Role of CMR in Valvular Regurgitation, Multivalvular Disease: When Is It Indicated?

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Disclosure: No relevant disclosures

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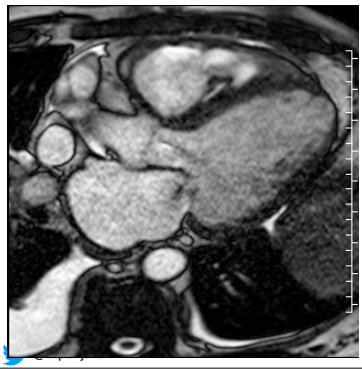
77 y.o. male with HTN, HLD, COPD, AF on Eliquis with severe MR and chronic heart failure presents to clinic for MitraClip evaluation



AORTIC VALVE: SEVERE aortic regurgitation:
- Aortic regurgitant volume 70 ml
- Aortic regurgitant fraction 55%

MITRAL VALVE: SEVERE mitral regurgitation:
- Mitral regurgitant volume 65 ml
- Mitral regurgitant fraction 53%

Volumetric Analysis

		LV (Reference)		RV (Reference)	
EDV	[ml]	383	(113-181)	372	(101-191)
ESV	[ml]	191	(25-68)	312	(16-72)
CO	[L/min]	9.98	(--)	3.12	(--)
MASS	[g]	214	(109-174)		(--)
SV	[ml]	192	(76-123)	60	(70-135)
EF	[%]	50	(59-77)	16	(57-83)

OUTLINE:

- CMR approach to isolated valve regurgitation and stenosis
  - Severity of lesion
  - Consequences of lesion
- Effect of Multiple Valve Lesions:
  - Pathophysiologic Effects
  - Imaging caveats/pitfalls
- Approach to mixed regurgitant lesion
- Approach to mixed regurgitant and stenotic lesions

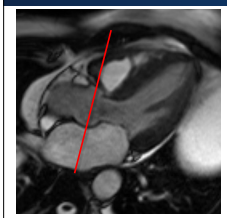
Mini-Recap:

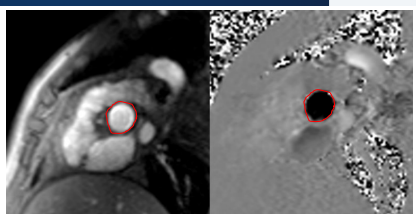
How do we approach isolated valve regurgitant or stenotic lesions by CMR ?

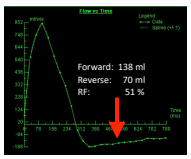
Quantitative Methods

Semi-Quantitative Methods

AORTIC REGURGITATION:

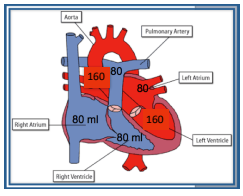






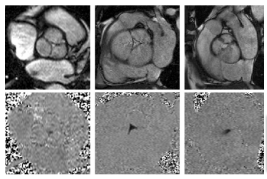
Quantification of AR Severity

Aortic Regurgitant Volume =
1. Direct measurement of regurgitant flow
2. Indirect methods:
   - LVOT FF - Pulmonic Net
   - LVSV - RVSV



Regurgitant Fraction (%) = $\frac{\text{AI Regurg Volume}}{\text{AV Flow}}$

Anatomic Regurgitant Orifice Area

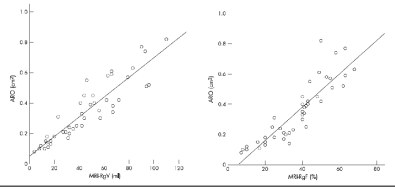


- Debl et al, Heart 2008

Table 3 MRI-planimetry of ARO, predictive values

	Cases/total (n)	ARO-cutoff (cm^2)	ROC-area (95% CI)	Sensitivity/ specificity (%)
MRI-AR ≥III	26/45	0.28	0.99 (0.99 to 1.0)	96/95
CATH-AR ≥III	21/32	0.28	0.95 (0.85 to 1.0)	90/91

ARO > 0.28 had more than 90% sensitivity/ specificity for 3+ Aortic Regurgitation



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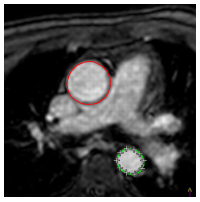
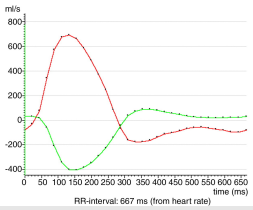
Flow Reversal Descending Aorta

80 pts





TTE Grade	Sensitivity (%)	Specificity (%)	Odds Ratio	*P* Value
4	100	93	164 (8)	<.001
3 or 4	61	100	192 (10)	<.001

Holodiastolic Flow Reversal: defined as flow reversal with a minimum flow of 10 mL/sec that persists through the entirety of diastole.

