Paravalvular Regurgitation after TAVR

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Definitions

TAVR

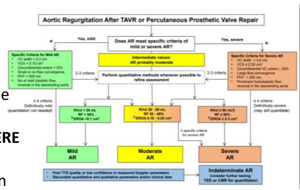
- Transcatheter aortic valve replacement

Paravalvular Regurgitation (PVR)

- Regurgitation OUTSIDE the circumference of the stent valve

Meeting Goals

- TTE v TEE
- Mechanism of Paravalvular Regurgitation
- Severity Algorithm – New guideline paper
- **Diagnose definitely MILD or SEVERE**
  - Color Doppler Quantification
  - Spectral Doppler Quantification



Introduction

TAVR

Balloon Expandable Vs. Self Expanding Valves

Introduction

Past decade Transcatheter aortic valve replacement (TAVR) has increased.

- TAVR is an accepted alternative to SAVR
  - High & intermediate-risk as well as inoperable patients
  - April 2019: Severe AS in low-surgical risk patients

How does this affect you?

- Post TAVR – assess for regurgitation via echo
- Residual regurgitation predictor of mortality
  - Moderate or severe regurg. ↑ mortality
- Sonographer:
  - Assess and **quantify** regurgitation after TAVR
  - Provide a guide to the cardiac team

TAVR Follow Up

Uncomplicated

Clinical Deterioration

TAVR Follow Up – Uncomplicated TAVR

Pts w/ uncomplicated TAVR implantation:

- Complete TTE soon after implantation to establish baseline valvular function
- 1-3 months
- 1 year

Clinical Deterioration: As needed (underlying cause?)

The baseline post TAVR TTE is integral to accurate follow-up

Valves

Balloon Expandable Vs. Self Expanding Valves

Balloon Expandable – Edwards SAPIEN

Balloon assisted expansion

Self Expandable - Medtronic Corevalves/Evolut

Spontaneously expand on release

Paravalvular Regurgitation Post TAVR

Causes

Cause: Poor Positioning (Malapposition)

Definition: The separation of at least one stent strut from the surface of the wall with evidence of blood behind the strut

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Malapposition: Causes

1. Under-expanded
2. Placed too low
3. Placed too high

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Mechanism: Incomplete

Causes
Examples

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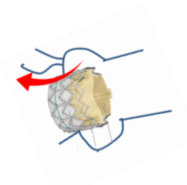
Incomplete Positioning

Causes:
1. Under expansion of the prosthesis
2. Heavy calcification



- Flow is outside the circumference of the prosthetic stent frame (paravalvular)
- PVR originates from space between Stent & Annulus

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Example: Incomplete Positioning

- TEE PSAX
- Device is not co-axial to the root
- Space between prosthetic valve and left annulus
- Edwards SAPIEN 26mm
- Balloon Expandable Device

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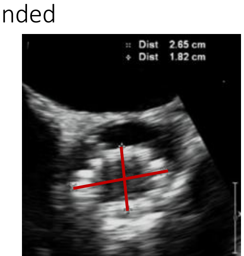
Example: Under-Expanded

- **Under-expanded**
- TEE short axis: **Assess shape** (circular or non circular)
- Oval-shaped waist
- Medtronic CoreValve 29mm
- Self Expandable



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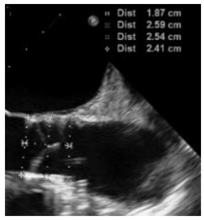
Valve Measurement

- Example: TEE long axis
- Diameters of 24 to 26 mm indicating reasonable expansion in the presence of PVR
- Edwards SAPIEN XT 26-mm
- Balloon Expandable Device



Mechanism: Supra-skirt

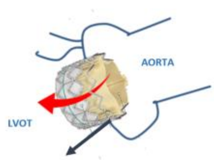
Cause

Examples

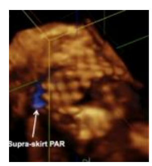
Mechanism: Supra-skirt

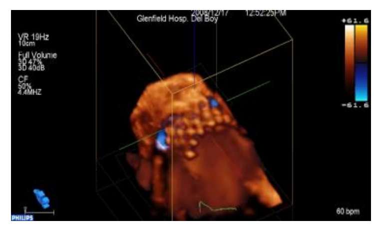
- Low implant ("too ventricular")
- Prosthesis is deployed at a depth that exceeds the height of its tissue skirt
- Regurgitant jet passes above the skirt outside the circumference of the stent (PVR)
- Flow Pattern:

