

# Measurement of $Q_p:Q_s$ in the setting of congenital heart disease

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# How is $Q_p$ best determined following bidirectional Glenn in the setting of single ventricle?

- A. Phase contrast acquisition through the main pulmonary artery
- B. Phase contrast acquisitions through the branch pulmonary arteries
- C.  $Q_p$  cannot be determined in this clinical setting
- D. Phase contrast acquisitions through the pulmonary veins
- E. Phase contrast acquisition of the superior vena cava.

# Traditional Methods of Measuring Qp:Qs

Qp = Pulmonary flow

Qs = Systemic flow

Qp:Qs describes the magnitude of a cardiovascular shunt

Normally = 1:1

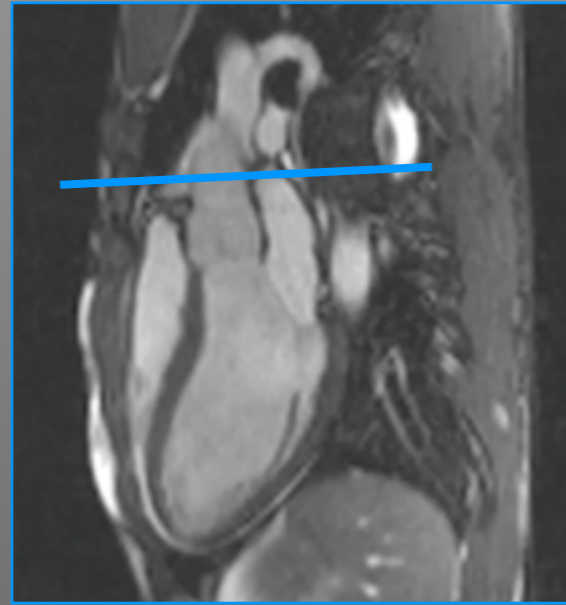
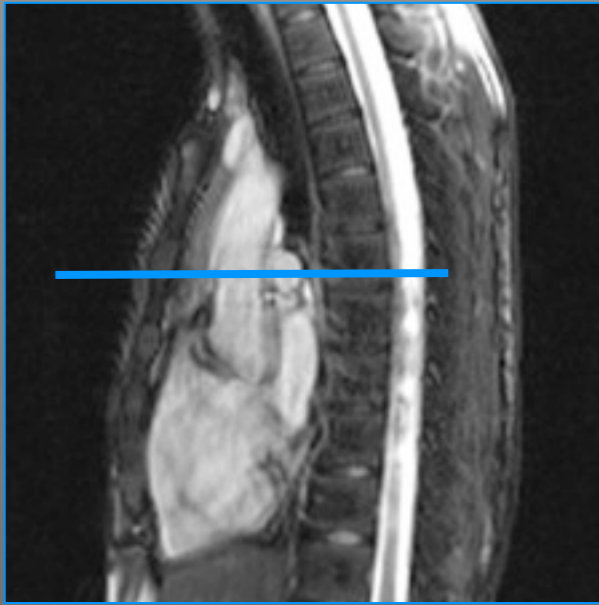
Left to right shunts >1.0

Right to left shunts <1.0

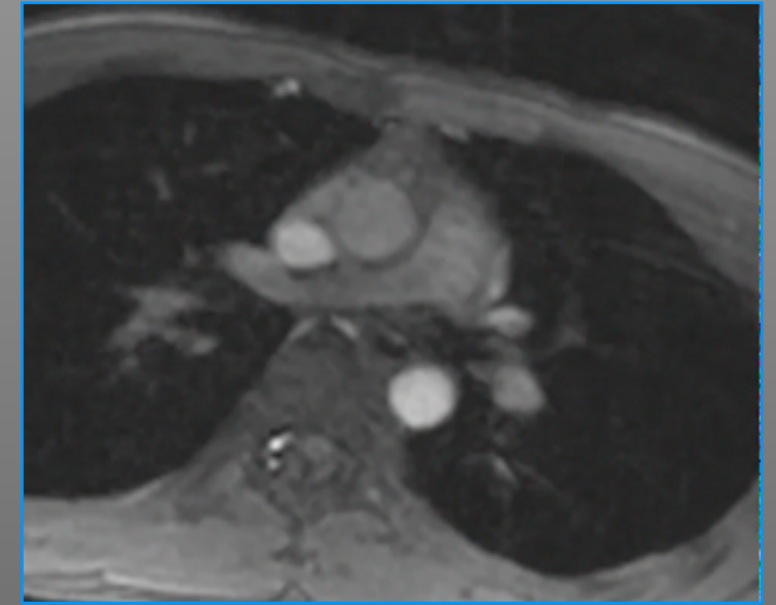
Qp:Qs is classically determined with oximetry via cardiac catheterization

- Fick Principle
- $VO_2 = (CaO_2 - CvO_2) * Q$
- $Qp:Qs = (Sat_{Aorta} - Sat_{SVC}) / (Sat_{Pulmonary\ Venous} - Sat_{Pulmonary\ Artery})$