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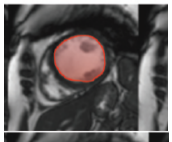
- Bolen et al, Radiology 2011

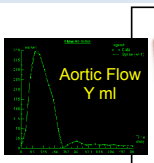
Quantification of Mitral Regurgitation Severity:

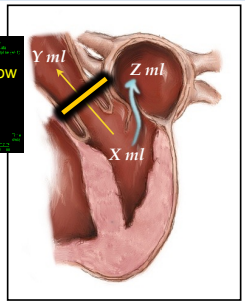
End-Diastole



End-Systole

Mitral Reg Vol = LV stroke volume – Aortic forward volume
Z = X - Y





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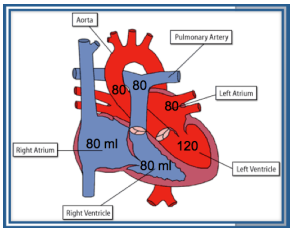
Quantification of MR Severity

- **Mitral Regurgitant Volume** =
  1) LVSV – Aortic FF
     - Applies even in presence of AI
     - more practical and reproducible than the other methods
  2) LVSV – Net Pulmonary SV
     - AoSV is within 5% of PA SV (in absence of intra-cardiac shunt)
     - Useful in patients with AS, where asc aortic flow may have aliasing
  3) LVSV – RVSV
     - RVSV less reproducible due to extensive trabeculation of RV
     - Significant concomitant regurgitant lesions invalidates use
     - Useful in setting of atrial fibrillation.
- **Regurg Fraction (%)** = MR Rvol / LVSV*

* in absence of concomitant left sided valve lesions



Quantitative Definitions of Severity of Mitral Regurgitation

Degree of Regurgitation	Regurgitant Volume (mL/beat)	Regurgitant Fraction
Mild	<30	<30
Moderate	30–59	30–49
Severe	>60	>50

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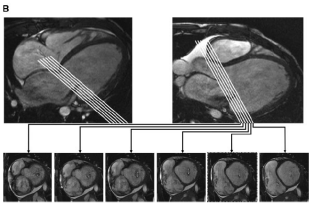
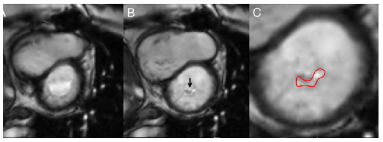
Direct Planimetry of the AROA Using CMR



En face view of the regurgitant orifice



CMR-AROA>0.40cm2 had a 94% sensitivity and specificity for identification of Sellers angiographic grade 3 or 4 MR

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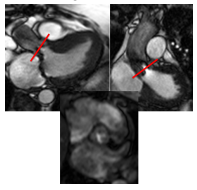
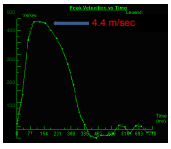
Buchner Circ Cardiovasc Imaging 2008;1;148-155;

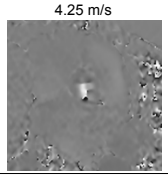
Aortic Stenosis: Velocity/Gradients

Magnitude

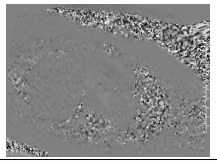




4.25 m/s



4.50 m/s



- Peak and Mean Velocity
- Continuity Equation can be used to derive EOA

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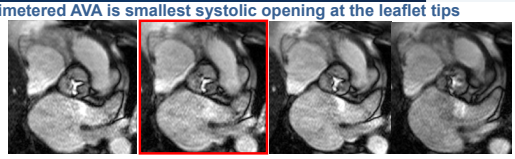
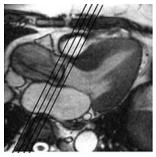
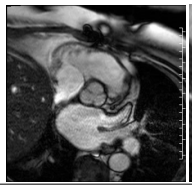
Aortic Stenosis: Anatomic Orifice Area

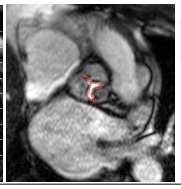
Planimetered AVA is smallest systolic opening at the leaflet tips



Thin (≤4mm) overlapping slices







AVA
0.8 cm sq.

