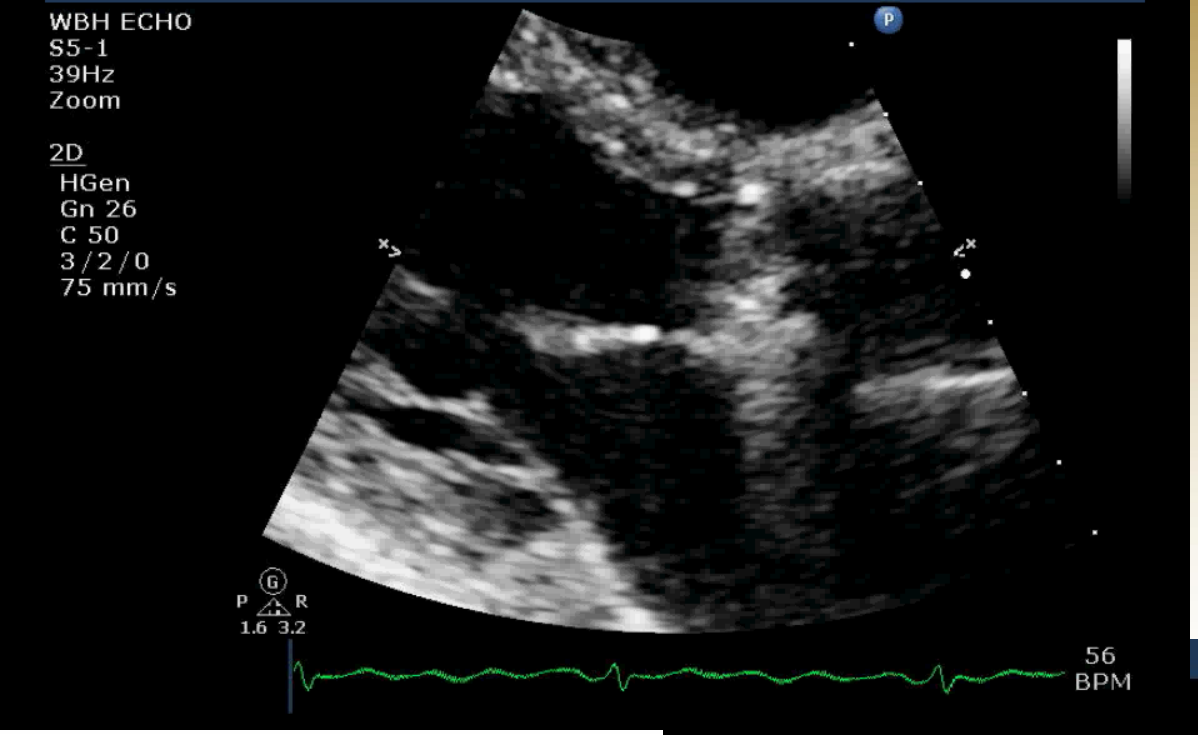
- D) Prosthetic Valve Stenosis
- E) Improper LVOT Velocity (Prosthetic valve stenosis)

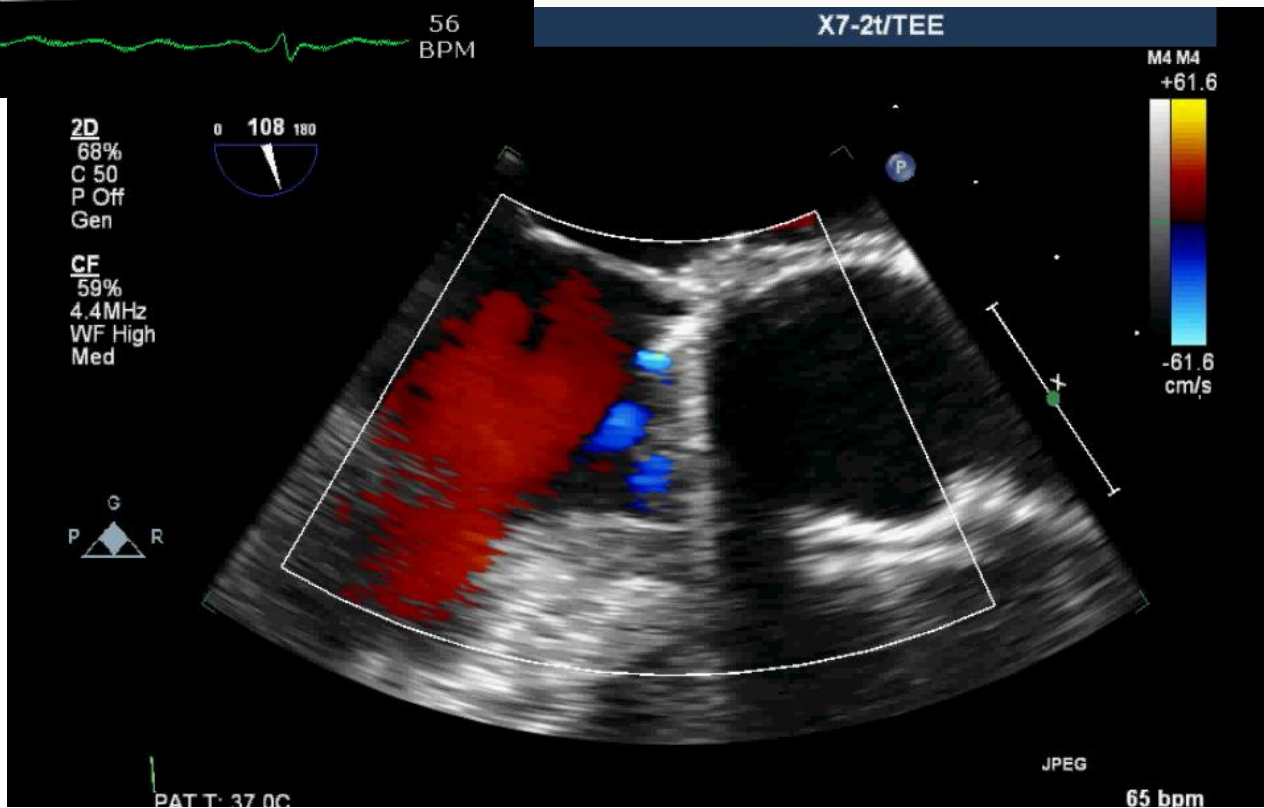
OU WB



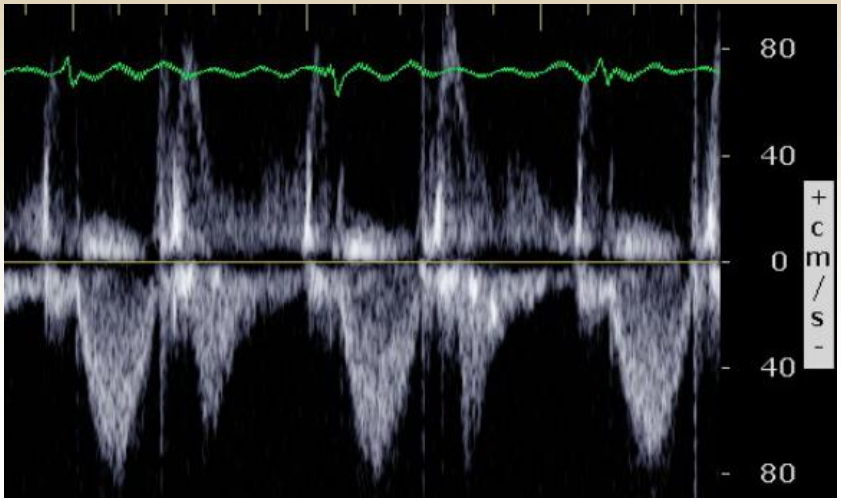
- CASE PRESENTATION (3):
- 66 Y/O F Hx AVR (St Jude Valve Conduit 2002 for AR)
- Progressive DOE

OU WB

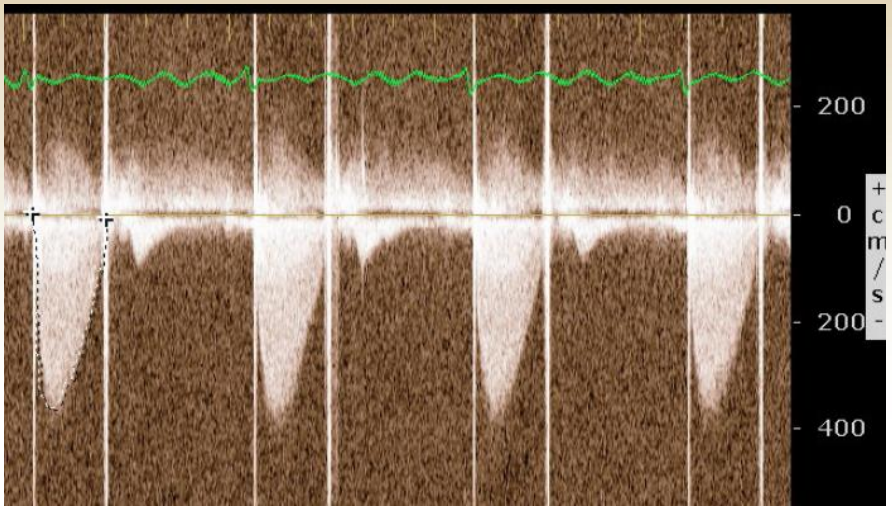

WBH ECHO
S5-1
39Hz
Zoom
2D
HGen
Gn 26
C 50
3/2/0
75 mm/s
P
G
P R
1.6 3.2
56
BPM


X7-2t/TEE
2D
68%
C 50
P Off
Gen
0 108 180
CF
59%
4.4MHz
WF High
Med
M4 M4
+61.6
-61.6
cm/s
G
P R
JPEG
65 bpm