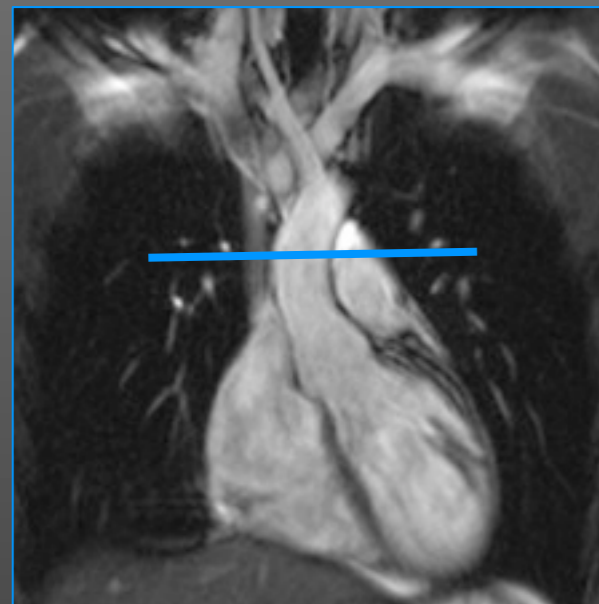
# $Q_s$ = Systemic Flow



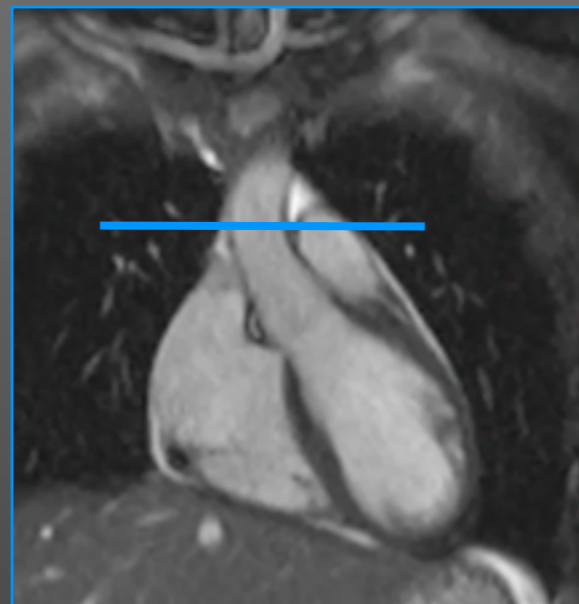
3 Chamber



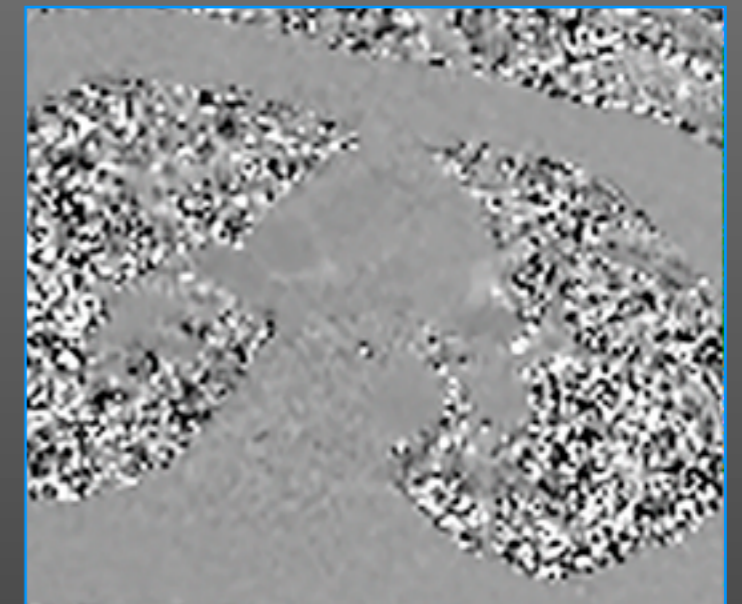
Magnitude



Localizers

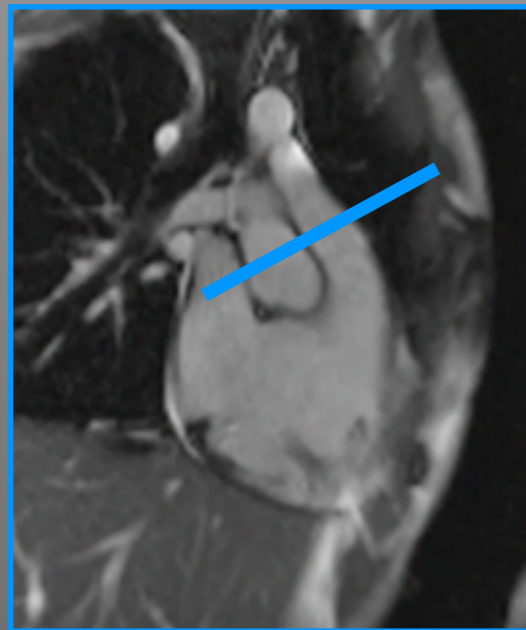
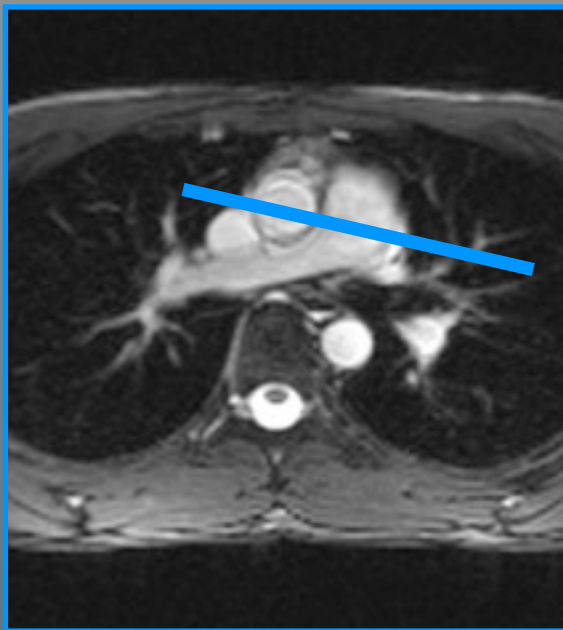


LVOT

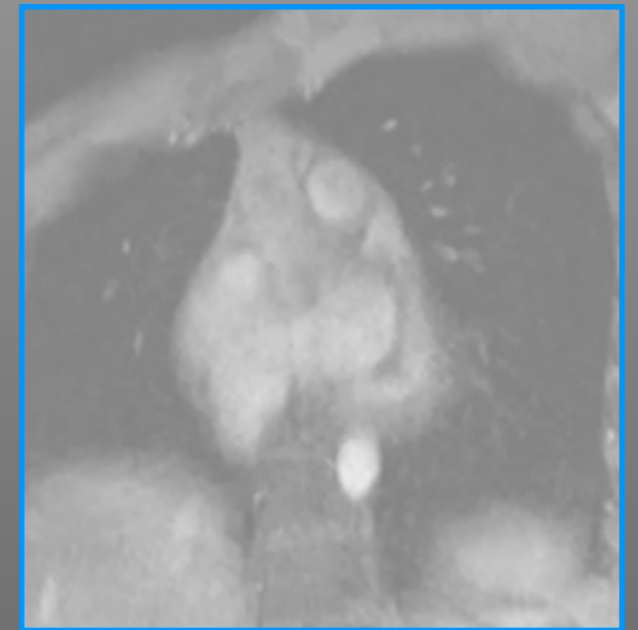


Phase

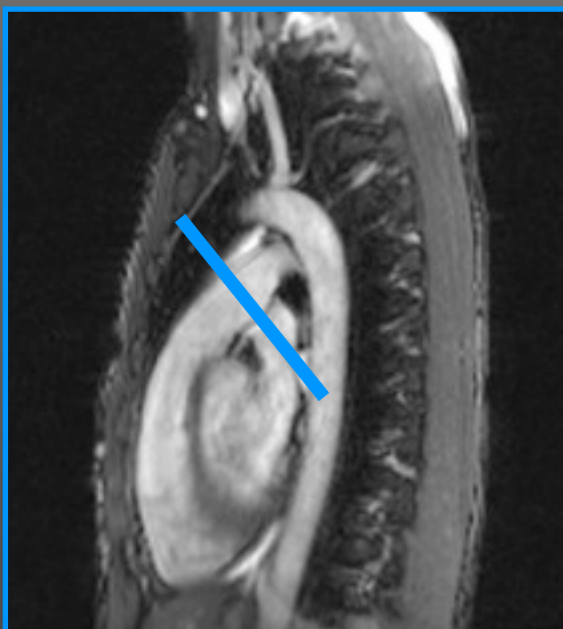
# $Q_p$ = Pulmonary Flow



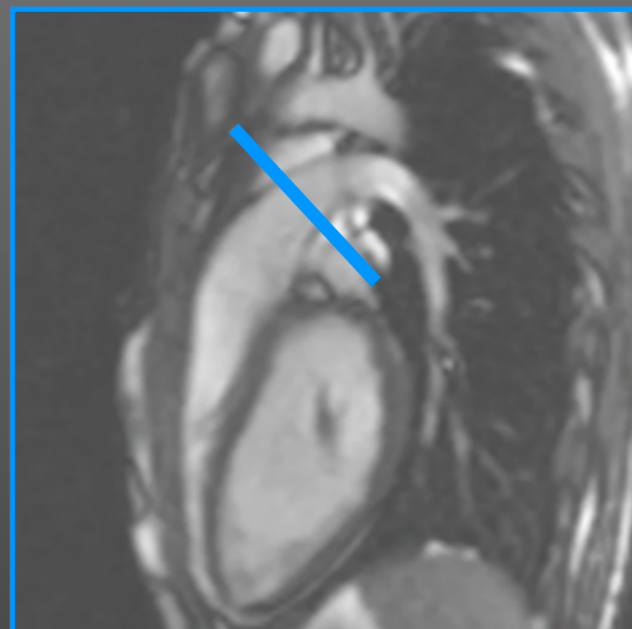
RVLA



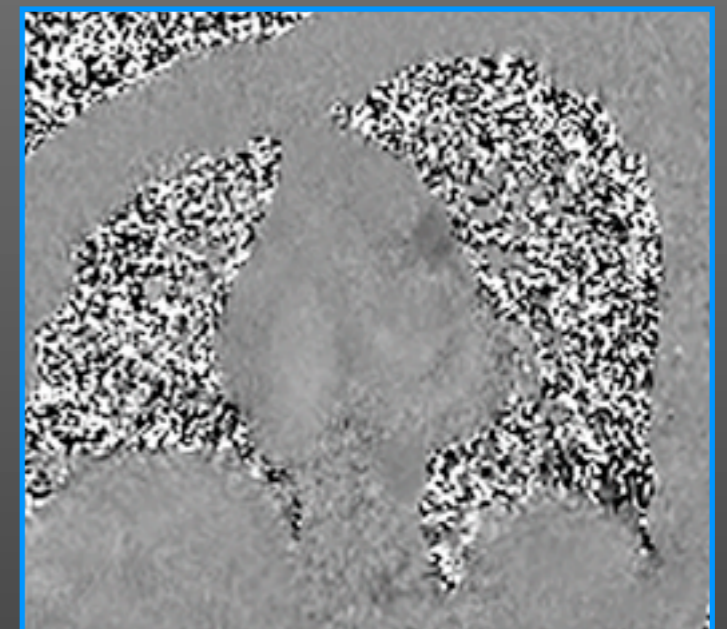
Magnitude



Localizers

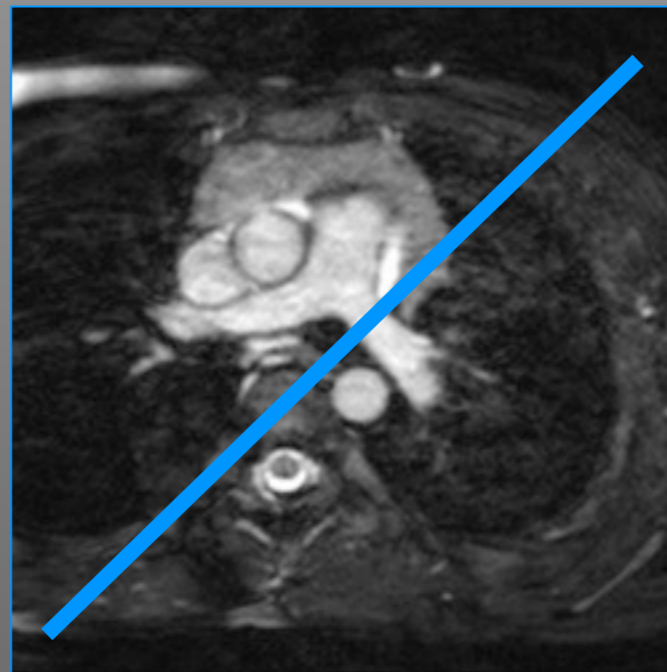
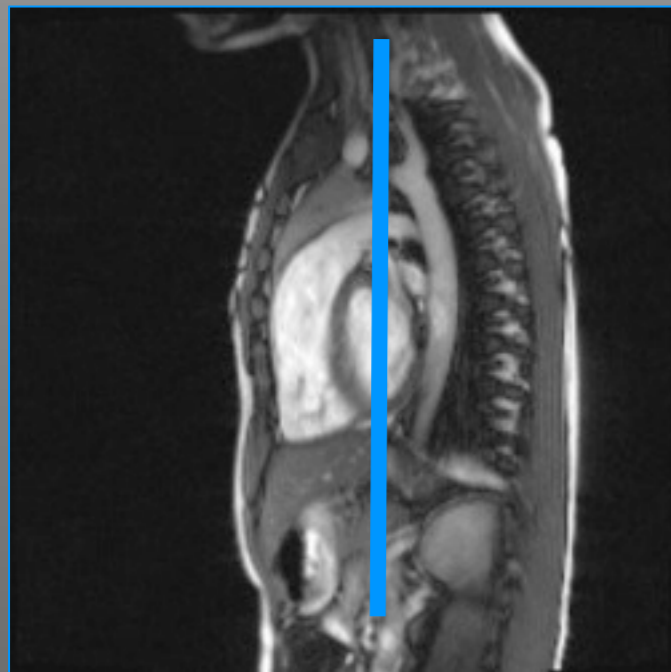