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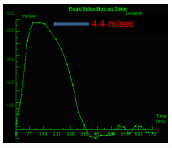

CMR IS ABLE TO PROVIDE 2 INDEPENDENT MEASURES OF AS SEVERITY:

1. VELOCITY
2. ANATOMIC ORIFICE AREA

Suggestive of severe AS

V_{max} = 4.5 m/sec
Peak Gradient = 81 mm HG

AVA 0.7 cm sq

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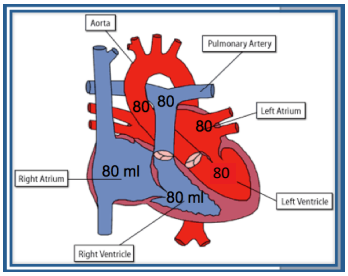
HOW TO APPROACH MULTIVALVULAR DISEASE:

Solve for Flow in All Chambers:



PRINCIPLE #1: IN ABSENCE OF REGURGITATION: LVSV = RVSV = AO = PA

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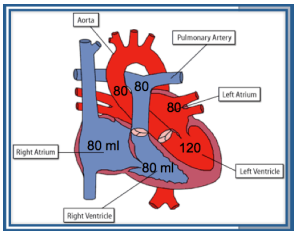
HOW TO APPROACH MULTIVALVULAR DISEASE:

PRINCIPLE #2:

1. LVOT/AOFF = Systemic Flow + AR
2. RVOT/PAFF = Systemic Flow +PR
3. LVSV = Systemic Flow + AR + MR
4. RVSV = Systemic Flow +PR + TR



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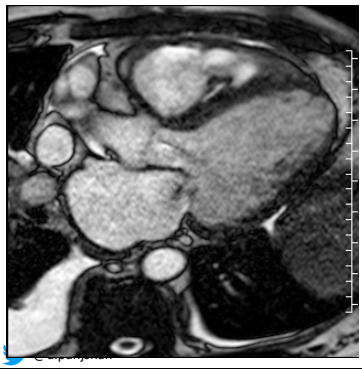

AORTIC VALVE: SEVERE aortic regurgitation:
- Aortic regurgitant volume 70 ml
- Aortic regurgitant fraction 55%

MITRAL VALVE: SEVERE mitral regurgitation:
- Mitral regurgitant volume 65 ml
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Volumetric Analysis

		LV (Reference)		RV (Reference)	
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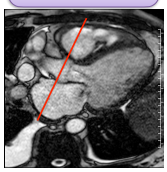
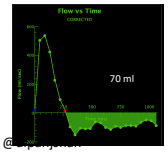
Direct Reverse AR

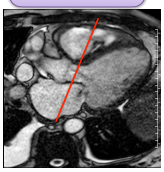


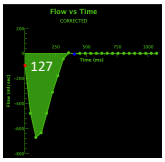


ARVol = 70 ml

ARF = ARVol/LVOT FF
ARF = 70 / 127 = 55%

LVOT FF





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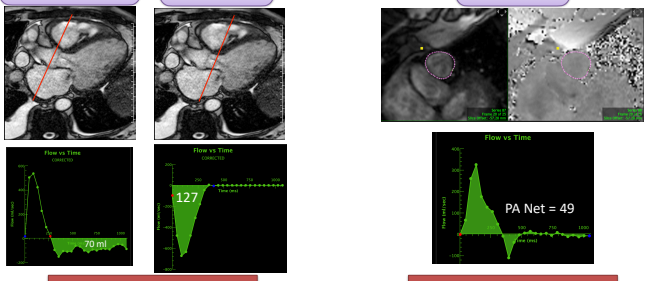
Direct Reverse AR | LVOT FF | PA Flow