OU WB



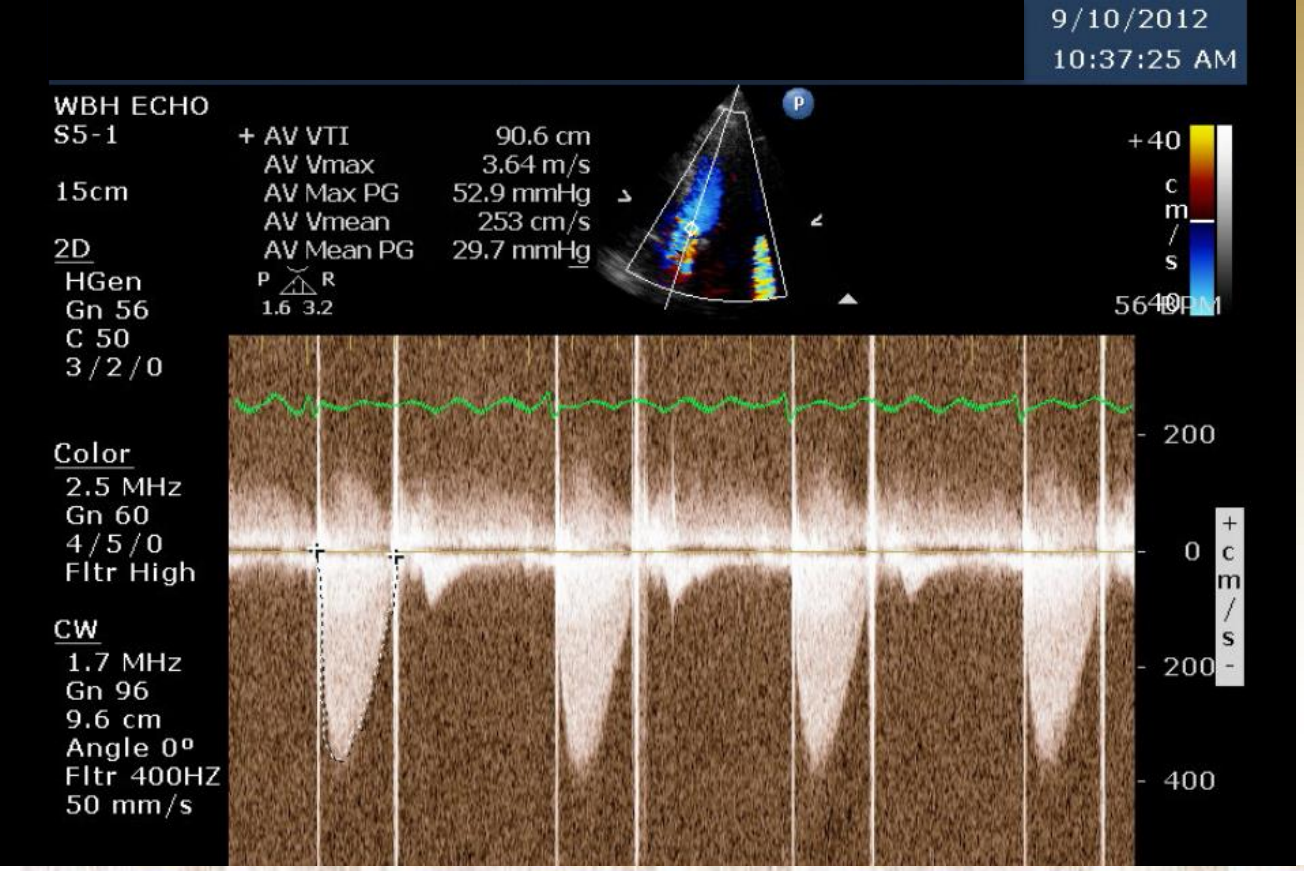
LVOT VELOCITY = 0.85



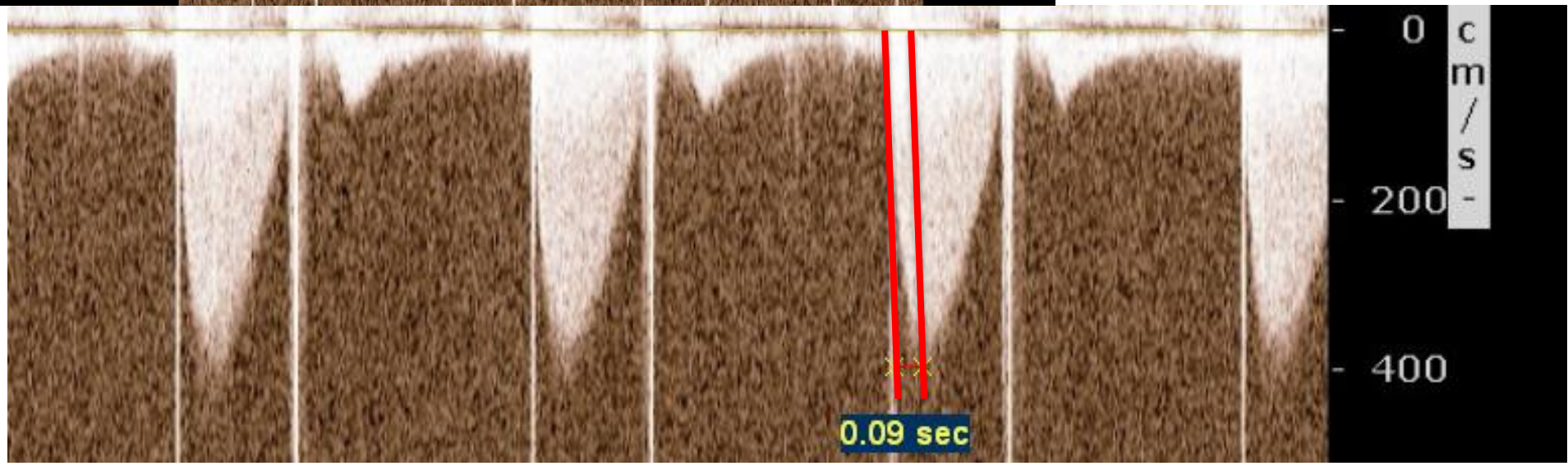
AVA VELOCITY = 3.4

- DVI= 0.85/3.4 = 0.25
- AVA VELOCITY = 3.4 m/s

OU WB


9/10/2012
10:37:25 AM
WBH ECHO
S5-1
15cm
2D
HGen
Gn 56
C 50
3/2/0
Color
2.5 MHz
Gn 60
4/5/0
Fltr High
CW
1.7 MHz
Gn 96
9.6 cm
Angle 0°
Fltr 400HZ
50 mm/s
+ AV VTI 90.6 cm
AV Vmax 3.64 m/s
AV Max PG 52.9 mmHg
AV Vmean 253 cm/s
AV Mean PG 29.7 mmHg
P R
1.6 3.2
+40
cm/s
200
0
200
400
+ cm/s -

AT= 0.09 sec


0.09 sec
0
200
400
cm/s

Doppler Parameters of Prosthetic Aortic Valve Function

	Normal	Suggests Stenosis
Peak Velocity	< 3 m/s	> 4 m/s
Mean Gradient	< 20 mmhg	> 35 mmhg
Doppler Velocity Index	>= 0.3	< 0.25
Effective Orifice area	> 1.2 cm2	< 0.8 cm2
Contour of Jet	Triangular Early Peaking	Rounded Symmetrical contour
Acceleration Time	< 80 ms	> 100 ms

Doppler Parameters of Prosthetic Aortic Valve Function

	Normal	Suggests Stenosis
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Effective Orifice area	> 1.2 cm2	< 0.8 cm2
Contour of Jet	Triangular Early Peaking	Rounded Symmetrical contour
Acceleration Time	< 80 ms	> 100 ms