Aortic portion --> paravalvular space → LVOT



Too Low "Supra-Skirt" PVR





Mechanism: Infra-skirt

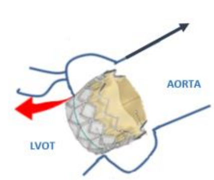
Causes

Examples

Mechanism: Infra-skirt

- High implant ("too aortic")
- Partially above the native annulus
- Flow Pattern outside the circumference of the stent (PVR) :

Paravalvular space → irregular inflow edge → LVOT



Too High “Infra-Skirt”

Transvalvular Regurgitation Post TAVR

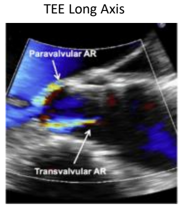
Definition

Example

Transvalvular Aortic Regurgitation

- Easy to differentiate from PVR
- WITHIN the circumference of prosthetic stent frame (central jet)
- Transvalvular AR - **Assess valve leaflets**
    - Structural damage vs. insufficient diastolic pressure to close them?

TEE Long Axis



Example: Transvalvular Aortic Regurgitation

- TEE long-axis view
- Both: Transvalvular central jet
- PVR Posterior Jet
- Edwards SAPIEN 23-mm
- Balloon Expandable Device

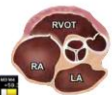
Jet Location Tips

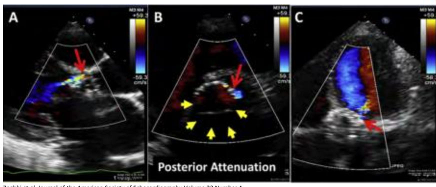
- **The jet must enter the LV to be considered true regurgitation**
    - Image just below the edge of the stent to *confirm true PVR*
- Color flow around valve within S of V, but *above the annular valve skirt should not be mistaken for PVR.*
    - This low velocity flow (not aliased) does not connect with the LVOT in diastole
- Scan through the long axis of the valve to distinguish sinus flow from PVR.

TTE vs. TEE

Advantages and Disadvantages

TTE: Good for Anterior Regurg (PVR)





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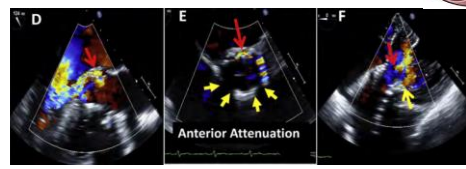
TEE: Good for Posterior Regurg (PVR)



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Echo Quantification of PVR After TAVR

4 Principles
Color Doppler
CW and PW Doppler
Quantification (Rvol & RF)

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4 Principles: Evaluation of PVR with Echo

1. Comprehensive Exam – 2D, color, CW, PW, TTE, TEE, 3D
2. Individualization to the patient (mechanism, location of PVR)
3. Integration of multiple parameters
4. Precise & standardized language to describe findings (TEE/TTE)
   - Severity
   - Location

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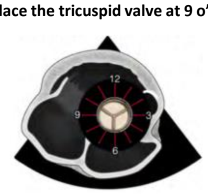
Location Description: Clock Face

Place the tricuspid valve at 9 o'clock



transTHORACIC

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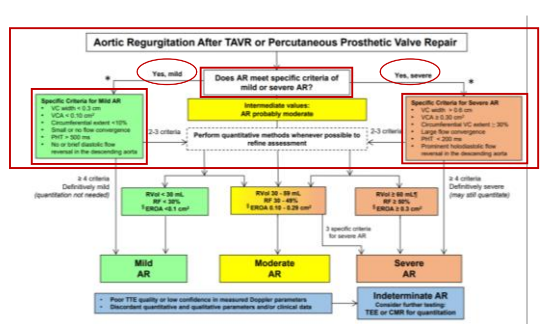


Semi Quantitative Color Doppler

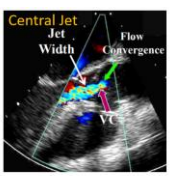
VCW
VCA
Circumferential Extent

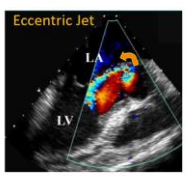
Vena Contracta Width (VCW)

Advantages
Disadvantages
Technique

Vena Contracta Width

- Vena contracta: Narrowest region between the proximal laminar flow and the distal turbulent regurgitant jet spray





Vena Contracta Width: Advantages

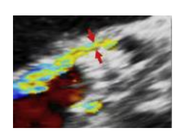
- Valid in eccentric jets
- Independent of flow rate and driving pressure
- Less dependent on technical factors – simple & reproducible
- Good at identifying mild or severe AR
- Rapid qualitative assessment