RVOT

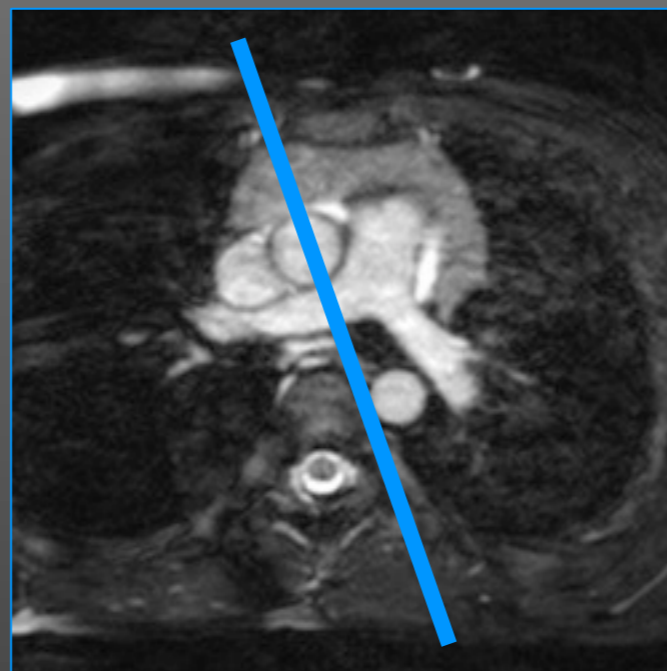
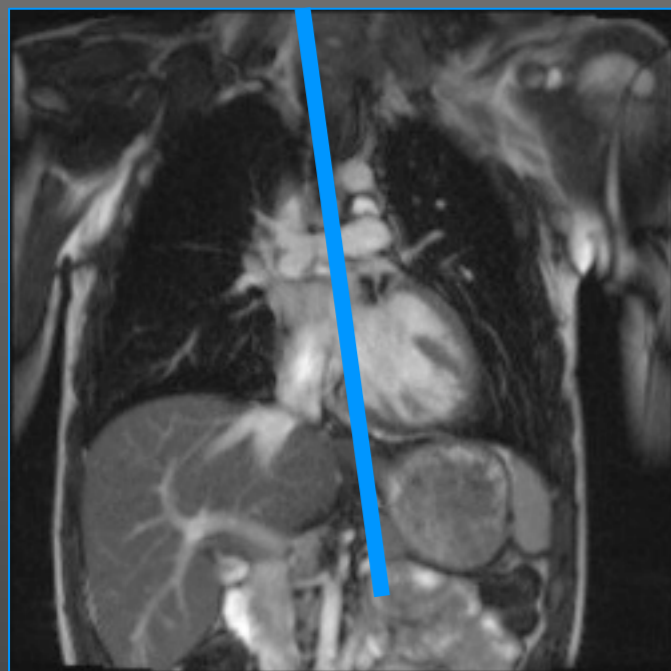


Phase

# Qp = Branch Pulmonary Arteries



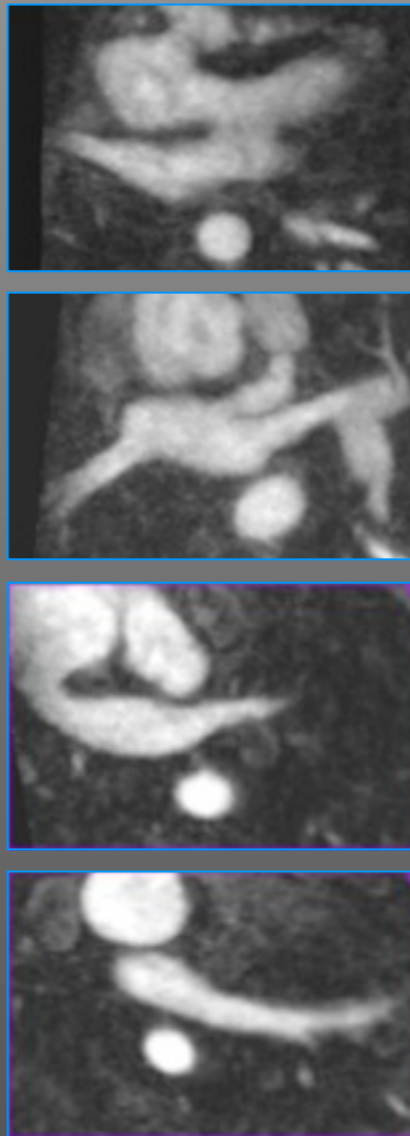
→  
Left



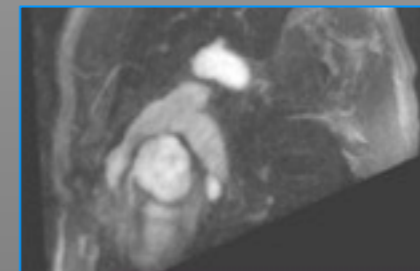
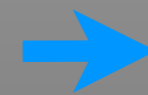
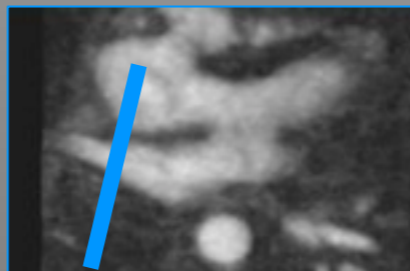
→  
Right



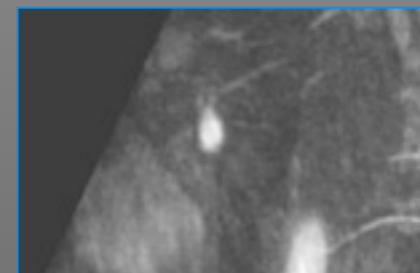
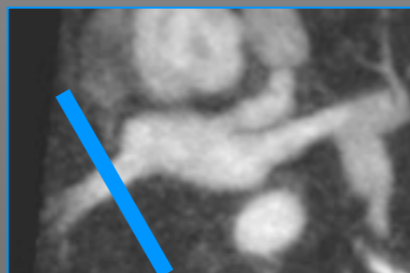
# Qp = Pulmonary Veins



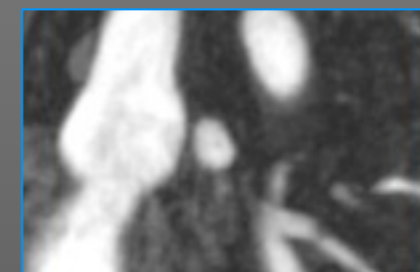
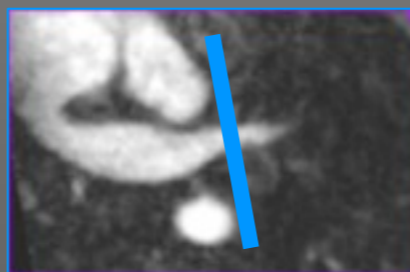
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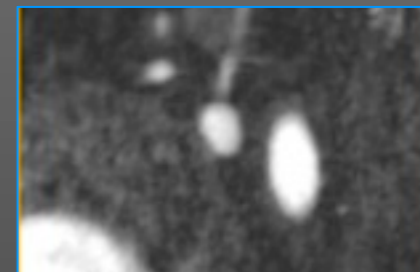
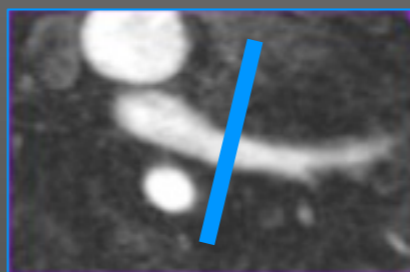
RUPV