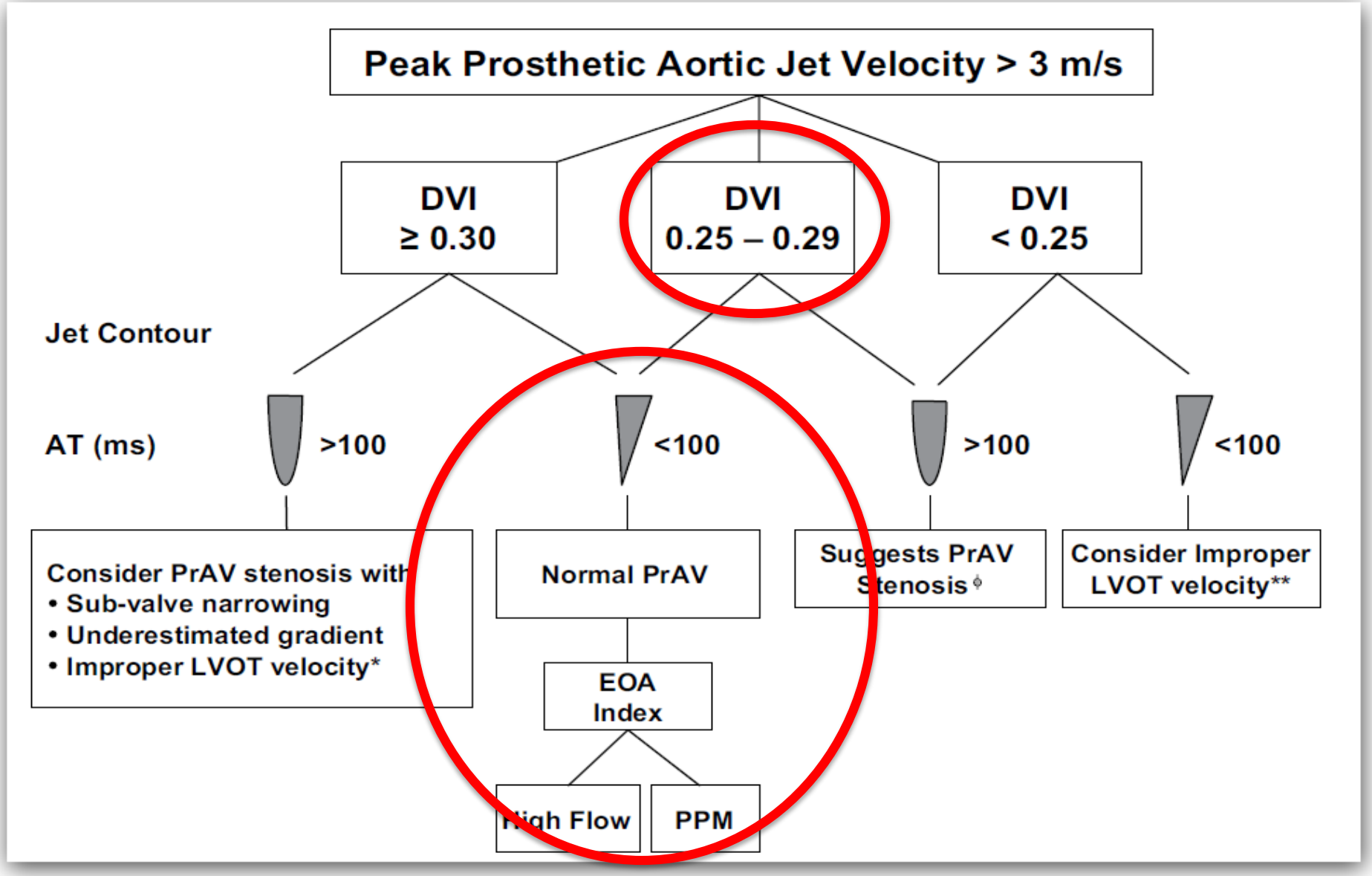
3.4

30

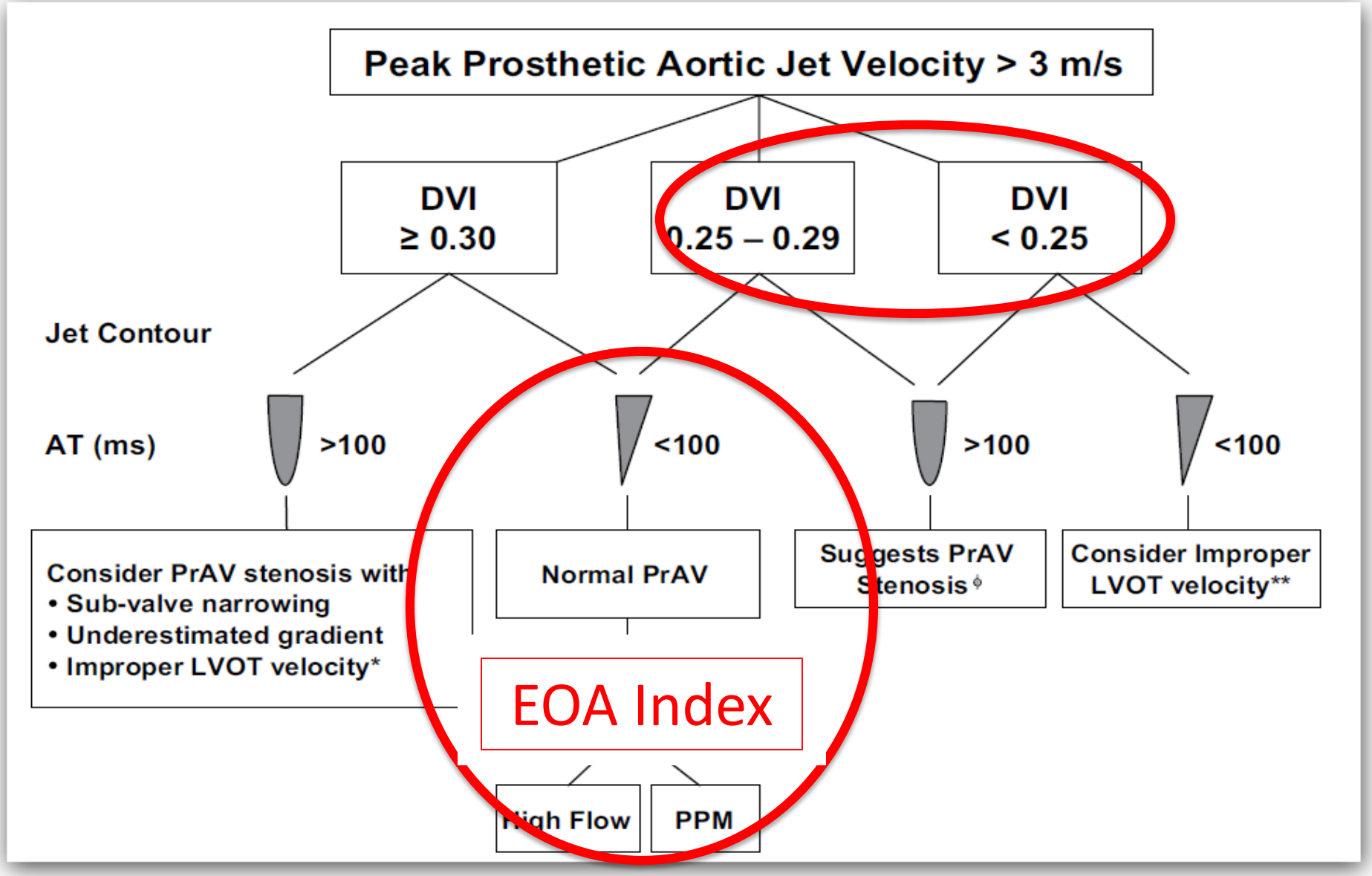
0.25

90 ms

An approach to prosthetic AV stenosis



An approach to prosthetic AV stenosis



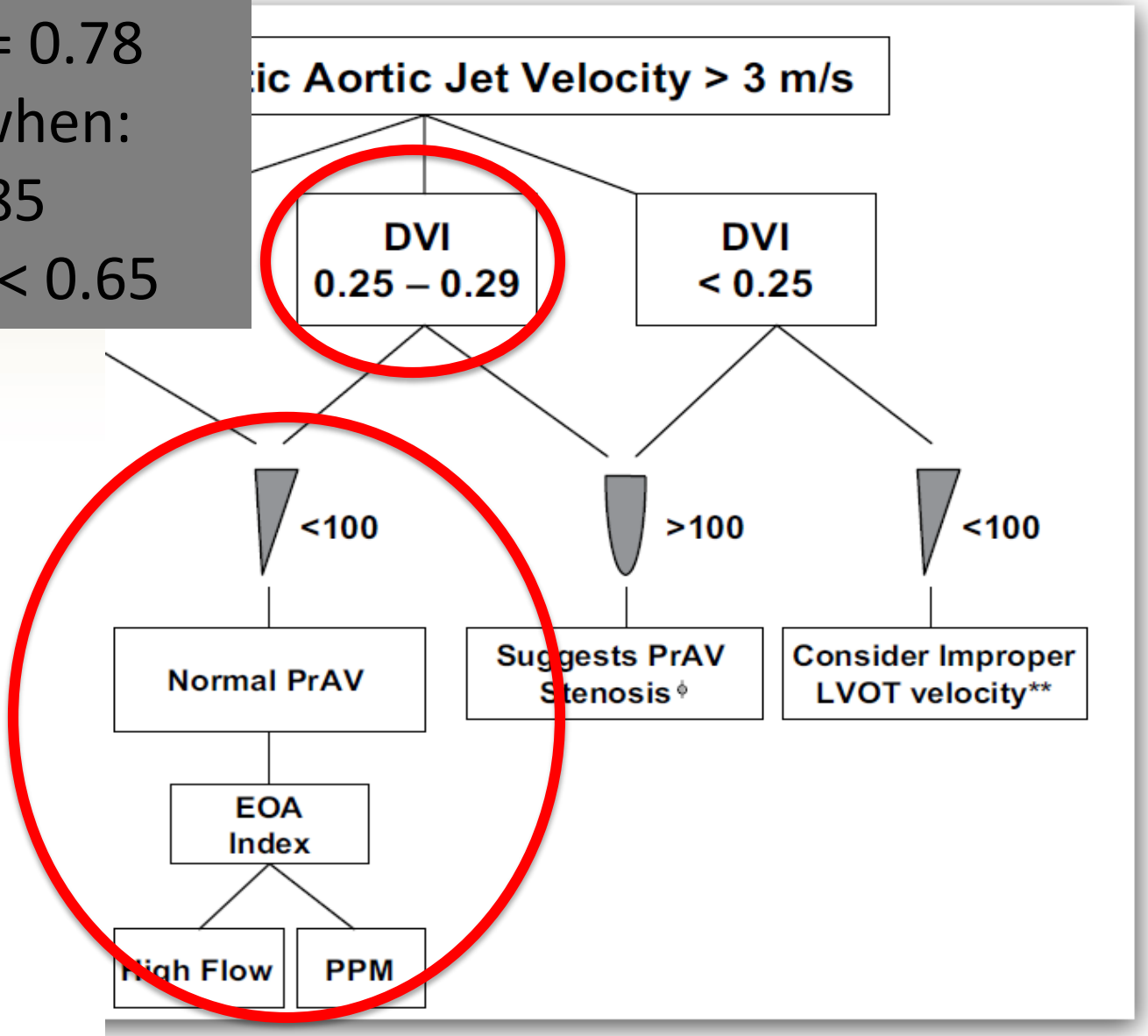
An approach to prosthetic AV stenosis

Indexed EOA = 0.78

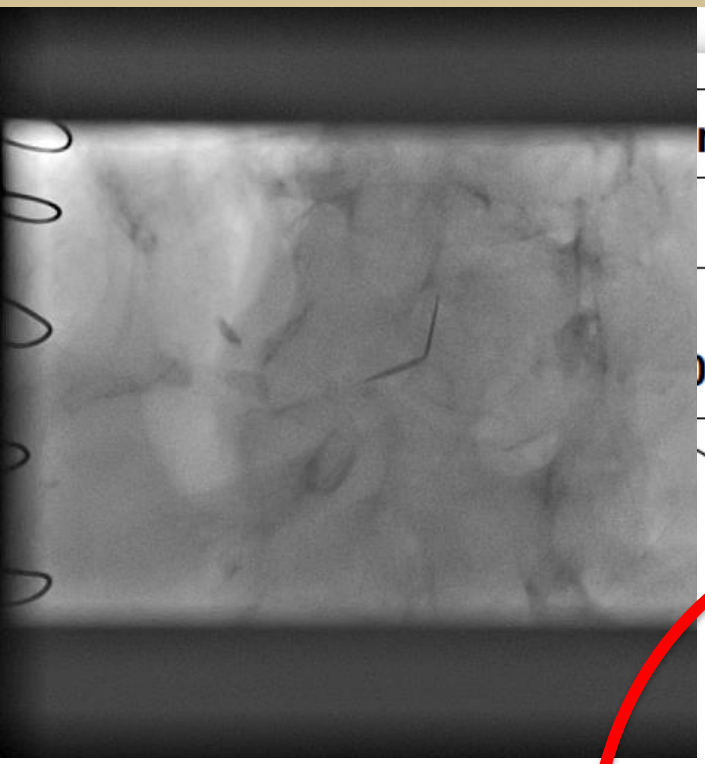
PPM occurs when:

iEOA < 0.85

Severe if iEOA < 0.65



An approach to prosthetic AV stenosis



rosthetic Aortic Jet Velocity > 3 m/s

DVI
0.25 – 0.29

DVI
< 0.25

<100

>100

<100

Normal PrAV

Suggests PrAV Stenosis

Consider Improper LVOT velocity**

EOA Index

High Flow

PPM

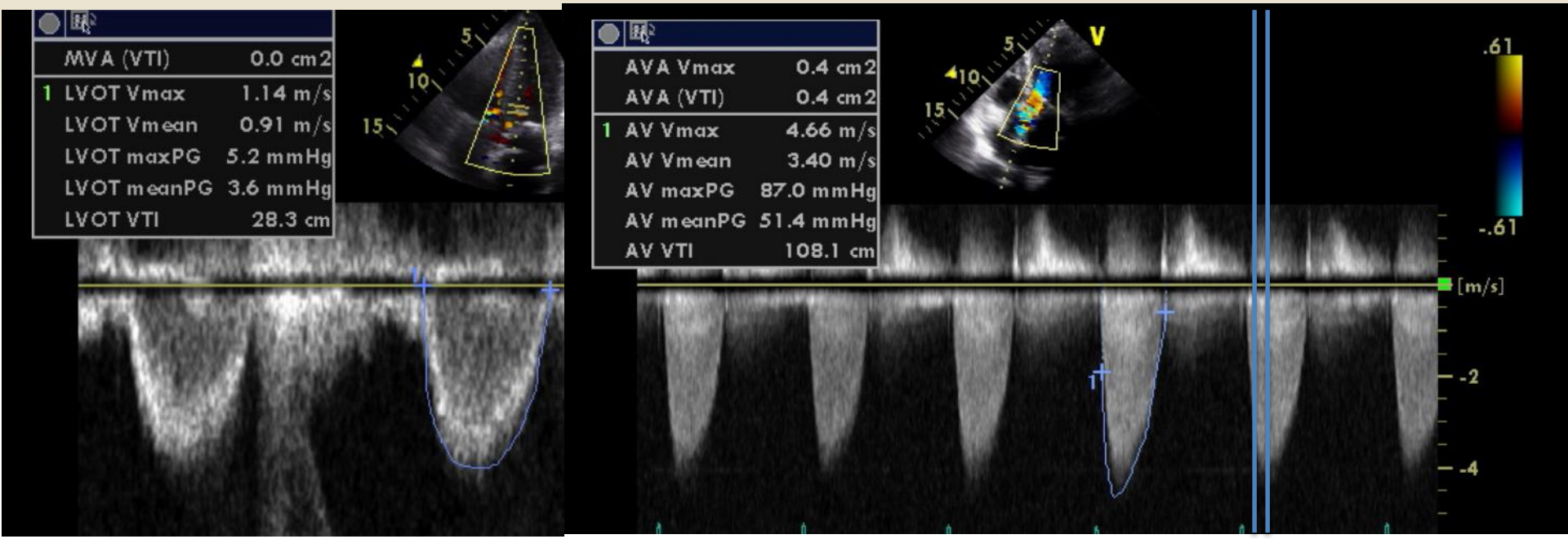
OU WB

What is your diagnosis?

- A) Prosthesis – Patient Mismatch
- B) Normal Prosthetic Valve Function
- C) High Flow State
- D) Prosthetic Valve Stenosis
- E) Improper LVOT Velocity (Prosthetic valve stenosis)

OU WB

Patient Prosthesis Mismatch



- AVA velocity:4.6
- DVI: 1.14/4.6 = 0.25, AVA= 0.4 cm^2
  - Acceleration Time: 60 msec

B

Patient Prosthesis Mismatch

OU WB

Patient Prosthesis Mismatch

- $\Delta P = Q^2/(K \times EOA^2)$

- Q = Flow, K = Constant
- For gradients to remain low, EOA has to accommodate and be proportionate to flow
- At rest, Q is determined by BSA
- In patients with large BSA and increased flow, a “too small of a valve” with a small EOA will produce a high gradient

OU WB

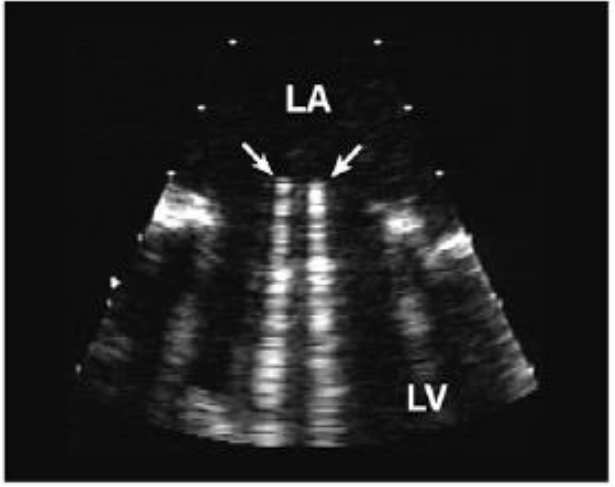
Echocardiographic Evaluation of Prosthetic Valve Regurgitation

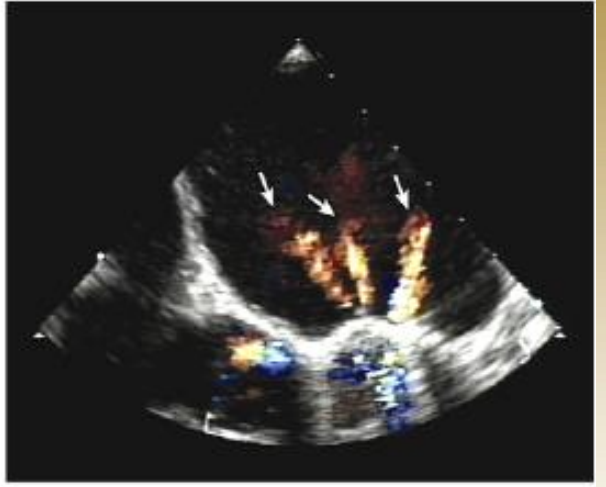
OU WB

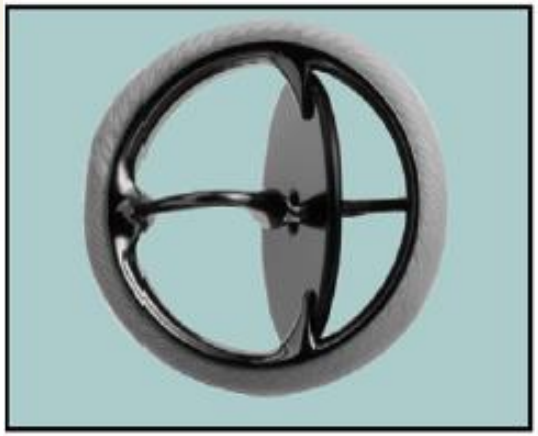
Types of Regurgitation

- Regurgitation may be
  - Physiological
  - Pathological
- Physiological regurgitation
  - Closing volume (blood displacement by occluder motion)
  - At the hinges of occluder

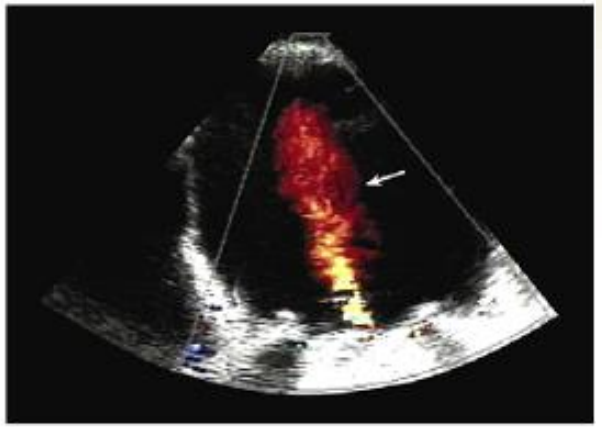
OU WB

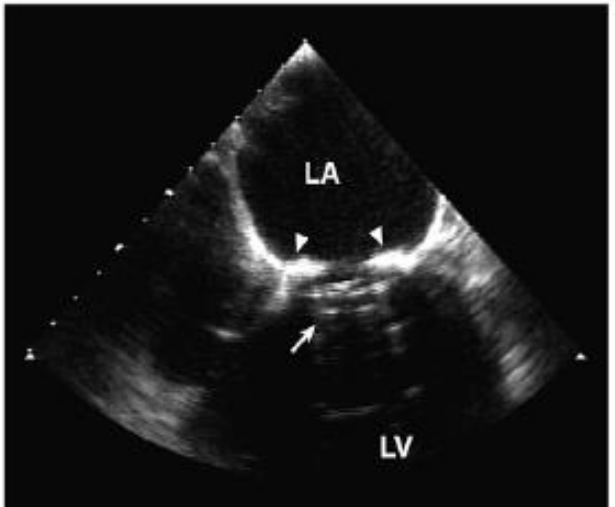

LA
LV

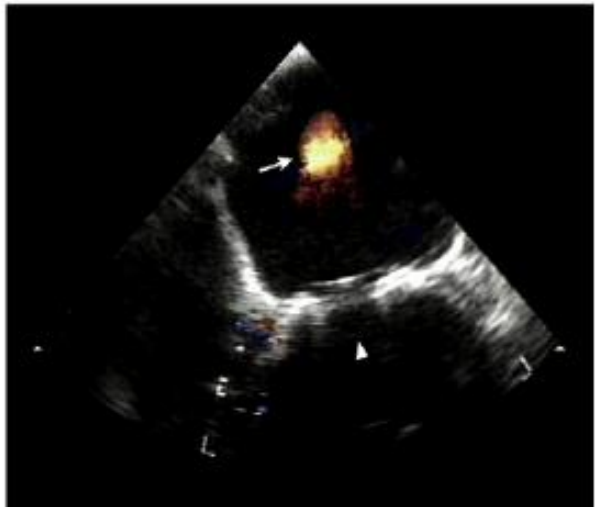





LA




LA
LV



Types of Regurgitation

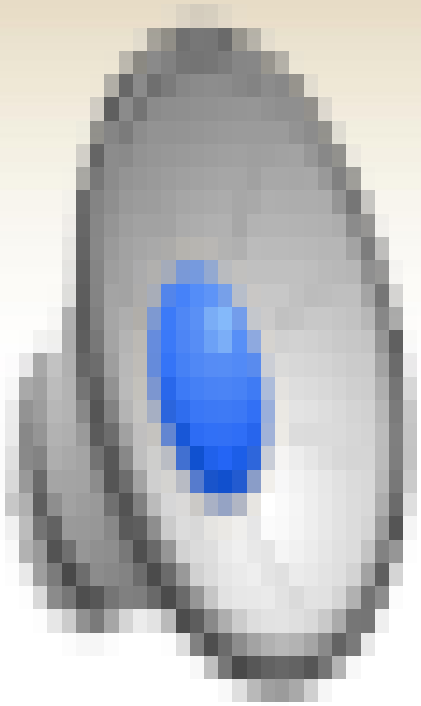
- Pathological
  - Central
    - Mostly with bioprosthetic
    - Technical or infection related
  - Paravalvular
    - Either type, usually the site with mechanical
    - Mild is common after surgery (5-20%) and likely insignificant in the absence of infection
    - Usually after calcium debridement, redo, older patients
    - Hemolytic anemia
    - TAVR