Vena Contracta Width: Disadvantages

- Smaller jets - difficult to evaluate severity
- Problematic with multiple jets
- Irregular shaped jets: <u>Over or underestimate severity</u>

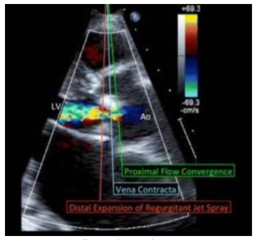
VC Width – Correct Technique

- Select image plane that optimizes the Vena Contracta – not always PLAX
- Zoom Image
- Narrowest area of jet
- Avoid surrounding blurred color signals
  - Remove color from frozen image (color suppression)



VC Width – Tips

- Sweep Valve to ensure smallest VC
  - **Flow convergence → VC →, to jet spray**
- Maximize Nyquist limit (>65 cm/sec):
  - Distinguish high vs. low velocity



Cardiovasc Ultrasound. 215; 13: 24.

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Vena Contracta Width Values

AR Vena Contracta Width (VCW)	
Mild	< 0.3 cm
Moderate	0.3 – 0.6 cm
Severe	> 0.6cm

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Vena Contracta Area (VCA)

Advantages
Disadvantages
Blooming Artifacts
Technique

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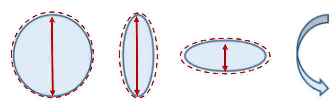
VC Area: Advantages

- May allow addition of multiple jets
- Strong correlation existed between 2D VCA and 3D VCA
- Good for VC jet shapes that are irregular or ellipsoid

2D VCA



3D VCA

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VC Area: Disadvantages

- Accuracy limited by spatial resolution for small jets
- User Error
- Prone to *blooming artifacts*
  - Color extends beyond true boundaries
  - Mainly distal portion
  - **Lower the color gain to reduce color bleed!**

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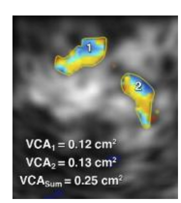
VC Area – Correct Techniques

- Trace each jet and add together
- Narrow color flow sector
  - ↑ resolution
- Mid-diastole
  - Minimize effect of cardiac motion



3D VCA

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Vena Contracta Area

AR Vena Contracta Area (VCA)	
Mild	< 10 cm^2
Moderate	0.10 – 0.29 cm^2
Severe	$\geq$ 0.30 cm^2

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Circumferential Extent %

Technique

Severity Values

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Circumferential Extent %

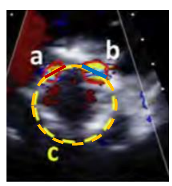
Assess the extent of the PVR around stent

1. Trace Circumference (C)
2. Measure length of jet along valve curvature

Single Jet: (a/c)*100

Multiple Jets: [(a + b)/c]*100

**Multiple jets: Measure each jet



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Circumferential Extent: Technique

- **Measure:** Parasternal Short Axis
- **Scan and Check:** PLAX, Apical 5 and Apical 3
- Some jets may not be detected in PSAX
  - Shadowing from the prosthesis (PSAX)
- Complete interrogation:
  - Transducer rotation & tilting upward or sideways
  - Off-axis planes

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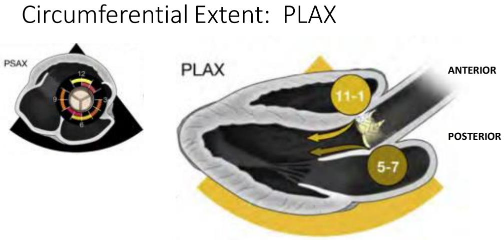
Circumferential Extent: PLAX



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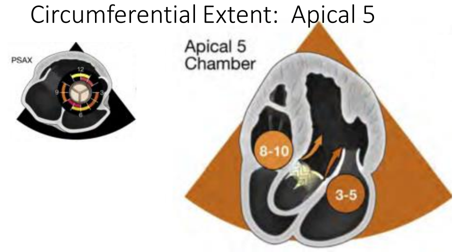
Circumferential Extent: Apical 5



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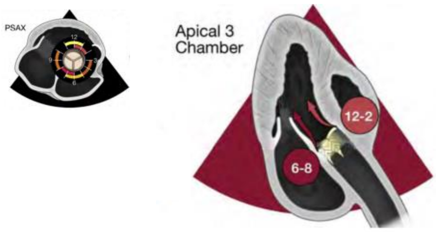
Circumferential Extent: Apical 3