RLPV



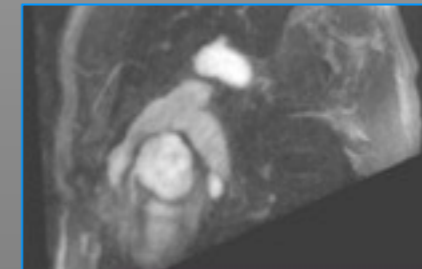
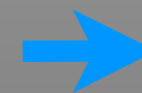
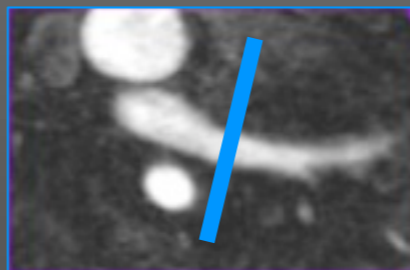
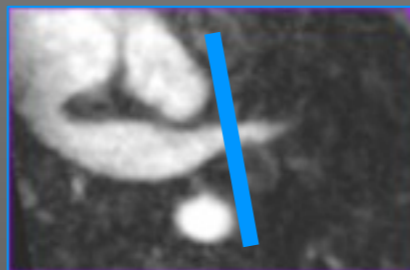
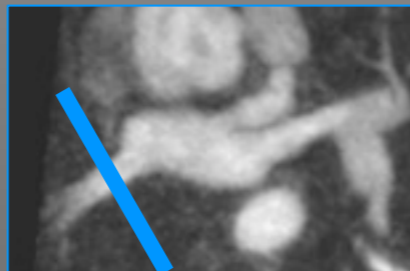
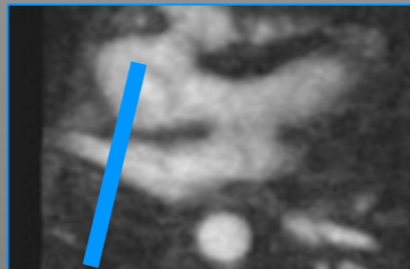
LUPV



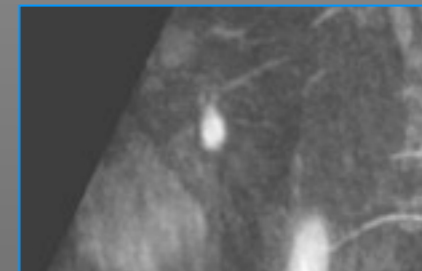
LLPV



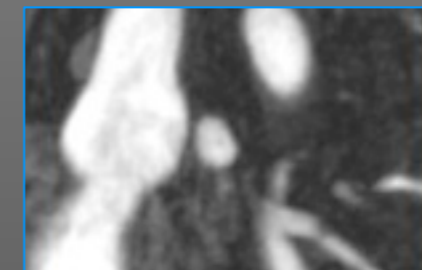
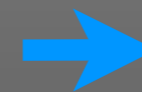
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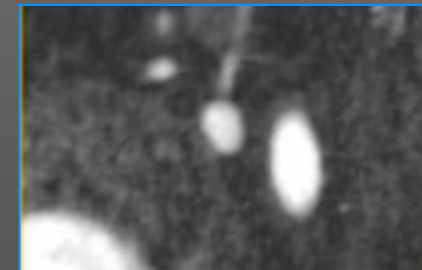
RUPV



RLPV



LUPV



LLPV

Helpful in situations with -

- Slow or turbulent pulmonary arterial flow - Glenn or Fontan shunts
- Aorticopulmonary collaterals
- PAPVR

# Phase Contrast Slice Prescription Tips

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Reference images -

- Cine *versus* static images
- Most recent sequences *versus* localizers

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Vessel of interest near  $B_0$  isocenter for optimal flow measurements

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Desired spatial resolution - watch voxel size relative to vessel

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Desired temporal resolution

- Lines of k-space collected per cardiac cycle
- $T_{\text{resolution}} = 2 * T_R * VPS$

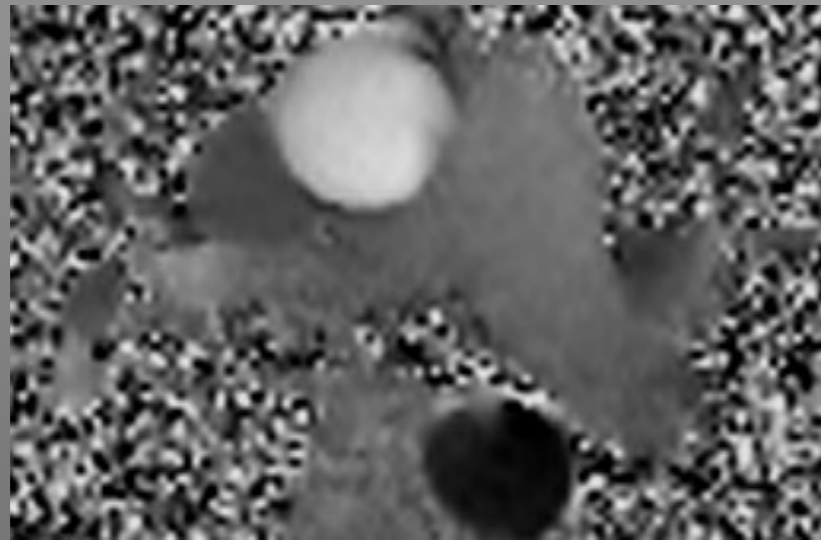


# Phase Contrast Post Processing Tips

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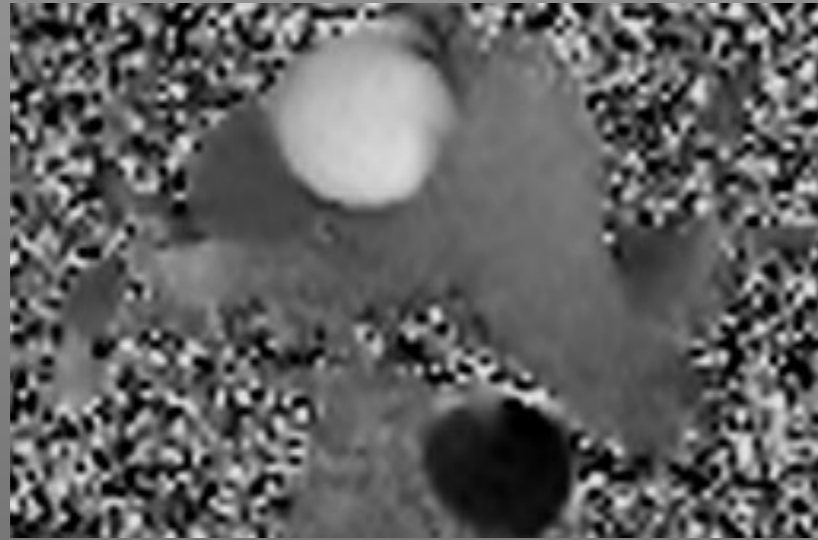
- VENC correction
- Manual *versus* automated ROI contouring
- Draw on magnitude, but check phase images
- Slightly generous contours
  - *versus* too small
    - Underestimates flow
  - *versus* too large
    - Avoid other vessels, lung, and paramagnetic artifacts

# Flow Quantification VENC Optimization

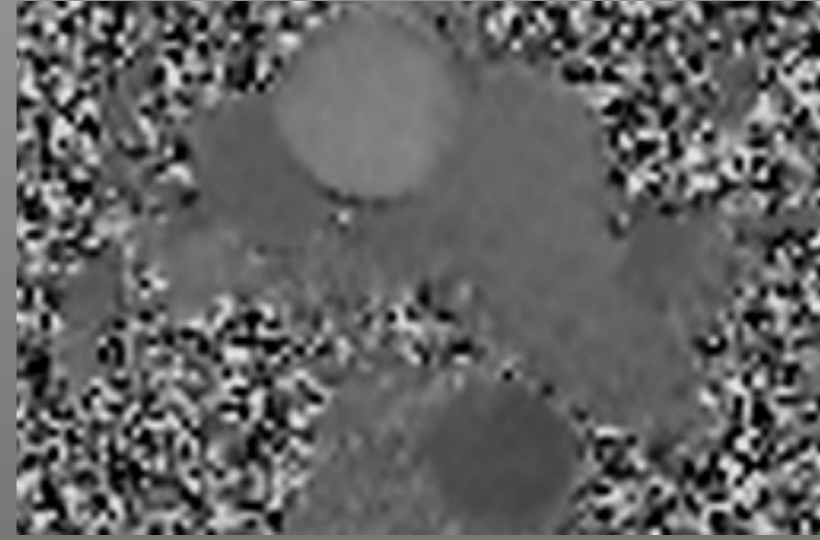


**VENC optimal**  
max black/white & no aliasing

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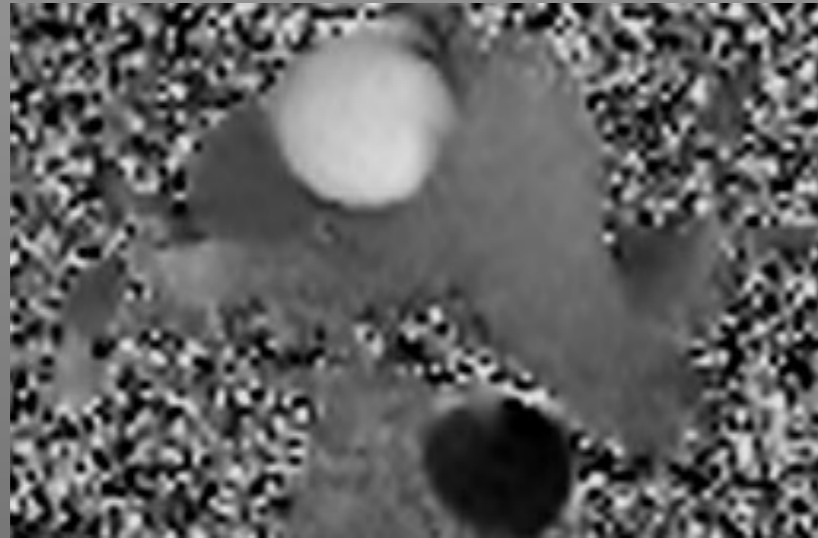