OU WB

Central Aortic Regurgitation

Central Aortic Regurgitation

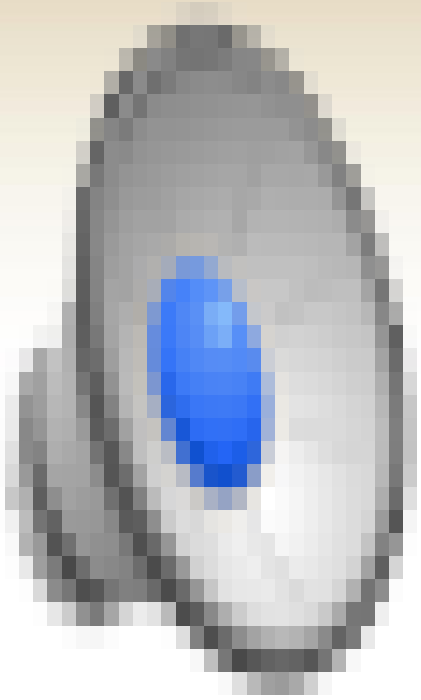
Central Aortic Regurgitation



OU WB

Paravalvular Aortic Regurgitation

Paravalvular Aortic Regurgitation



OU WB

Assessment of Prosthetic Aortic Valve Regurgitation: TTE

- Challenging due to
  - Shadowing
  - Eccentric Jet
  - Difficult to quantify paravalvular leak
- Width of vena contracta may be difficult to measure
- Off axis views may be required

OU WB

Assessment of Prosthetic Aortic Valve Regurgitation

- Jet diameter/LVO diameter <25% in PS views
- Pressure Half Time < 200 ms
- Holodiastolic flow reversal in Descending aorta
- Neck in the short axis view
  - < 10% of sewing ring is mild
  - 10-20% moderate
  - > 20% severe
  - > 40% rocking motion

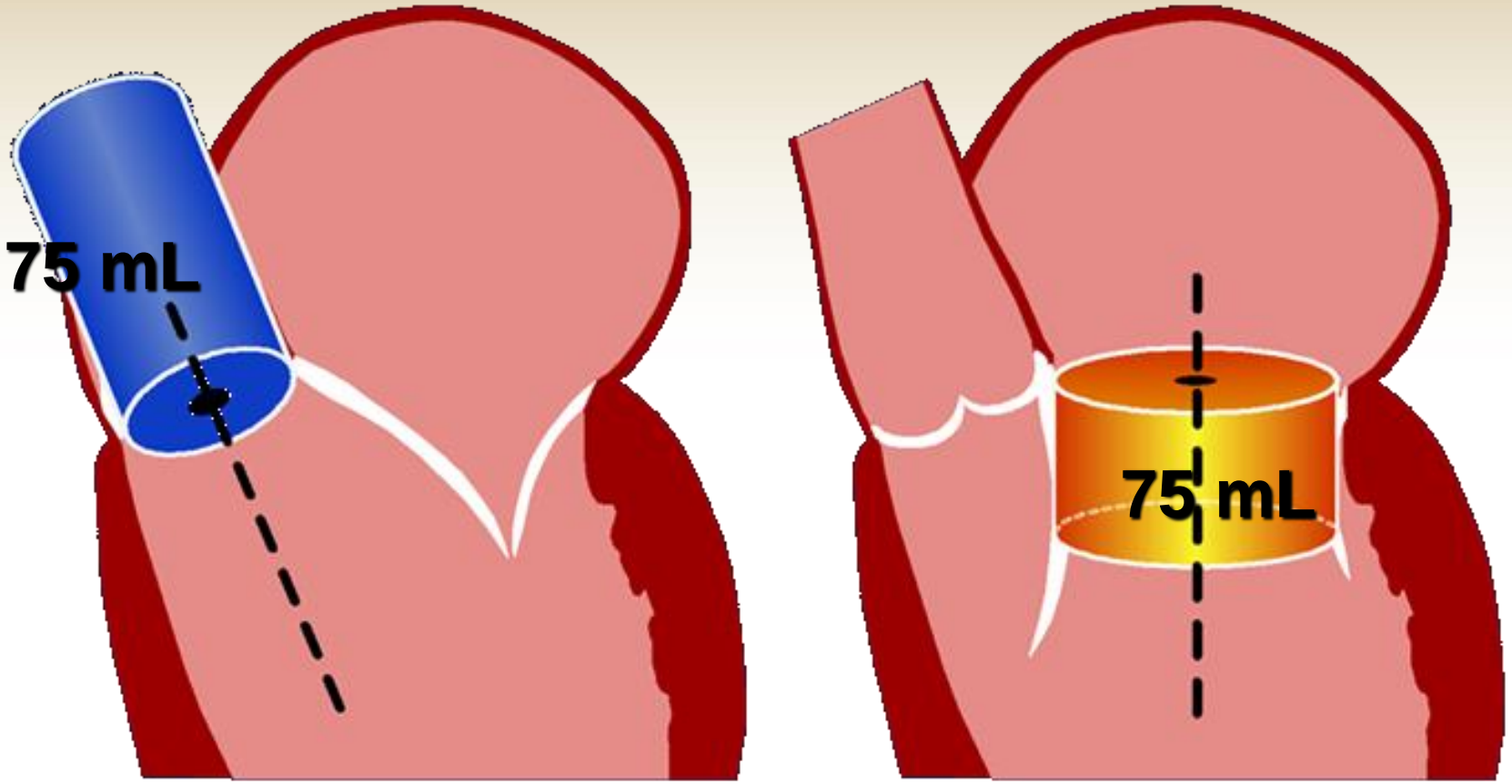
OU WB

Assessment of Prosthetic Aortic Valve Regurgitation

Parameter	Mild	Moderate	Severe
Valve structure and motion			
Mechanical or bioprosthetic	Usually normal	Abnormal†	Abnormal†
Structural parameters			
LV size	Normal‡	Normal or mildly dilated‡	Dilated‡
Doppler parameters (qualitative or semiquantitative)			
Jet width in central jets (% LVO diameter): color*	Narrow (≤25%)	Intermediate (26%-64%)	Large (≥65%)
Jet density: CW Doppler	Incomplete or faint	Dense	Dense
Jet deceleration rate (PHT, ms): CW Doppler§	Slow (>500)	Variable (200-500)	Steep (<200)
LVO flow vs pulmonary flow: PW Doppler	Slightly increased	Intermediate	Greatly increased
Diastolic flow reversal in the descending aorta: PW Doppler	Absent or brief early diastolic	Intermediate	Prominent, holodiastolic
Doppler parameters (quantitative)			
Regurgitant volume (mL/beat)	<30	30-59	>60
Regurgitant fraction (%)	<30	30-50	>50

OU WB

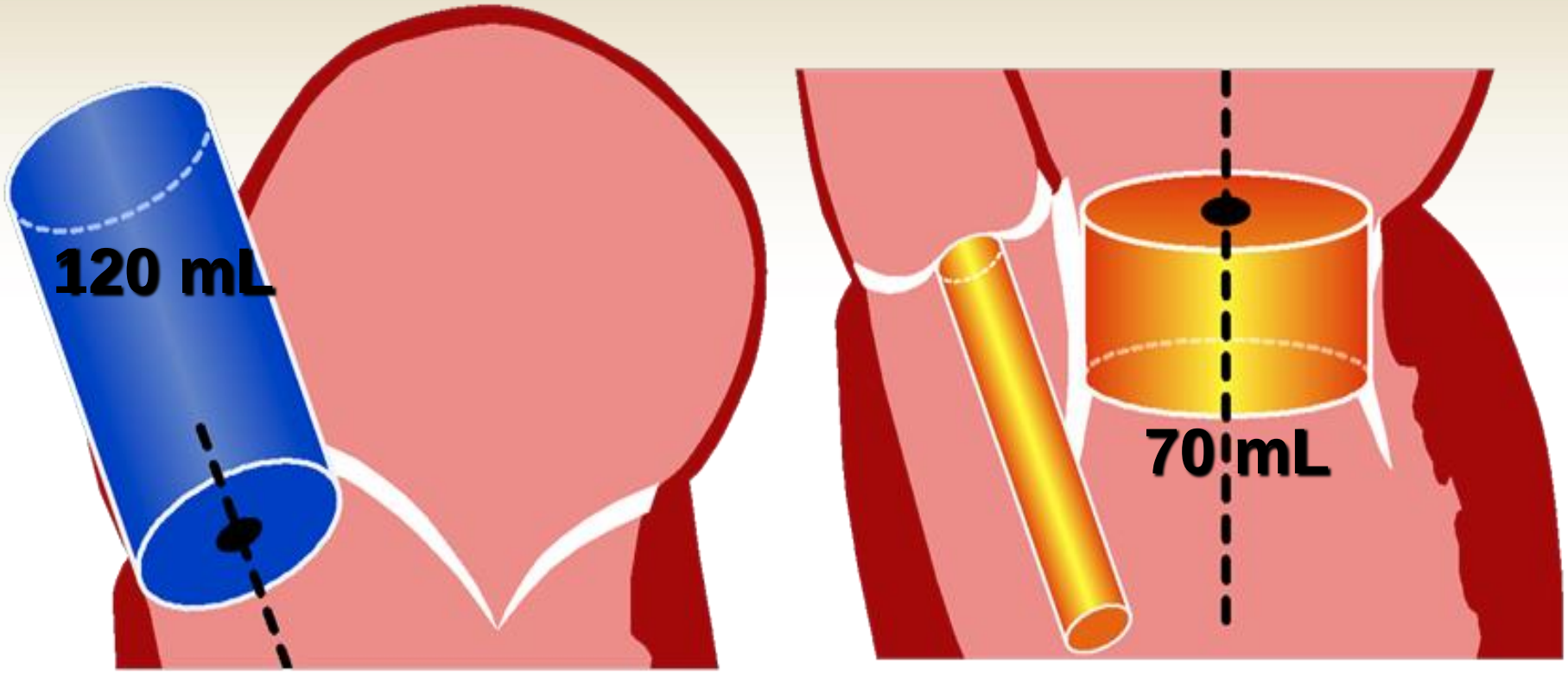
Assessment of Prosthetic Aortic Valve Regurgitation