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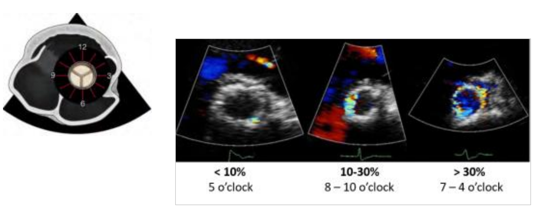
Circumferential Extent

Severity of PVR	Circumferential %
Trace	Pinpoint Jet
Mild	< 10%
Moderate	(10 – 30%)
Severe	> 30%

Circumferential Extent: Reporting

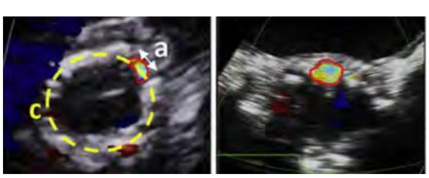


Circumferential Extent %: Caution

VCA Factor

Correct Imaging Plane

Circumferential Extent & VCA



MILD Circumferential Extent: 8%
MILD VCA: 0.1 cm^2

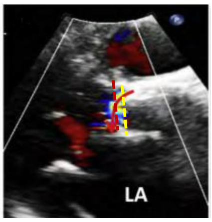
MILD Circumferential Extent: 10%
MODERATE VCA: 0.2cm^2

Circumferential Extent & VCA

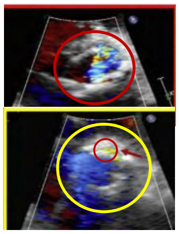
- Circumferential Extent **DOES NOT factor in VCA**
  - Only measures the length of the jet in relation to circumference NOT JET THICKNESS
- Similar Circumferential Extent BUT larger VCA = greater PVR
- ↑ VCA = ↑ jet thickness = ↑ severity

- Severity of PVR is affected by **both circumferential extent and thickness** of the PVR

Circumferential Extent: Correct Plane

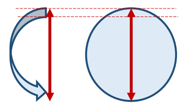


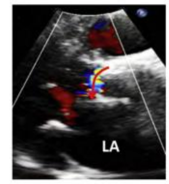
TTE, Anterior Eccentric Jet



Jet/LVOT ratio not used post TAVR

- PVR jets are frequently eccentric & constrained by the LVOT, leading to rapid jet broadening
- TTE, anterior eccentric jet





Qualitative Color Doppler

Proximal Flow Convergence

Proximal Flow Convergence

Advantages / Disadvantages

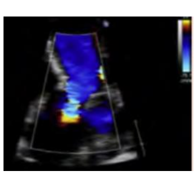
Technique

Proximal Flow Convergence

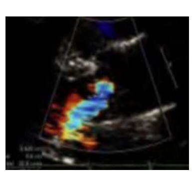
- Large flow convergence - indicative of severe PVR
- Rapid qualitative assessment

Disadvantages:

- Multiple jets



Apical 5C



PLAX

Proximal Flow Convergence: Technique

- Zoomed view
- **Change baseline** of Nyquist limit in the **direction of the jet**
- **Adjust lower Nyquist limit** to obtain the most hemispheric flow convergence
- Align direction of flow parallel to US beam to avoid distortion of hemisphere

Proximal Flow Convergence: Severity

Proximal Flow Convergence	
Mild	Absent
Moderate	May be present
Severe	Often present

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Color Doppler Summary

Key Points
Tips and Artifacts
Severity Chart

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PVR Color Severity: Semi-Quantitative/Qualitative

TAVR: Color Flow Severity of AR			
Semi Quantitative	**Mild**	**Moderate**	**Severe**
VCW	< 0.3 cm	0.3 – 0.6 cm	> 0.6 cm
VCA	< 10 cm^2	0.10 – 0.29 cm^2	$\geq$ 0.30 cm^2
Circumferential	<10%	10-29%	$\geq$ 30%
Qualitative	**Mild**	**Moderate**	**Severe**
Prox. Flow Convergence	Absent	May be present	Often present

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Summary: Color Doppler

Scan entire Valve: Distal - Prox (Aortic - LVOT) to identify jet:

1. Width (VCW/VCA)
2. # of Jets / Circumferential extent of jet
3. Location (o'clock, ant/post) (Mechanism: supra-skirt / infra-skirt)
4. Direction (eccentric)