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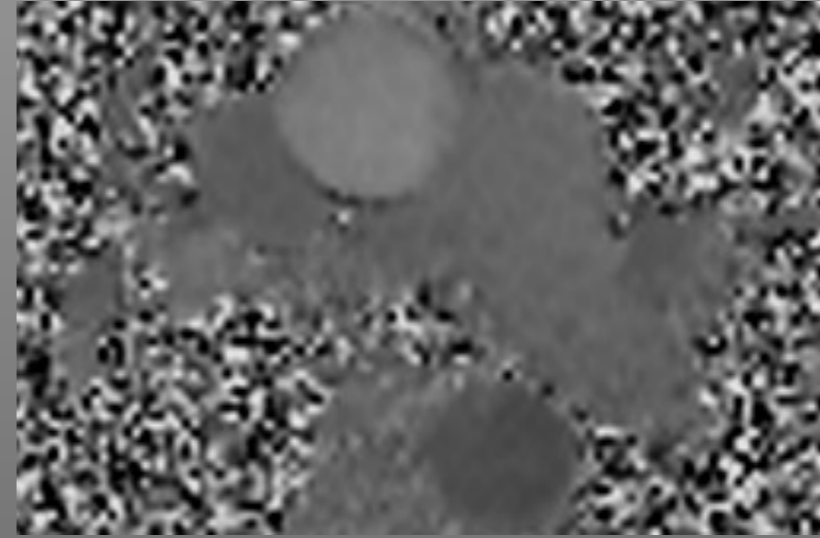


**VENC much too high**  
washed-out black/white

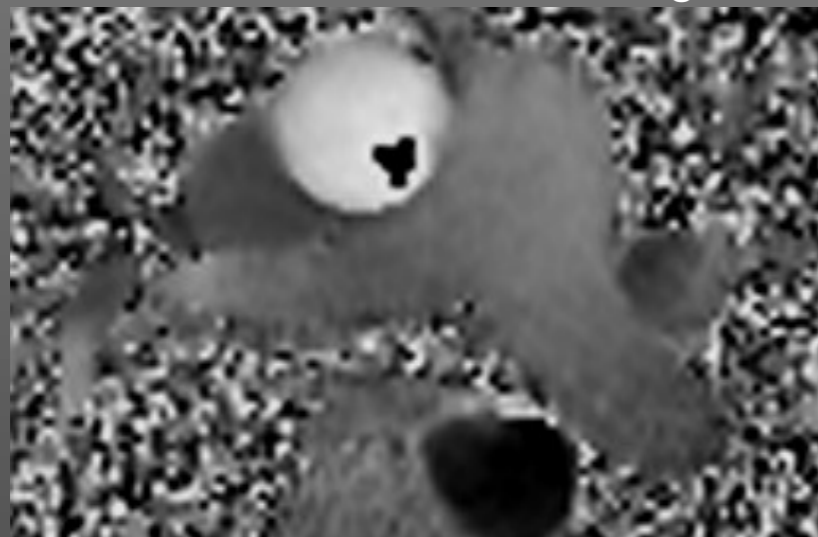
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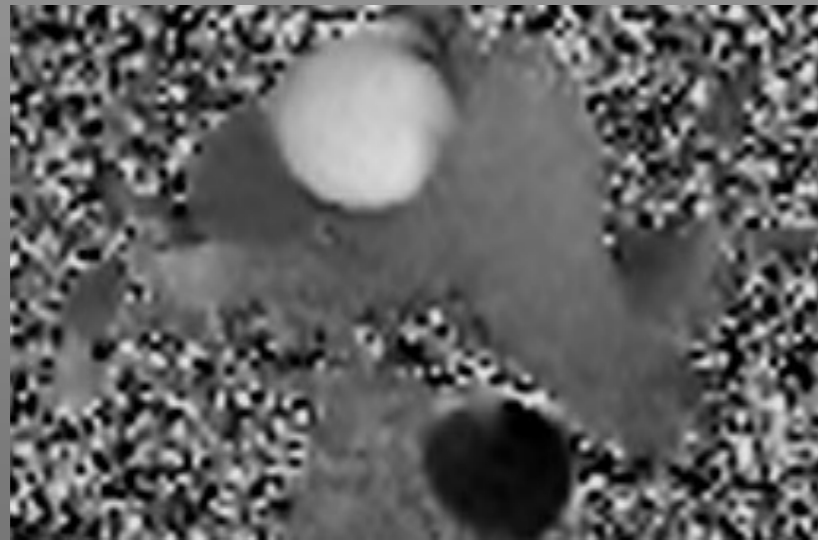


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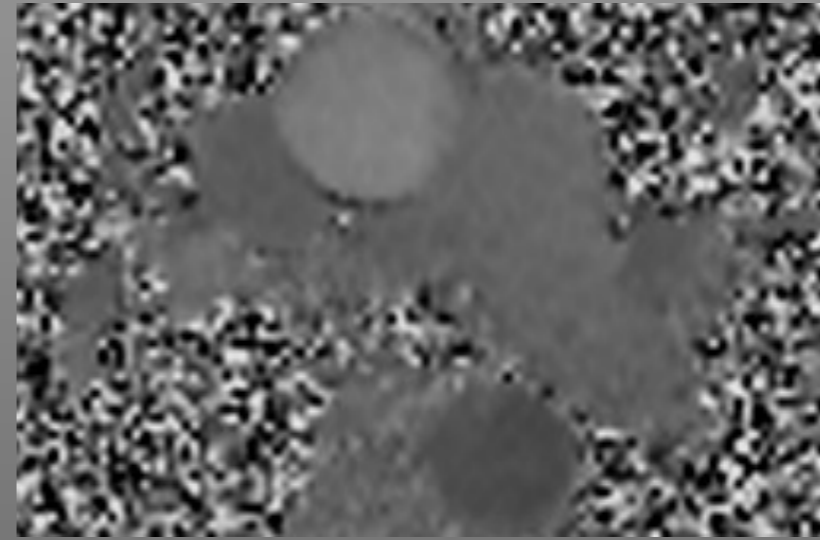


