The Pulmonary Arteries
How to Set Up Q-flow
What Measurements Are Normal

Quantitative Flow Studies

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DISCLOSURES

I do not have any relevant financial relationships with commercial interests.

I will discuss the use of a medical device/drug that is classified by the Food and Drug Administration (FDA) as investigational for the intended use.
Use of Oblique Images

Optimize RVOT Flow Planes

Axial-Oblique MPA

Coronal-Oblique RVOT

Coronal Image MPA
Double-Oblique : RVOT Plane
Stenotic Pulmonary Valve

SSFP Sagittal-Oblique Images
Problems: Pulmonary Flow Measurement

Bicuspide

Dysplastic

Eccentric Flow Jets

Stenotic

Normal Anatomy

PVR/Valvuloplasty/Stent
Pulmonary Flow Direction

Flow Jet

Axial-Oblique Plane of RVOT
Main Pulmonary Artery
Flow Direction

SSFP Images (RVOT)
Sagittal-oblique Plane

SSFP images: Improved visualization of valve anatomy,
Less sensitive in depicting flow disturbances
3-D Rendering of Sagittal-oblique View

RVOT / Valve Plane

Double-Oblique Planes
Optimized Location for Phase Velocity Flow Mapping
Short-Axis View of RVOT Perpendicular to Flow

Thru-Plane Acquisition

End-Systole  
Magnitude Image  
Phase Image  
End-Diastole

Velocity Mapping Study
Based on the accumulated phase of moving protons

Children’s Healthcare of Atlanta
Helical Flow Patterns in the RVOT

4-D Flow: Flow Reversal Post Pulmonary Valve Replacement

Antegrade with Helical Flow Underestimation of flow Volumes
RVOT Post Repair: Pulmonary Regurgitation

4-D Flow: Post Transannular RVOT Patch

Antegrade and Retrograde Flow
Problems: Pulmonary Flow Measurement

RVOT Reconstruction: Patch / Conduit / Valve Replacement

Collateral Pulmonary Vessels, Stenotic and Hypoplastic Pulmonary Arteries
Flow Quantification

A Phase-Contrast Technique

1. Protons moving through a magnetic field gradient produce a phase shift proportional to their velocity & direction.
2. Stationary protons produce no phase shift.
3. Measures the difference in phase shift between moving and stationary protons.
4. Protons moving in the same direction as a magnetic field gradient (i.e., forward) create a positive phase.
5. Protons moving in a negative direction relative to the magnetic field gradient produce a proportional negative phase shift.
Phase Images

Forward Flow = Bright  Reverse Flow = Black

In Forward Flow:

The faster the flow velocity of blood the brighter the signal

In Reverse Flow:

The faster the flow velocity of blood the darker the signal
VENC = Velocity Encoding Sensitivity

Maximum velocity encoded by the sequence

Magnitude and Direction

Chosen by the user

VENC = velocity when measured phase angle reaches +/-180 degrees

Only through-plane VENC suitable for quantitative analysis!
VENC Scout
(3 Velocities - 1 Flow Direction)
Use in Selection Process of Accurate VENC

<table>
<thead>
<tr>
<th>Flow mode</th>
<th>Single dir.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Encodings</td>
<td>3</td>
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<tr>
<td>Velocity enc. 1</td>
<td>90</td>
</tr>
<tr>
<td>Velocity enc. 2</td>
<td>150</td>
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<tr>
<td>Velocity enc. 3</td>
<td>200</td>
</tr>
<tr>
<td>Direction</td>
<td>Through plane</td>
</tr>
</tbody>
</table>

Magnitude
VENC 150

VENC Scout
VENC 100
VENC 200
VENC too High:

Signal to noise and Vmax Inaccurate


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Correct VENC Selection

VENC too low:
‘Aliasing’
PEAK flows are not accurately captured

Error in Gradient Estimation
Slice Angle Error:
Underestimation of Vmax and Flow

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Accurate V max Assessment

Incident Angle Error is proportional to deviation from perpendicular plane
Angle (<) 10 to 15 degrees deviation produces acceptable error

Temporal resolution too long:
Inaccurate velocity and flow measurements

Temporal resolution (TR) should be short:
Sacrifice shorter scans for improved accuracy
Shorter TR = improved temporal resolution
Temporal Resolution

Temporal resolution (TR) = small as possible

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Branch Pulmonary Artery Flows

The Issue of Discrepant Pulmonary Flows

Discrepant pulmonary artery sizes
Unilateral or bilateral pulmonary artery stenosis
Pulmonary venous obstruction or anomalies
Intrapulmonary and extrapulmonary abnormalities
Arteriovenous malformations
Pulmonary vascular obstructive disease
Pulmonary hypertension
Scimitar syndrome
Veno-lobar syndrome, etc.....
Normal pulmonary valve flow velocity across the RVOT/Pulmonary Valve is 60 to 120 cm/sec

Normal homografts have a peak velocity < 2.5 m/s (mean gradient < 15 mm Hg)
Normal xenografts have a peak velocity < 3.2 m/s (mean gradient < 20 mmHg)

Conduit stenosis studies (pulmonary) typically underestimate severity at the conduit to PA anastamosis due to jet lesions with eccentric projections and multiplicity

Regurgitation of < 5% is considered negligible


Eddy currents: are induced by the gradient coils within the magnet. These produce a background phase ‘velocity’ in stationary tissue. **Background phase correction:** may be applied over a selected portion of immobile tissue and subtracting this from the flow outcome in the vessel of interest to reduce flow error.
1. Pulmonary Flow can be reliably assessed by Phase Velocity Mapping studies but confounding conditions and lesions must be accounted for to improve accuracy and consistency.

2. Enlarged or redundant outflow tracts, stenotic valves, stents and conduits are associated with turbulence, eccentric flow jets, regurgitant flow and helical flow patterns which can introduce error in flow measurements.

3. Imaging of additional vascular flows may need to be acquired to estimate flows that can be used to validate desired flows.