NORMAL

OU WB

Assessment of Prosthetic Aortic Valve Regurgitation



AORTIC REGURGITATION

R Volume = 120-70 = 50 mL

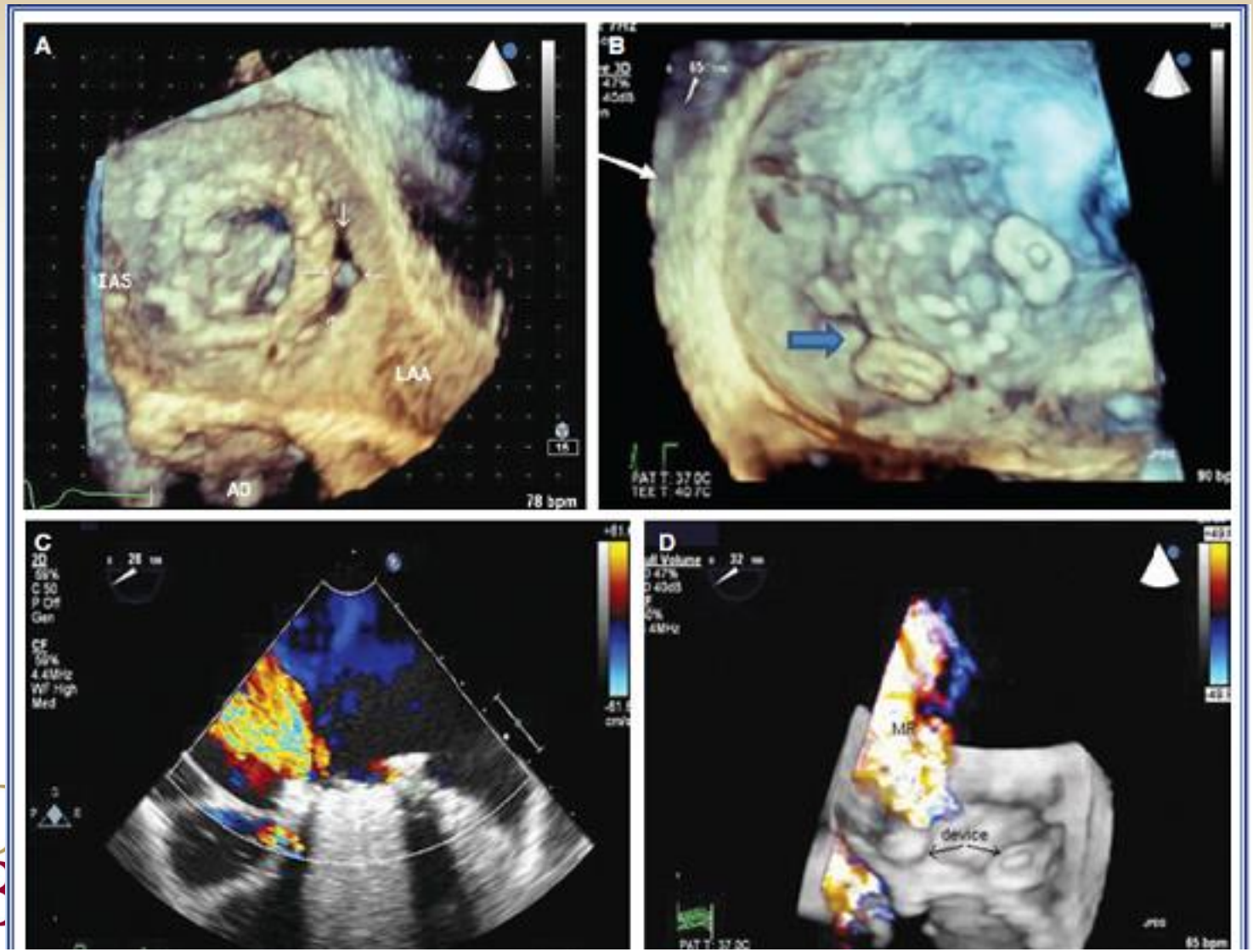
R Fraction = 50/120 = 42%

Assessment of Prosthetic Aortic Valve Regurgitation: TEE

- Identifies:
  - Location,
  - Mechanism,
  - AR width to LVOT width,
  - Posterior jets may be identified
- LVOT obscured by accompanied MV prosthesis
- 3D: value? Especially for transcatheter repair

OU WB

3D in Paravalvular Leak Repair



Echocardiographic Evaluation of Prosthetic Valve Endocarditis

OU WB

Endocarditis

- Incidence < 1% and has declined with perioperative antibiotics
- Form in valve ring and extend to and spread to stent, occluder, or leaflet
- Irregular and independently mobile
- Can not adequately differentiate between vegetations, thrombus, pledgets, sutures, etc

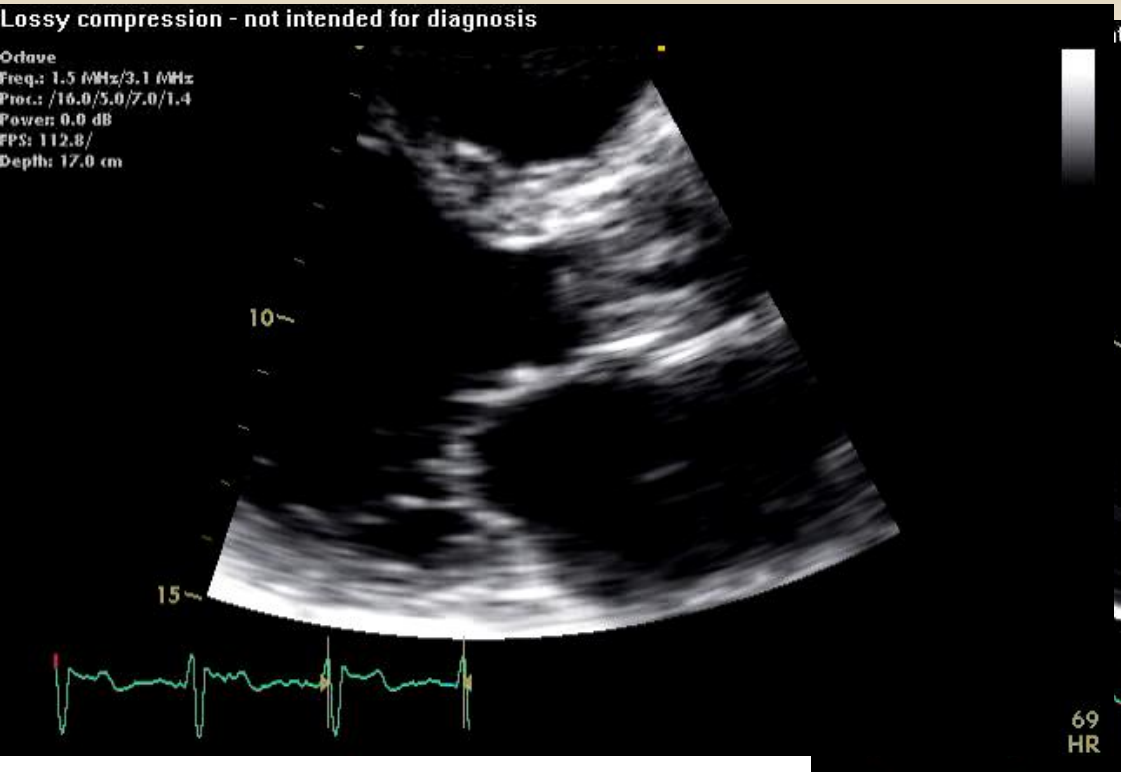
OU WB

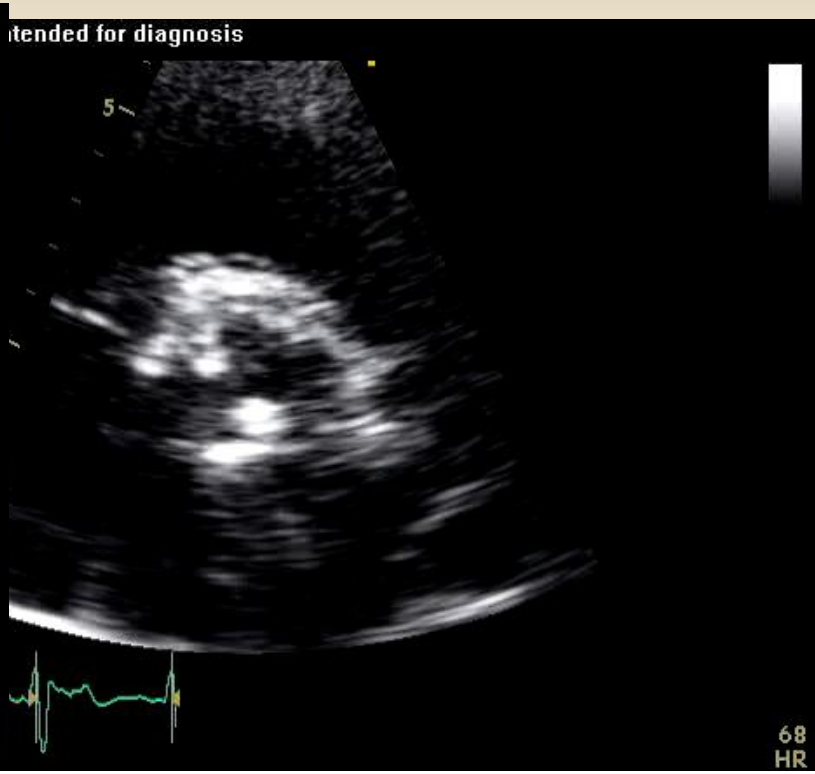
Endocarditis

- TEE has better sensitivity and specificity for
  - Vegetations
  - Abscess in the posterior but not anterior location
- Combined TEE and TTE have a NPV of 95%
- If clinical suspicion high and studies negative, repeat studies in 7-10 days