**VENC slightly low**  
slight aliasing

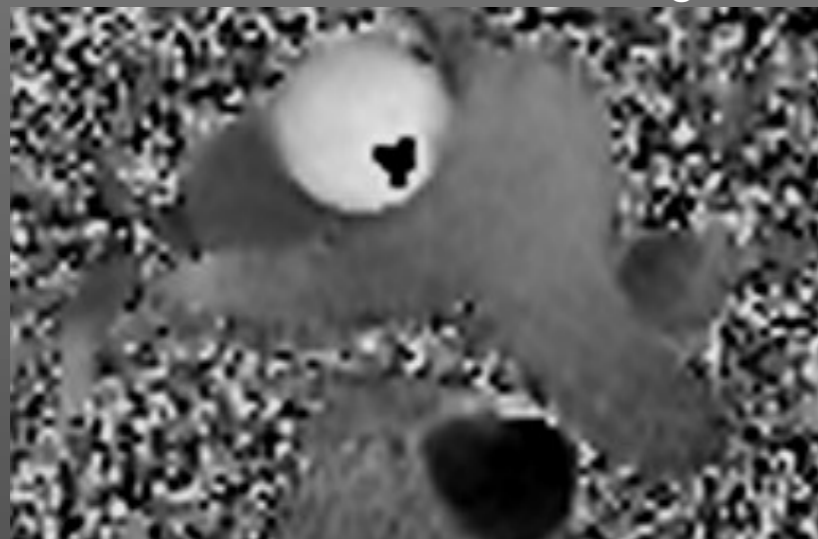
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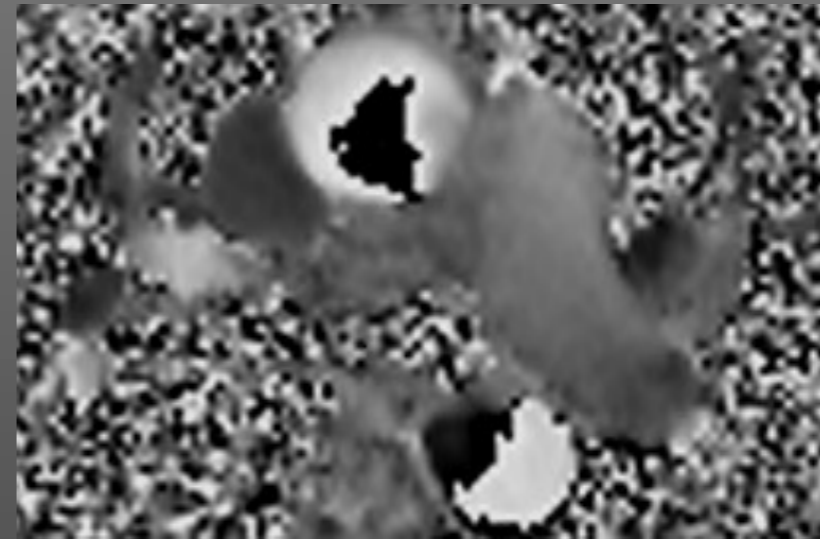
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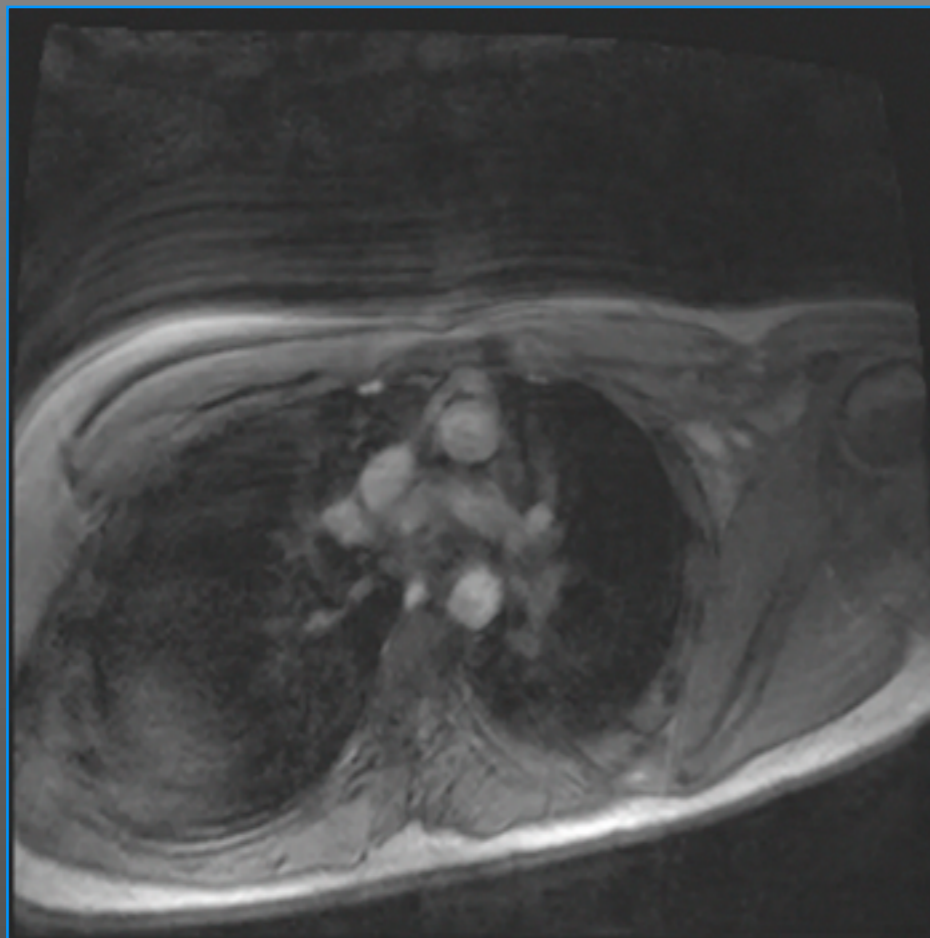
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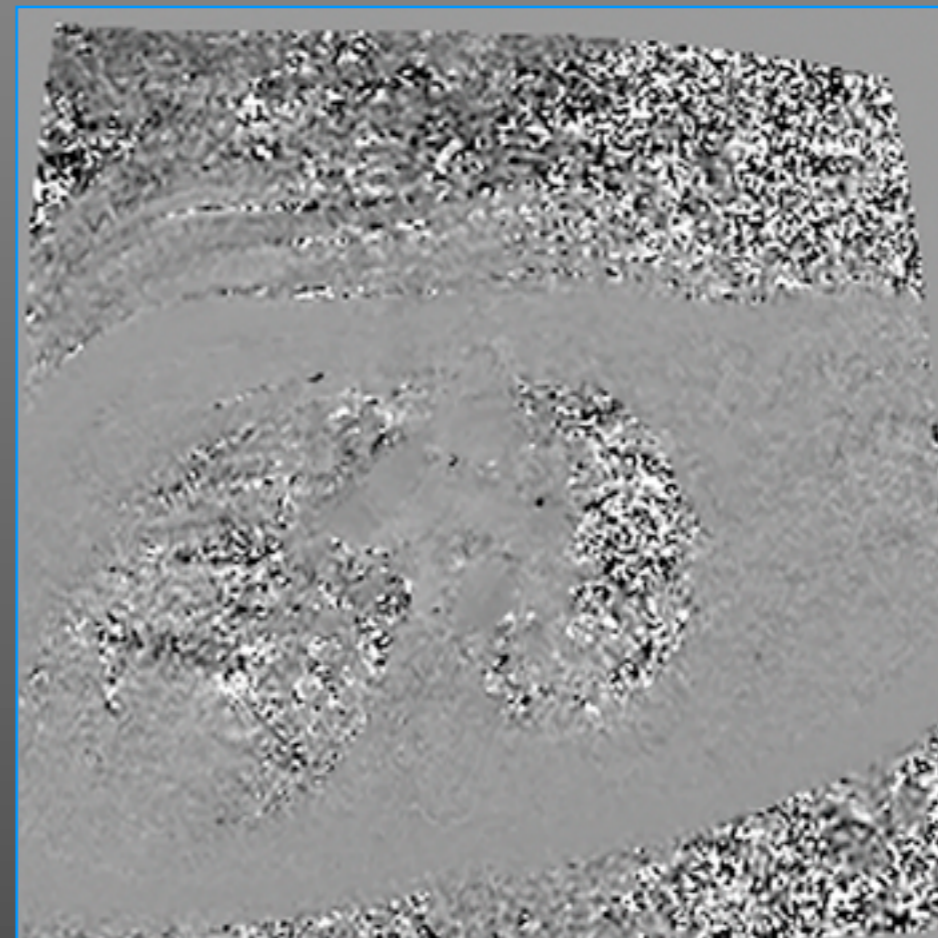
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marked aliasing