- Short-axis imaging below the valve may overestimate PVR severity in eccentric jets
- Attenuation hinders visualization of regurgitation
  - Anterior (TEE)
  - Posterior (TTE)

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Spectral Doppler (CW)/ PW)

Limitations
Desc. Aorta flow reversal

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Continuous Wave (CW)/ Pulse Wave (PW)

Native Valves:
- Pressure half-time
- Jet density (CW)
- Desc. Aortic Flow Reversal

TAVR:
These values have ***limited application – multiple jets***

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Pressure Half Time

PHT & LV Compliance

Jet Density

PVR: Pressure Half Time Limitations

- Multiple Jets
- LV Compliance affects PHT

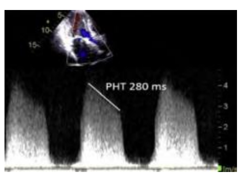
↑ Stiffness = ↓PHT (over-estimate)

Pressure half-time **in extremes** may be helpful

Pressure Half Time	
Mild	> 500 ms
Severe	< 200 ms

PVR: Jet Density

- Multiple PVR jets limits CW spectral density from a single jet
- Jet Density: Very dense waveform signals at least moderate AR



PVR: Desc. Aorta Flow Reversal

Exceptions

Severity

False Readings: Desc. Aorta Flow Reversal

1. NO Holodiastolic flow reversal … in the presence of SEVERE REGURG.
   - Severe bradycardia
2. Flow reversal….with NO regurgitation
   - HTN patients
   - Pre-TAVR assessment of descending aortic flow is essential

Desc. Aorta Flow Reversal

In the absence of baseline flow reversal:

- Severe PVR: End-diastolic flow $\geq$20 cm/s (Normal HR)

Flow reversal in the *abdominal aorta* *is a more specific indication of significant regurgitation*

TAVR: Desc. Aorta Flow Reversal

Diastolic Flow Reversal (PW)			
	Mild	**Moderate**	**Severe**
Desc. Aorta	Brief Early Diastolic	May be holodiastolic	Holodiastolic $\geq$ 20cm/s (end D)
Abdominal Aorta	Absent	Absent	Present

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Integrated Approach

Mild
Severe

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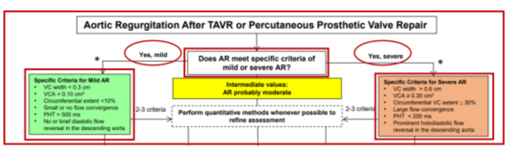
Integrated Approach



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Mild AR

Meet 4 or more Criteria: Definitively MILD

No Need To Perform Additional Quantification

MILD AR	
VCW	< 0.3 cm
VCA	< 0.10 cm^2
Circumferential Extent	< 10%
Flow Convergence	None / Small
PHT	> 500 ms
Desc. Aorta Flow Reversal	None / Brief

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Severe AR

Meet 4 or more Criteria: Definitively SEVERE

No Need To Perform Additional Quantification

SEVERE AR	
VCW	> 0.6 cm
VCA	$\geq$ 0.30 cm^2
Circumferential Extent	$\geq$ 30%
Flow Convergence	Large
PHT	< 200ms
Desc. Aorta Flow Reversal	Holodiastolic $\geq$ 20cm/s

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Did not meet $\geq$ 4??

Only met 2-3 criteria??

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Advanced Quantification

Rvol
RF
EROA

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PVR Color Severity: Quantitative

TAVR: Color Flow Severity of AR			
Quantitative	Mild	Moderate	Severe
RF	< 30%	30 – 49%	$\geq$ 50%
RVol	< 30 mL	30 – 59 mL	> 60 mL ↓ in low flow
EROA	< 0.10 cm_2	0.10 – 0.29 cm_2	$\geq$ 0.30 cm_2

TAVR population: CMR RF in PVR showed a reduced survival with a RF of 30%

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RVol = LV SV – Systemic SV

- Post TAVR patients have smaller RVol
  - LVH, Smaller LV cavity, Abnormal LV compliance
  - (explaining why even mild regurg. post TAVR impacts clinical outcomes)
- Native AR cut-off for severe (RVol of > 60 mL) seems inappropriate early after TAVR

RF = RVol / SV_{LVOT}

- More physiologically important parameter
- **Normalizes for ↓ SV**
- Cardiac MRI grading relies on RF: **Reduced survival with a RF of 30%**
- Echo RF : Moderate **30**-49%

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Regurgitant Volume (Rvol)