ARVol = 70 ml
ARF = ARVol/LVOT FF
ARF = 70 / 127 = 55%

ARVol = LVOT FF - PA Net Flow
ARVol = 127 - 49 =78 ml

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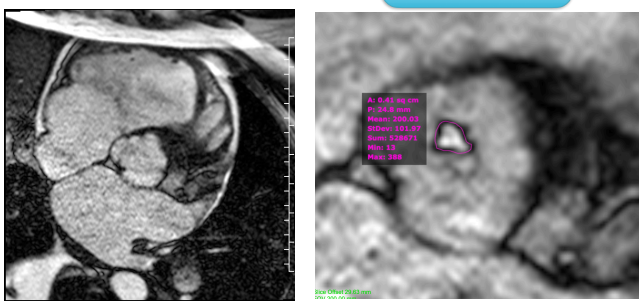
ARO = 0.41



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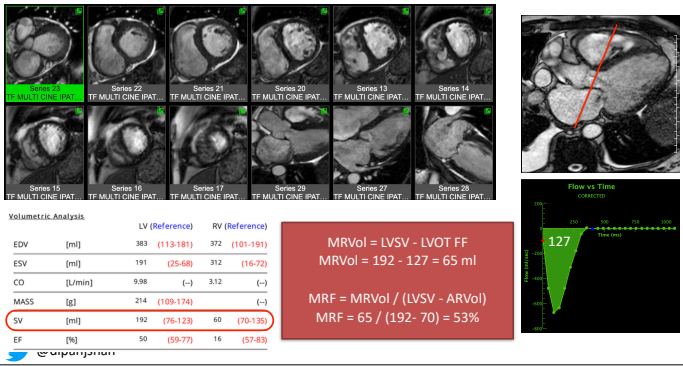

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MRVol = LVSV - LVOT FF
MRVol = 192 - 127 = 65 ml

MRF = MRVol / (LVSV - ARVol)
MRF = 65 / (192- 70) = 53%

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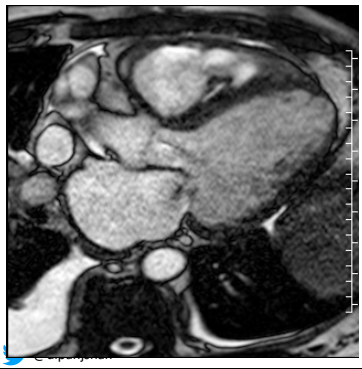
METHOD OF CALCULATING REGURGITANT FRACTION IN MIXED VALVE LESIONS:



AORTIC VALVE: SEVERE aortic regurgitation:
- Aortic regurgitant volume 70 ml
- Aortic regurgitant fraction 70/192 = 36%

MITRAL VALVE: SEVERE mitral regurgitation:
- Mitral regurgitant volume 65 ml
- Mitral regurgitant fraction 65/192 = 34%

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For Mixed MR/AR:

1. ARVol = Standard Method (direct reverse)
2. ARF = Standard Method (ARVol / LVOT FF)
3. MRVol = Standard Method (LVSV - LVOT FF)
4. MRF = MRVol / (LVSV - ARVol)

- Coexisting right sided lesions have no impact on these measures
- Calculate coexisting right sided TR/PR in same method as used for the left sided valves
- In setting of Afib (direct AO reverse may not be reliable). ARVol = LVOT FF - PA Net Flow

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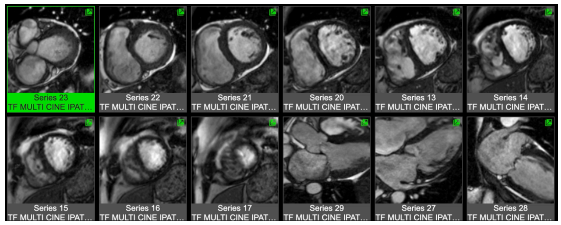
What if phase contrast not reliable at all ?



