Specialty area: Challenges in Quantitative Cardiovascular Imaging (Basic to Intermediate)

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Title: Flow Quantification (Ao, MPA, Branch PAs, VENC, Background Errors, Temporal/Spatial Resolution, ROIs)

Highlights: Flow, Regurgitation, Shunt (Qp/Qs ratio) measurements.
Clinical examples and common pitfalls.
New developments with potential clinical impact.
*Excludes* Peak velocity for pressure 'gradients'.

Target Audience:
Clinical users of cardiac MRI flow seeking more understanding of phase-contrast flow measurements and how to improve them.

Educational Objectives:
This talk hopes to enable participants to:

- Understand and optimise flow measurements to suit their clinical setup.
- Recognize pitfalls in clinical flow methods and where possible correct them.
- Consider emerging flow methods.

**Key references:**

Lotz J et al, Radiographics 2002;22:651-71.
Heart valve disease: investigation by cardiovascular magnetic resonance
Myerson, JCMR 2012,14:7
Chatzimavroudis, Walker et al. Slice location dependence of aortic regurgitation measurements with MR phase velocity mapping, MRM 1997;37:545-51.
Reid, Walker et al. The quantification of pulmonary valve haemodynamics using MRI. Int J Cardiov Imag 2002;18:217-25.

**Summary:**

Acquire Free-Breathing (FB) or Breath-Hold (BH)?
Can depend on clinical environment (slow FB flows at around 200 seconds each try, or can patient tolerate up to 20second BH). BH SNR and resolution poorer than FB which depends on slow averaging of resp ghosting. BH alters flow slightly. (Pitfall: FB blurring still remains, "outer" not "inner" loop for FB averaging). FB can usefully acquire "multiVENC".

Positioning:
Transect vessel in both axes (cross-cut localisers).
Misregistration due to Time-of-Flight.
Ao flow: Above diastolic valve location, at sinutubular junction.
PA flow: Above diastolic valve location, cut MPA midway between valve and PA bifurcation.
Pitfall: can be inaccurate if narrow jet/ turbulent flow present.
Ao/PA regurg: Pitfall if measured far above valve, regurgitation is underestimated. Accepts some error in forward flow as slightly more turbulence through valve. Sub-valve preferable.
L/RPA: Ensure proximal to first branching.

VENC:
Incorrigible aliasing if VENC too narrow, or poor SNR if VENC too wide.
Pitfall if a valve is stenotic and regurgitant, combine images from multiple VENC scans.

Background Errors:
Contradictory reports (e.g. see Meierhofer C, Lyko C et al, Clinical Imaging 2015).
May add 20% error in derived flow measurements (shunt, regurg) under certain conditions (slow RR, dilated vessels, unpredictable sequence&scanner combinations)
Temporal stability of background error can be short-term.
Impact of incomplete spoiling in flow.

Temporal resolution (True Time per Cine Frame):
Unlike some other phase-contrast applications, for great-vessel flow measurement in adult humans, true temporal resolution 50ms is adequate. BH temporal resolution can be too coarse. Pitfall: ensure scanner does not interpolate to a different temporal resolution.
Retrospective ECG-gating: more stable signal and background than Triggered-mode scan.
Retro-gating flow artifacts if RR-interval variable.

Spatial resolution (True Acquired Pixel Size):
Main vessel diameter may imply resolution is not critical, caution if measuring flow in presence of a narrow jet (stenotic valve). Pitfall: find truly acquired not interpolated pixel size.

ROIs:
Oversimplifying, >16 pixels in lumen for 10% accuracy (Tang, Blatter, Parker JMRI 1993).
Subject to many factors: Velocity near wall (Eccentric/Plug/Laminar flow), Ratio of surrounding tissue signal to boundary blood signal.

Emerging methods:
Compressed sensing, flow imaging has additional redundancy → reliable acceleration?