Measurement of Qp:Qs in the setting of congenital heart disease

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How is Qp 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. Qp cannot be determined in this clinical setting
D. Phase contrast acquisitions through the pulmonary veins
E. Phase contrast acquisition of the superior vena cava.
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
  • \( VO_2 = (CaO_2 - CvO_2) * Q \)
  • \( Qp:Qs = (Sat_{Aorta} - Sat_{SVC})/(Sat_{Pulmonary Venous} - Sat_{Pulmonary Artery}) \)
Qs = Systemic Flow
Qp = Pulmonary Flow
Qp = Branch Pulmonary Arteries

Left

Right
Qp = Pulmonary Veins
Qp = Pulmonary Veins

RUPV
RLPV
LUPV
LLPV
Qp = Pulmonary Veins

Helpful in situations with -
- Slow or turbulent pulmonary arterial flow - Glenn or Fontan shunts
- Aorticopulmonary collaterals
- PAPVR
Reference images -

- Cine *versus* static images
- Most recent sequences *versus* localizers
Phase Contrast Slice Prescription Tips

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Vessel of interest near $B_0$ isocenter for optimal flow measurements
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Retrospective ECG-gating - Vectorcardiogram, Pulse oximeter
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Vessel of interest near B₀ isocenter for optimal flow measurements
Retrospective ECG-gating - Vectorcardiogram, Pulse oximeter
Multi-average free breathing *versus* single average breath hold
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Desired spatial resolution - watch voxel size relative to vessel
  • Field of view and matrix
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• Field of view and matrix

Desired temporal resolution
• Lines of k-space collected per cardiac cycle
• $T_{\text{resolution}} = 2 * T_R * VPS$
Phase Contrast Post Processing Tips

- 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
Flow Quantification VENC Optimization

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

- **VENC much too high**
  - washed-out black/white
Flow Quantification VENC Optimization

- **VENC optimal**: max black/white & no aliasing
- **VENC slightly low**: slight aliasing
- **VENC much too high**: washed-out black/white
Flow Quantification VENC Optimization

- **VENC optimal**
  - Max black/white & no aliasing

- **VENC slightly low**
  - Slight aliasing

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

- **VENC much too low**
  - Marked aliasing
Limitations with Phase Contrast Acquisitions

Motion

Magnitude

Phase
Limitations with Phase Contrast Acquisitions

Sternal Wires and Valvular Prostheses

Vascular Stents

Magnitude

Phase

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 (pulmonary) 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
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
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