LV Stroke Volume
Systemic Stroke Volume

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Regurgitation Volume (Rvol)

RVol = LV SV – Systemic SV

LV Stroke Volume	Systemic Stroke Volume
LVOT Stroke Volume	MV Stroke Volume
Volumetric LV Stroke Volume	RVOT Stroke Volume

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LV Stroke Volume

LVOT Stroke Volume
Volumetric Stroke Volume

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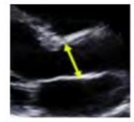
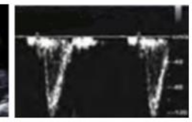
LVOT Stroke Volume

Method

LV Stroke Volume (SV_{LVOT})

- LVOT Diameter
- PW LVOT – same location

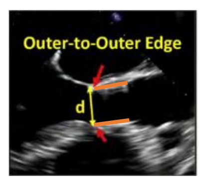



Challenges

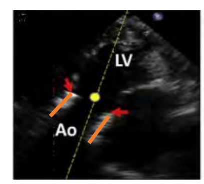
LVOT Measurement Challenges:
- Valve protrudes into the LVOT (unlike sutured surgical valve)
- Match PW LVOT sample with **LVOT diameter of valve**

LVOT Diameter: Preferred Method

Outer-to-outer border of the valve
Ventricular tip



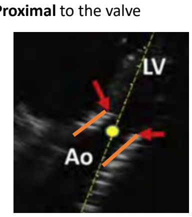
PW sample: **Apical to the valve**



LVOT Diameter: Deep Valve Placement

- **In-stent diameter,** mid-stent, level of leaflets
- **Inner-to-inner**

PW sample volume **IN STENT**
Proximal to the valve



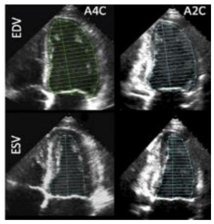
Volumetric Stroke Volume

Method

LV Stroke Volume: Volumetric Method

Bi-Plane LV Volumes

- End Diastole & End Systole
- 4 Chamber & 2 Chamber
- Use contrast if needed



Systemic Stroke Volume

MV Stroke Volume

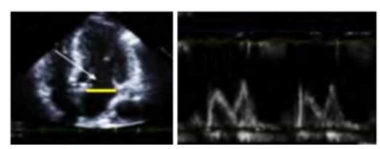
RVOT Stroke Volume

MV Stroke Volume

Method

MV Stroke Volume

- MV Annulus Diameter
- PW MV – same location

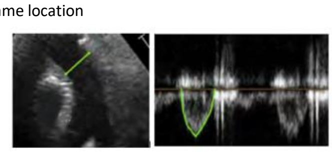


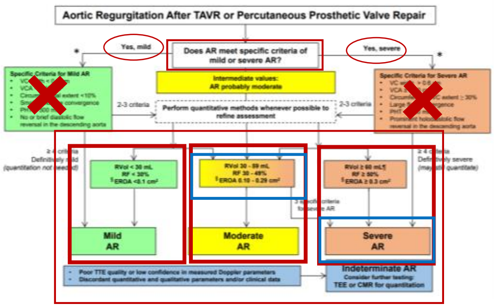
RVOT Stroke Volume

Method

RVOT Stroke Volume

- RVOT Annulus Diameter
- PW PV – same location





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Contradicting Data

- Advanced quantification required if do NOT meet $\geq$ 4 criteria
- If assessment is difficult and indeterminate or provides contradicting data:
  - Look carefully for technical and physiologic reasons to explain these discrepancies
  - Rely on the components that have the best quality / most accurate considering the underlying clinical condition

Further testing with either TEE or CMR:

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Summary

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Integration of Multiple Parameters

PVR after TAVR should be a comprehensive and integrative process
- More challenging compared to native AR
- Color flow Doppler – Most essential modality

Scan entire Valve: Distal - Prox (Aortic - LVOT) to identify jet:
1. Width (VCW/VCA)
2. # of Jets / Circumferential extent of jet
3. Location (o'clock, ant/post) (Mechanism: supra-skirt / infra-skirt)
4. Direction (eccentric)

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Color Doppler – Key Points

- Short-axis imaging below the valve may overestimate AR severity in eccentric jets
- Attenuation hinders visualization of regurgitation
  - Anterior (TEE)
  - Posterior (TTE)
- Valvular regurgitation severity classification:
  - Mild, moderate, severe

If the AR is definitely determined as mild or severe, no further quantification is required

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Thank you

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Hand out available at:

www.cardioserv.net/MCSS

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