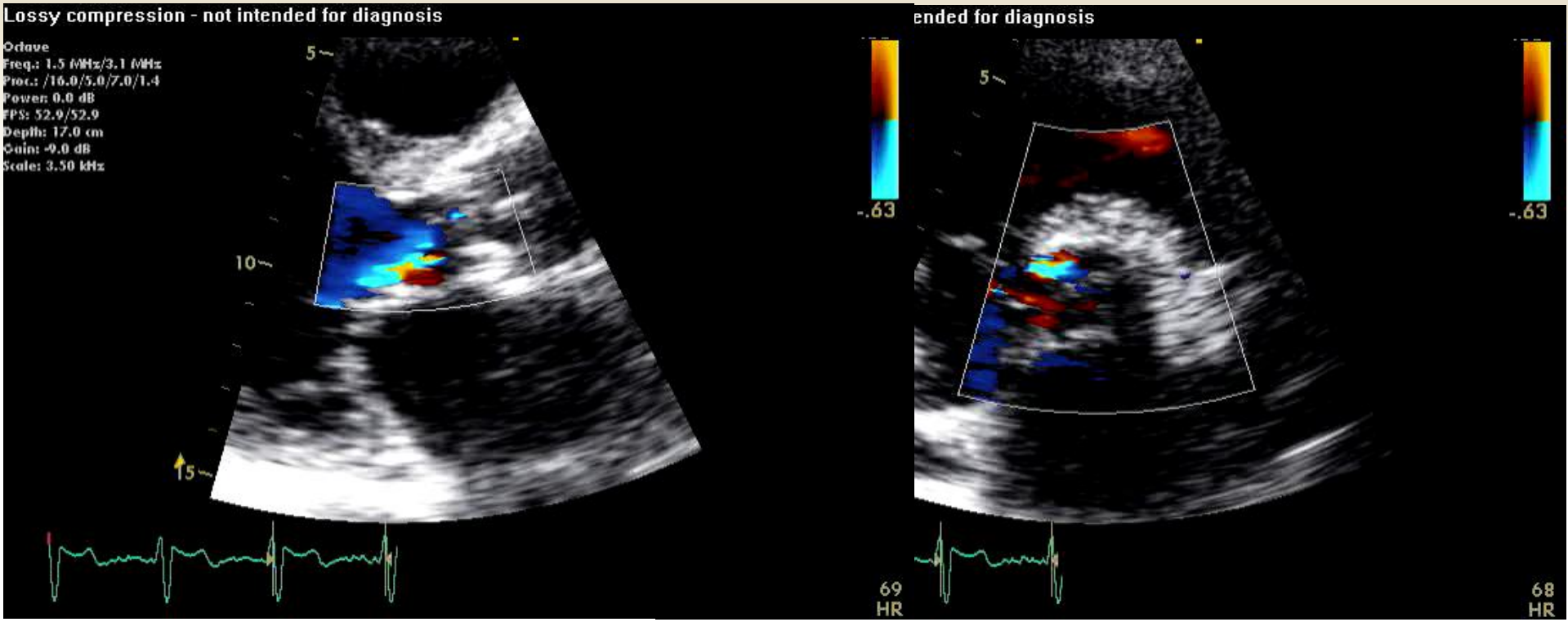
OU WB

Parasternal Long



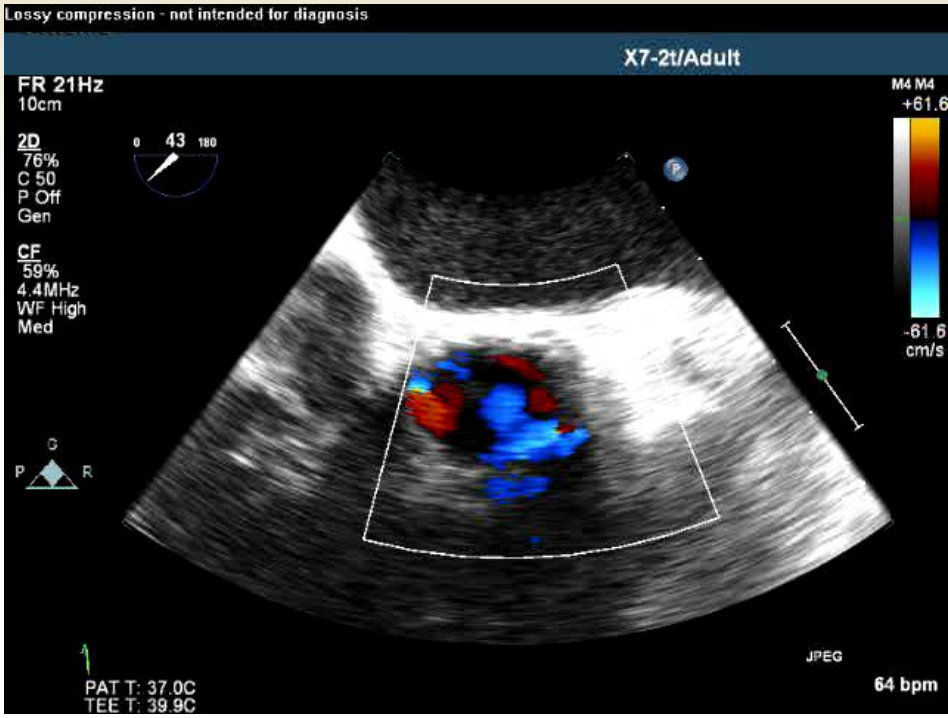


Color


Lossy compression - not intended for diagnosis
Octave
Freq.: 1.5 MHz/3.1 MHz
Proc.: /16.0/5.0/7.0/1.4
Power: 0.0 dB
FPS: 52.9/52.9
Depth: 17.0 cm
Gain: -9.0 dB
Scale: 3.50 kHz
5
10
15
-.63
69
HR
ended for diagnosis
5
-.63
68
HR