# Limitations with Phase Contrast Acquisitions

## Motion



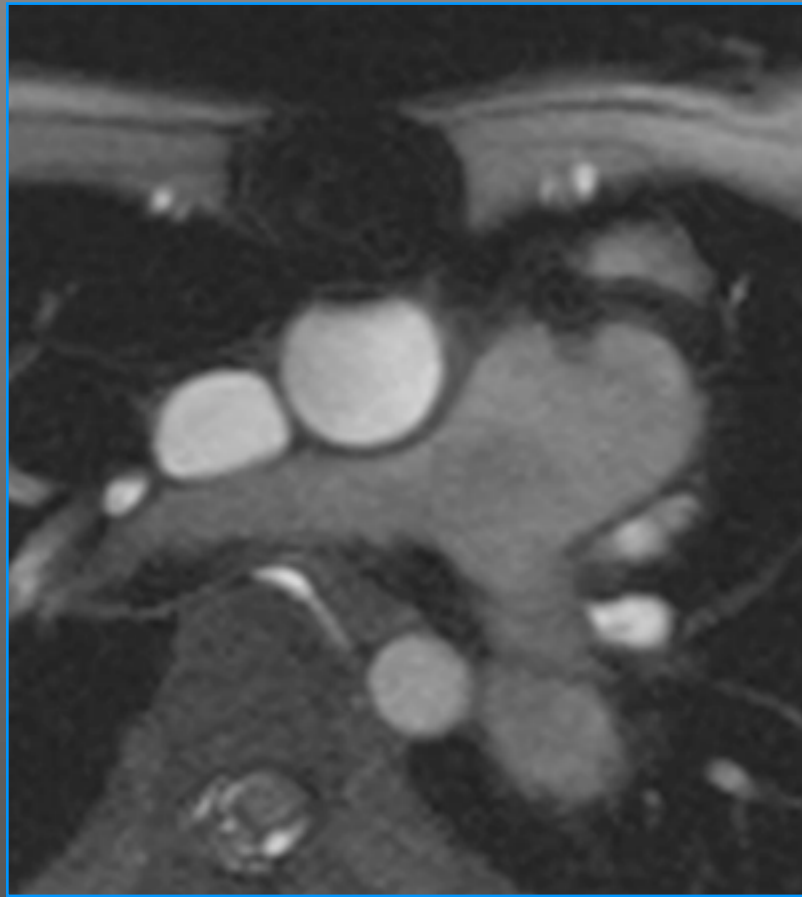
Magnitude



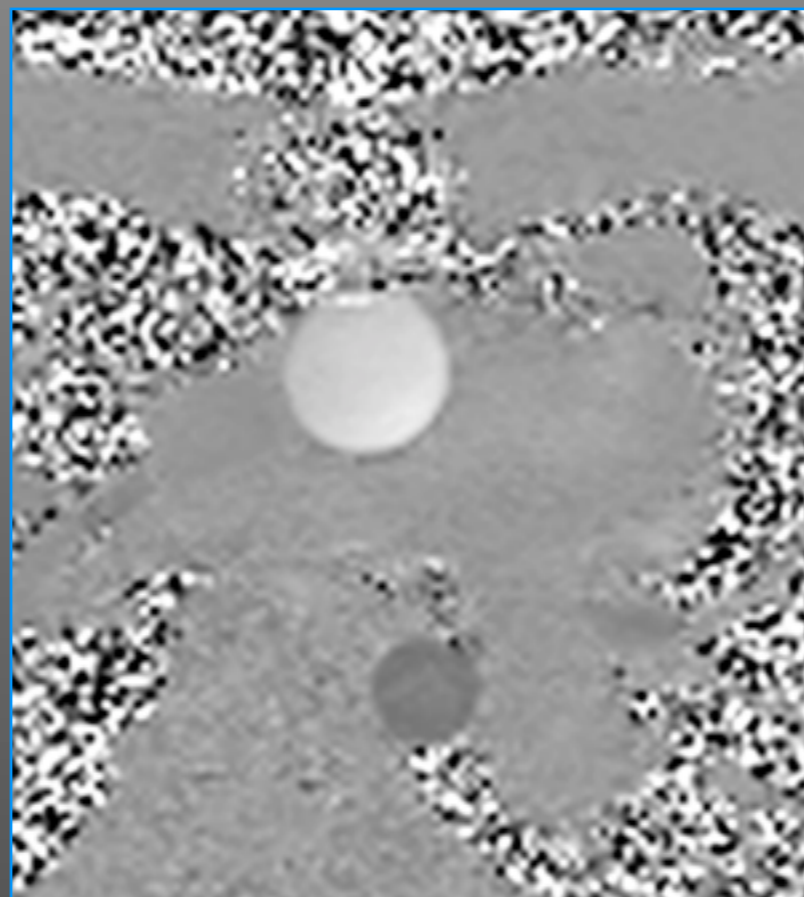
Phase

# Limitations with Phase Contrast Acquisitions

## Sternal Wires and Valvular Prostheses

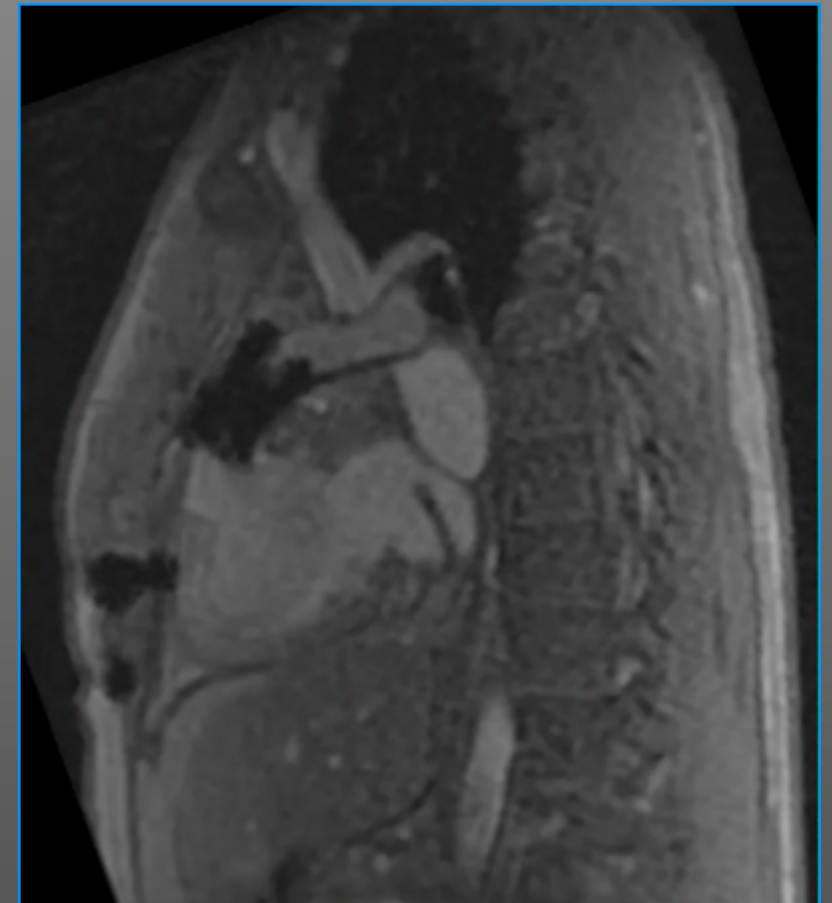


Magnitude



Phase

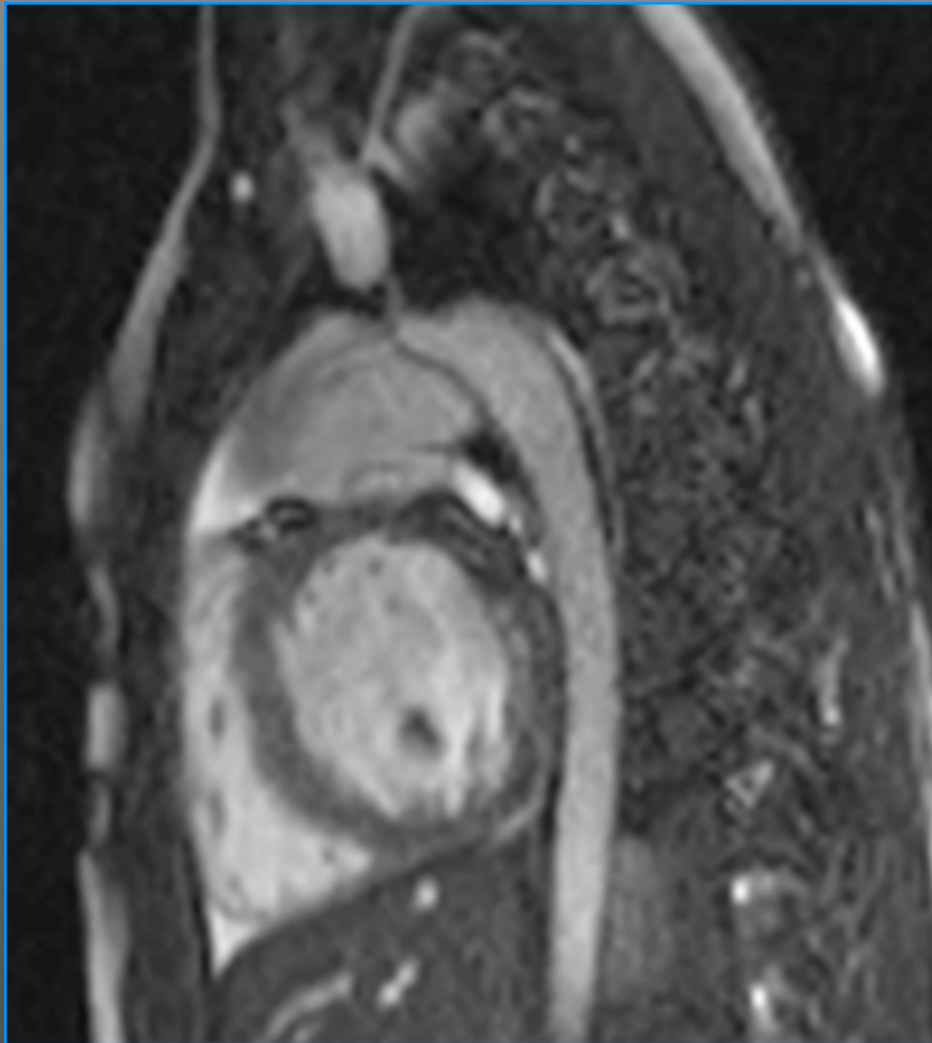
## Vascular Stents



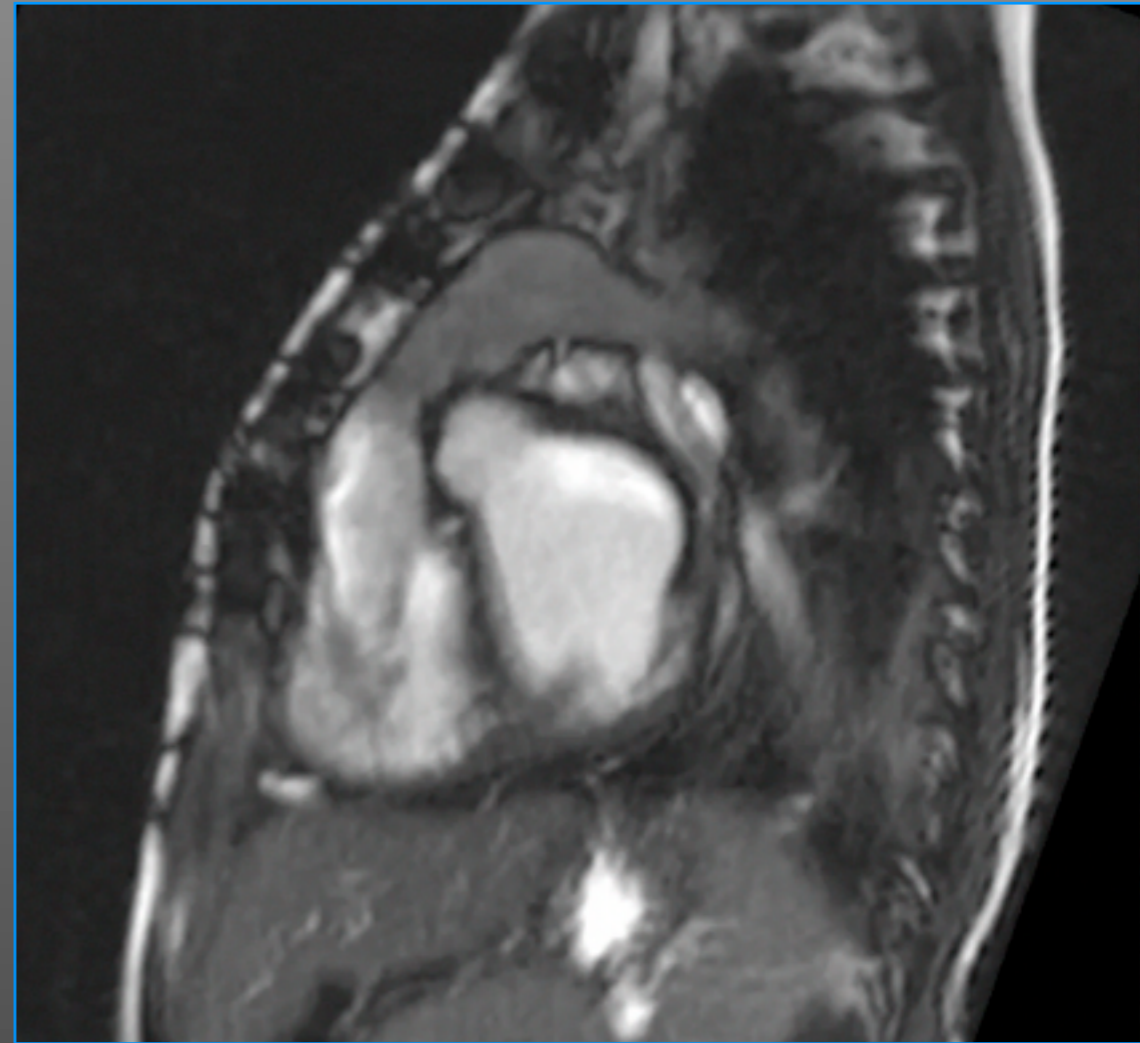
FLASH

# Limitations with Phase Contrast Acquisitions

## Turbulence



PDA



Valvular Stenosis

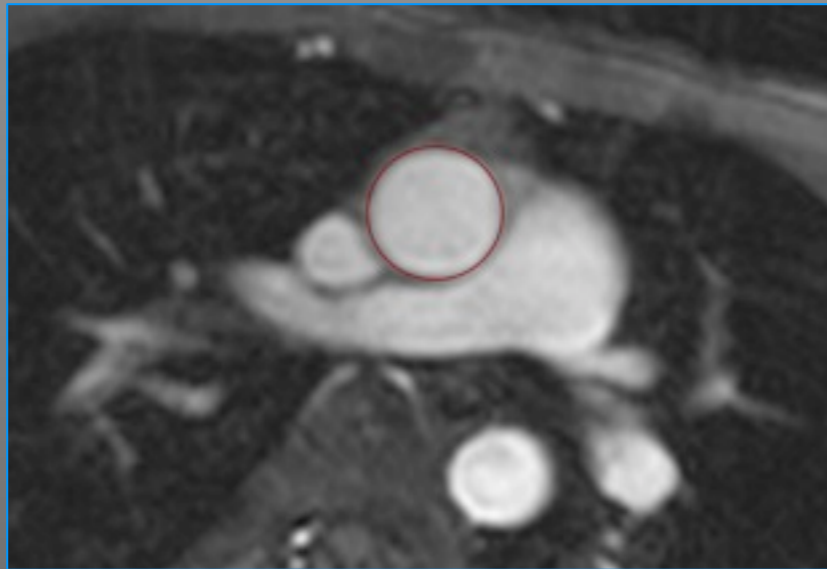


# Phase Contrast Flow - Sources of Error

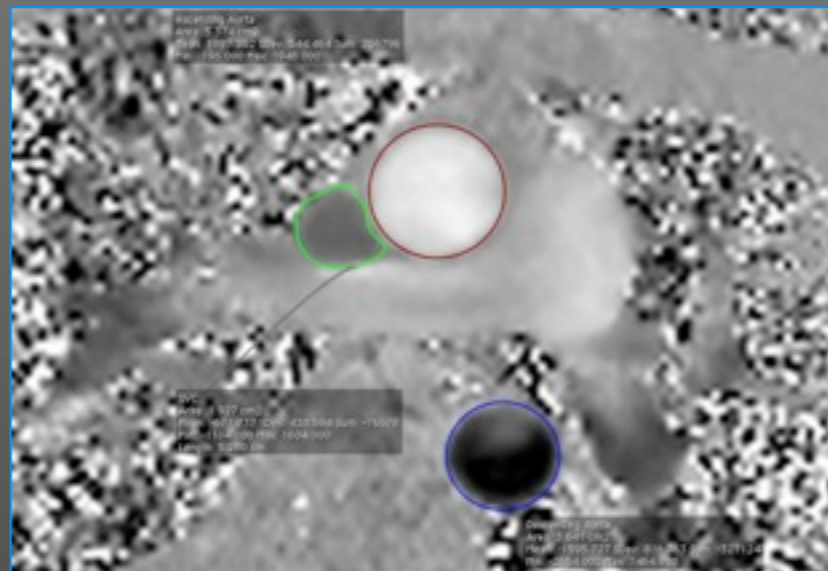
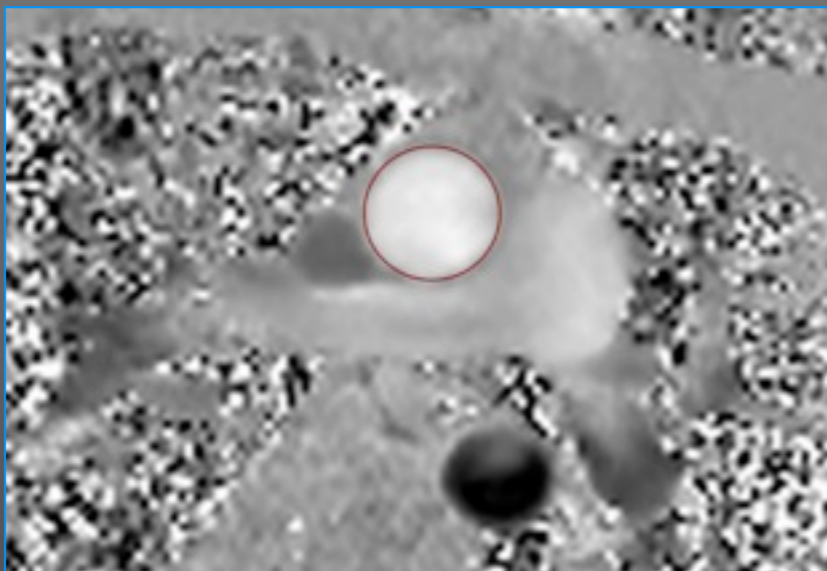
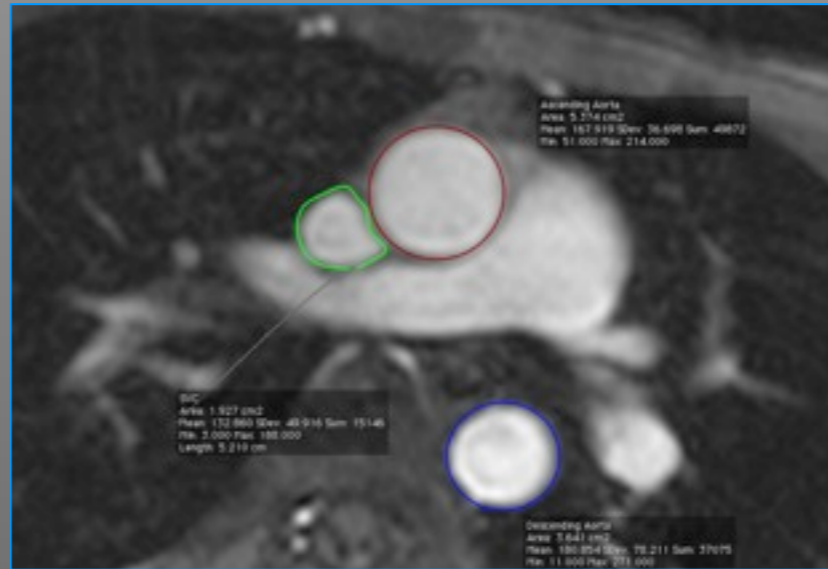
- Nonorthogonal orientation
- Dysrhythmias
- Undersampled temporal resolution
- Undersampled spatial resolution
- $B_0$  heterogeneity and gradient imbalances
  - Phase offsets
  - Eddy currents

# Post Processing - Internal Validation

Ascending Aorta ROI



Descending Aorta and SVC ROIs



Ascending Aorta Stroke Volume  
70.96 ml

Descending Aorta Stroke Volume  
44.52 ml  
Superior Vena Cava Stroke Volume  
26.10 ml

# Qp:Qs by Ventricular Volumetry

- Qp = Right (pulmonic) ventricular stroke volume
- Qs = Left (systemic) ventricular stroke volume
- Stroke volumes ~ Phase contrast forward flow
- Only practical without valvular regurgitation or ventricular septal defects
- Analyze flow and ventricular function independently
- Integrate data during interpretation

# Qp:Qs - Summary

Understand the underlying pathophysiology and clinical questions

## Acquisition

- Optimize slice prescription
- Optimize acquisition parameters
- Avoid turbulence, artifacts, and minimize spatial translation

## Post processing and Interpretation

- Internal validation
- Correlation with other functional parameters

# How is $Q_p$ best determined following bidirectional Glenn in the setting of single ventricle?

- A. Phase contrast acquisition through the main pulmonary artery
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## References

1. Kellenberger CJ, Macgowan CK, Roman KS et al. (2005) Hemodynamic evaluation for the peripheral pulmonary circulation by cine phase-contrast magnetic resonance imaging. *JMRI* 22:780–787
2. Korperich H, Gieseke J, Barth P et al. (2004) Flow volume and shunt quantification in pediatric congenital heart disease by real-time magnetic resonance velocity mapping. *Circulation* 109:1987–1993