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LV Regurgitant Load = LVSV - RVSV

AR + MR = 192-60 = 132

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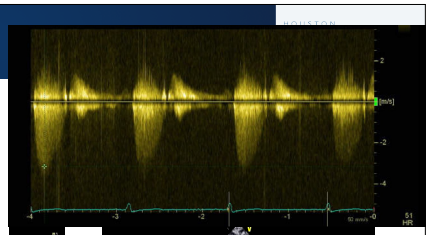
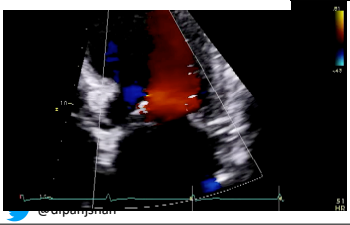
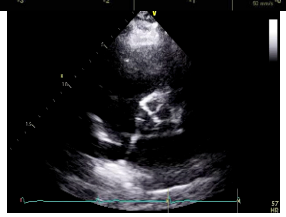
Another Case:







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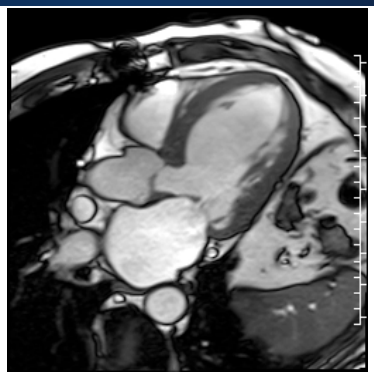
Mixed AS and MR:



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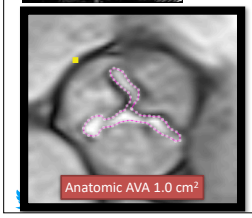
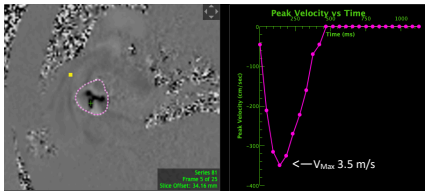
Mixed AS and MR:

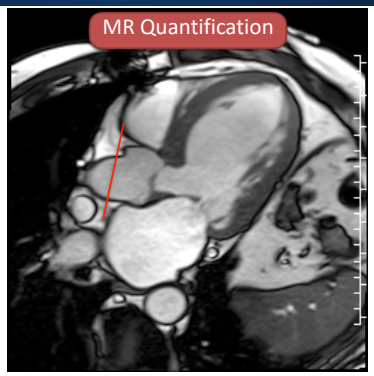
Trileaflet Aortic Valve
Moderate-Severe Aortic Stenosis
Anatomic AVA 1.0 cm²
Vmax 3.5 m/sec





Mixed AS and MR:

MR Quantification



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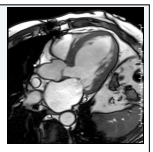
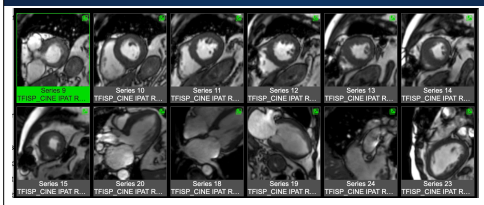
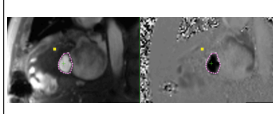
Mixed AS and MR:

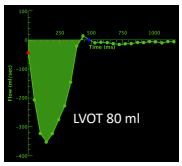




Volumetric Analysis

EDV	[ml]	169
ESV	[ml]	69
CO	[L/min]	4.90
MASS	[g]	162
SV	[ml]	100
EF	[%]	59





MRVol = LVSV - LVOT Fow
MR Vol = 100 - 80 = 20 ml

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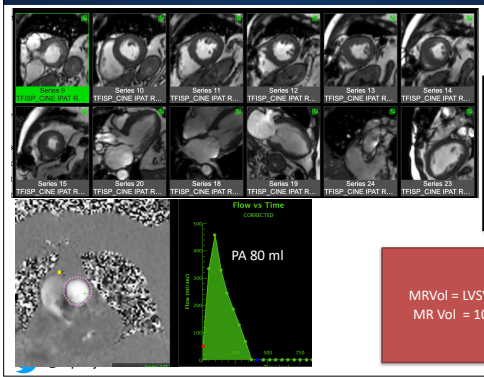
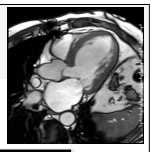
Mixed AS and MR:





		LV
EDV	[ml]	169
ESV	[ml]	69
CO	[L/min]	4.90
MASS	[g]	162
SV	[ml]	100
EF	[%]	59

MRVol = LVSV - Net PA Flow
MR Vol = 100 - 80 = 20 ml

Mixed AS and MR:

For Mixed AS/MR:

1. MRVol = LVSV - LVOT FF (or PA Net Flow)
2. MRF = Standard Method (MRVol / LVSV)
3. AS Velocity = Standard Method
4. AS AVA = Standard Method

- Increased transmittal pressure:
  - Mitral RVol increases in proportion to the square root of the rise in LV pressure
  - Jet area, increase is proportional to regurgitant orifice area and beyond the increase in MR Vol
- Decreased aortic forward flow: Lower AS velocity/gradient

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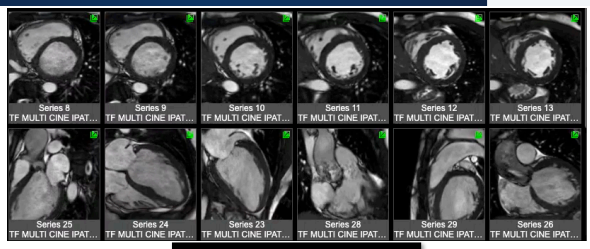
One More Case:



		LV (Reference)	RV (Reference)
EDV	[ml]	312 (111-172)	202 (108-188)
ESV	[ml]	204 (30-66)	139 (28-78)
CO	[L/min]	10.48 (--)	6.11 (--)
MASS	[g]	189 (101-158)	(--)
SV	[ml]	108 (73-115)	63 (68-124)
EF	[%]	35 (58-75)	31 (52-77)

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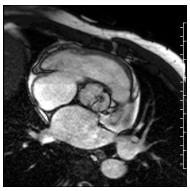
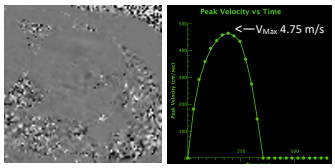
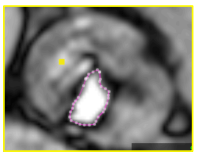
Mixed AS and AR:







Anatomic AVA 1.0 cm2
Peak velocity 4.75 m/sec

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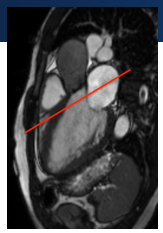
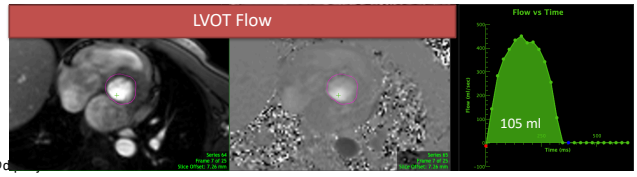
Mixed AS and AR:



AR Vol = LVOT FF (105) - PA net Flow (52) = 53 ml
ARF = AR (53) / LVOT FF (105) = 50%

LVOT Flow

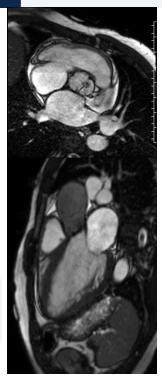


Mixed AS and AR:

For Mixed AS/AR:

1. AR Vol = LVOT FF - PA Net Flow
2. ARF = Standard Method (ARVol / LVOT FF)
3. AV Velocity/Gradient = Standard Method
4. Anatomic Valve Area = Standard Method

Aortic Velocity/Gradient are flow dependent



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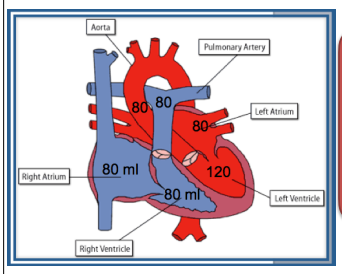
Conclusion:



Approach to Mixed Valve Disease:

1. Quantify flow in all chambers/great vessels
2. Systematically work through the equations

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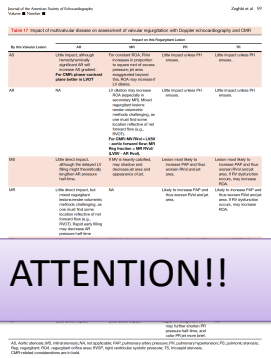
Conclusion:



THANK YOU FOR YOUR ATTENTION!!

@di