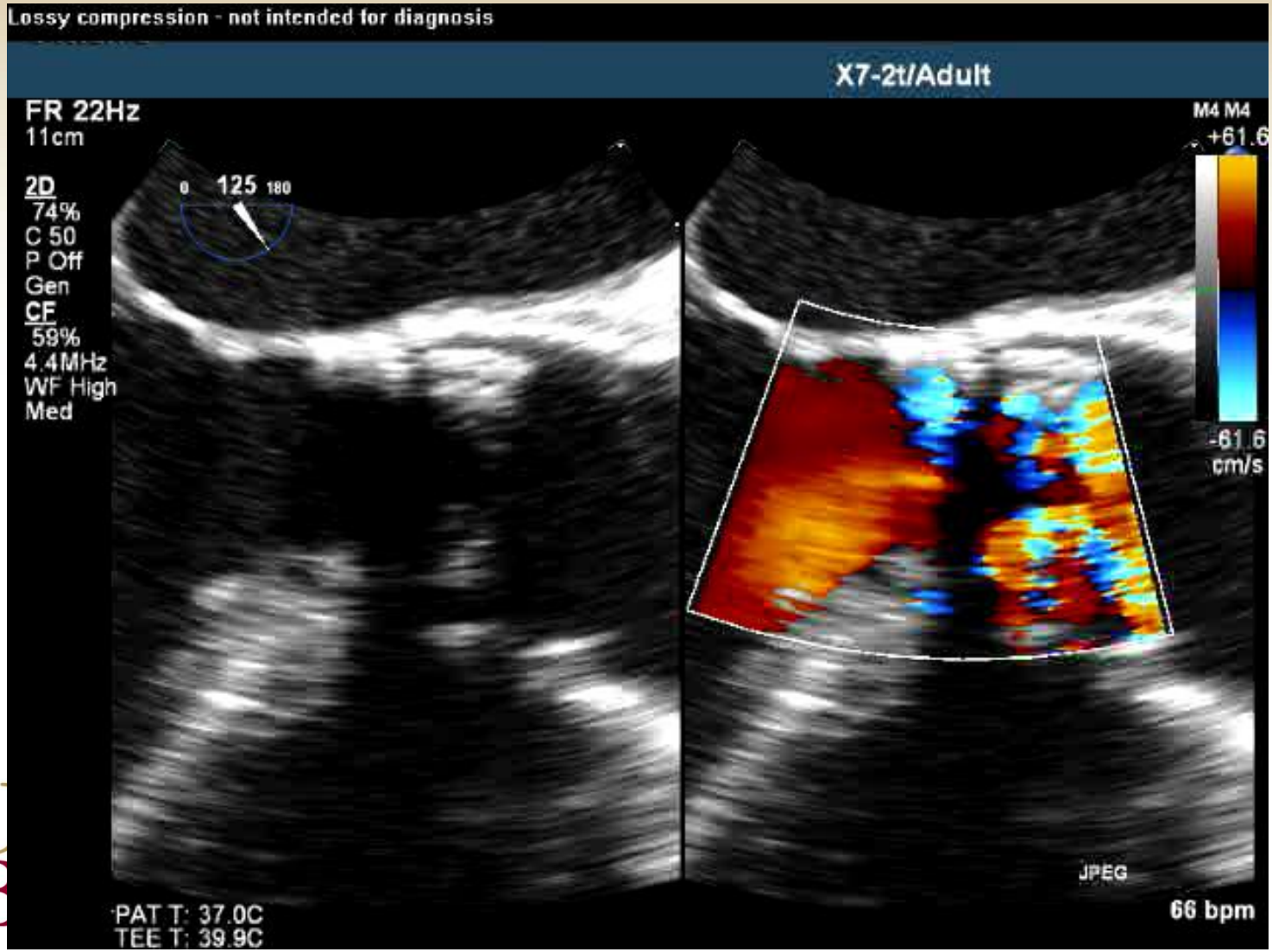
OU WB

TEE Short

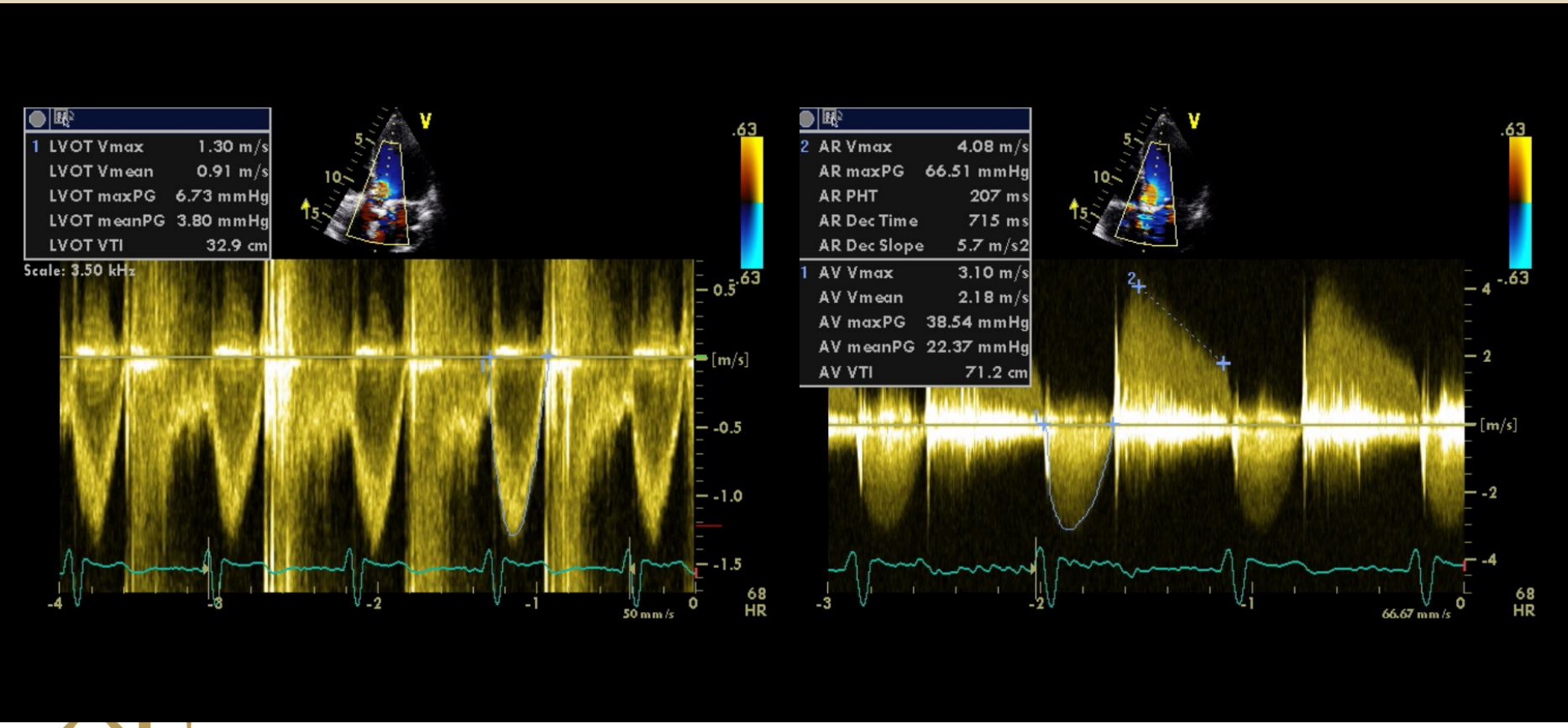


OU WB

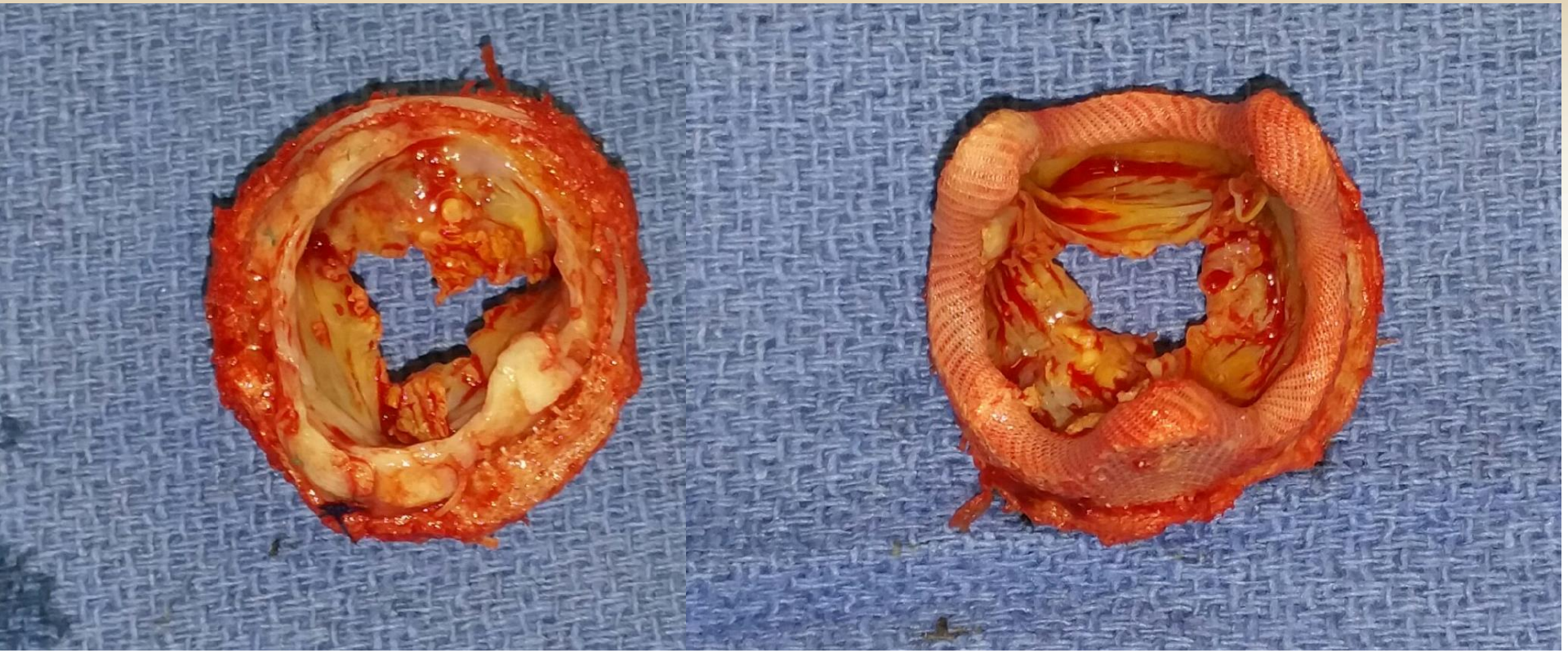
TEE Long


Lossy compression - not intended for diagnosis
X7-2t/Adult
FR 22Hz
11cm
2D
74%
C 50
P Off
Gen
CF
59%
4.4MHz
WF High
Med
0
125
180
M4 M4
+61.6
-61.6
cm/s
JPEG
66 bpm
PAT T: 37.0C
TEE T: 39.9C

Doppler


1 LVOT Vmax 1.30 m/s
LVOT Vmean 0.91 m/s
LVOT maxPG 6.73 mmHg
LVOT meanPG 3.80 mmHg
LVOT VTI 32.9 cm
Scale: 3.50 kHz
[m/s]
50 mm/s
68 HR
2 AR Vmax 4.08 m/s
AR maxPG 66.51 mmHg
AR PHT 207 ms
AR Dec Time 715 ms
AR Dec Slope 5.7 m/s2
1 AV Vmax 3.10 m/s
AV Vmean 2.18 m/s
AV maxPG 38.54 mmHg
AV meanPG 22.37 mmHg
AV VTI 71.2 cm
66.67 mm/s

Pathology



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Echocardiographic Evaluation of Prosthetic Valve Thrombosis/Pannus

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Thrombus versus Pannus

Thrombus

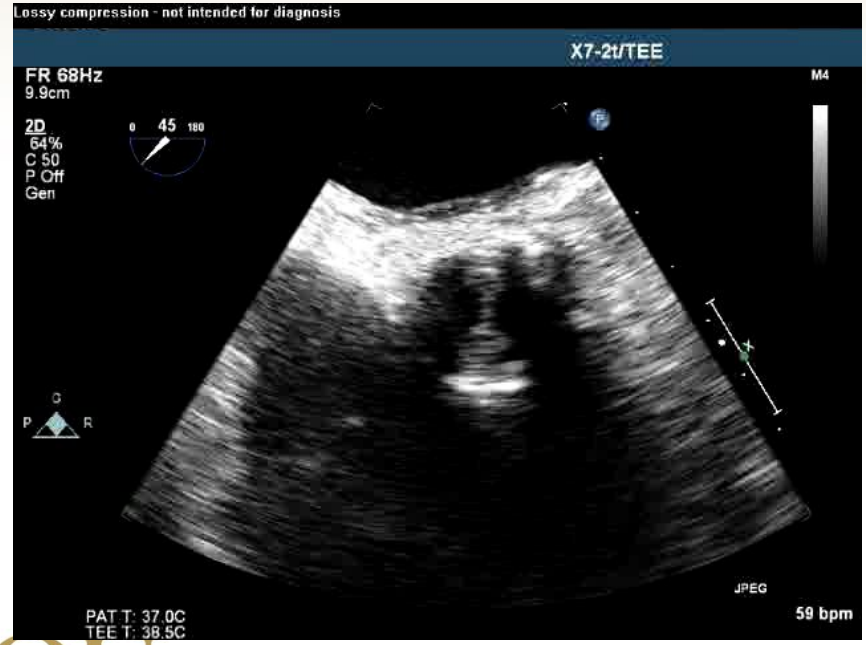
- Larger
- Soft density similar to myocardium
- More likely to encounter abnormal valve motion
- Short duration of symptom
- Poor anticoagulation
- Size < 0.85 cm2 less likely to embolize
- More with mechanical

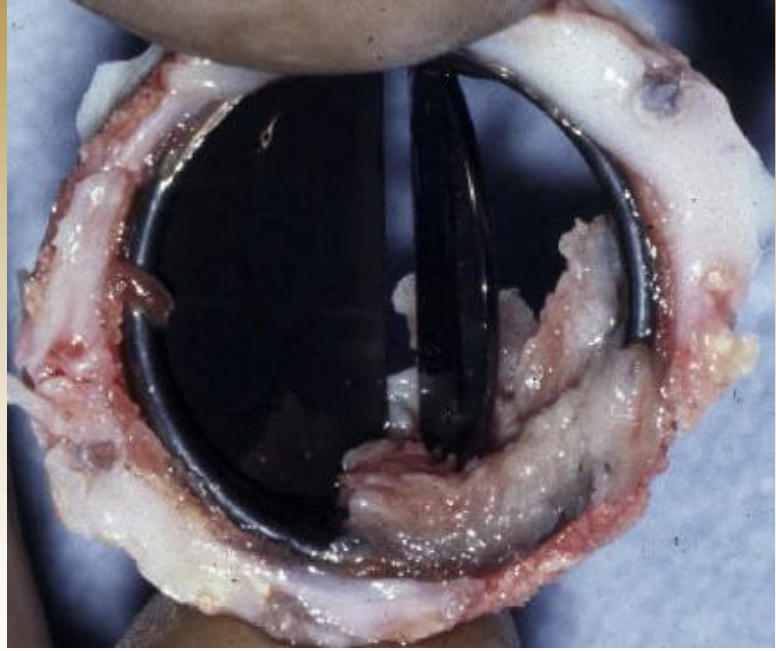
Pannus

- Small
- Dense, 30% may not be visualized
- Longer duration
- More common in aortic

Pannus

TEE


Lossy compression - not intended for diagnosis
X7-2t/TEE
FR 68Hz
9.9cm
M4
2D
64%
C 50
P Off
Gen
0 45 180
JPEG
PAT T: 37.0C
TEE T: 38.5C
59 bpm



Pre Questions (1)

- Regarding Aortic Prosthetic Valves
  - A. A routine echocardiogram is required very two years after AVR
  - B. An elevated gradient with a decreased EOA is always suggestive of valvular stenosis
  - C. Transthoracic echocardiogram alone is always sufficient to diagnose valvular stenosis
  - D. It is more challenging to quantify para-valvular versus valvular aortic regurgitation.

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Answer (1)

- D. It is more challenging to quantify para-valvular versus valvular aortic regurgitation.

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Pre Questions (2)

- Patients with Prosthesis-Patient Mismatch
  - A. Have abnormal prosthetic valve function
  - B. Progressively worsen with time
  - C. Have a small valve compared to the demands of their body and cardiac output
  - D. Have a benign condition

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Answer (2)

C. Have a small valve compared to the demands of their body and cardiac output

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Conclusions

- Elevated gradients across prosthetic aortic valves may be due to other factors besides stenosis
- Regurgitation may be physiological or pathological and may be valvular or paravalvular
- Endocarditis, pannus, and thrombosis may be difficult to distinguish based solely on echocardiographic findings

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"Please Let Them do Well on the Boards" Zane Abbas

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