Cardiac MRI Assessment of Valve Disease - A Practical Approach

Sangita Kapur, MD

OBJECTIVES

- What is phase contrast Imaging?
- Utility of 2D Phase contrast imaging in Valve disease
- How does it compare with other imaging modalities?
- Others

WHAT IS PHASE-CONTRAST IMAGING?

MRI sequence utilizing change in phase of moving protons upon application of a gradient pair in the region of interest to create an image.

- The phase shift is proportional to velocity
- Pixel brightness is proportional to phase shift

Velocity change a pixel brightness

PHASE CONTRAST IMAGING

1. Application of gradient pairs that sequentially de phase and re phase spins
2. 2 sets of images acquired
   - Flow sensitive
   - Flow compensated
3. Amount of flow sensitivity determined by strength of gradient pair

PHASE-CONTRAST IMAGE PAIR

Anatomic Image

Phase sensitive image
**IN-PANE PHASE CONTRAST SEQUENCE**

- Can demonstrate origin & direction of flow jet
- Can aid in through-plane prescription
- Subject to partial volume effects

3-chamber in place PC in patient with acute minimus

**THROUGH-PANE PHASE CONTRAST SEQUENCE**

- Thinner slices so less partial volume effects
- More accurate velocity measurement
- However rely on in-plane for accurate prescription

Sensacan ASD

Salt and Gordon MSk Part 1: Fundamentals

Reprinted with permission from AA

**ENCODING VELOCITY (VENC)**

Peak velocity that corresponds to a phase shift of 180°

Given in cm/sec

Determines highest and lowest velocity detectable e.g. if VENC is 100 cm/sec the detectable velocity range is +/-100 cm/sec

**MISMATCH OF VENC**

The better the encoding velocity matches the real velocity in the region of interest, the more precise the measurement

**VENC TOO LOW**

- Aliasing - implies wrapping around of velocity info within a voxel
- How to fix it
  - Automated or manual correction (not beyond VENC below 1.5mVmax)
  - Best repeat with a higher VENC

**ALIASING**

VENC=150cm/sec
**ADVANTAGES OF CMR**

Flow and velocity quantification in contrast to echo or invasive catheterization does not rely on calculation from complex equations.

Undulated imaging planes
- Especially useful in right-sided valves
- Can visualize flow jets and their direction

**HOW DOES CMR DO IN VELOCITY MEASUREMENT?**

1. Lower temporal resolution (25-45 ms)
2. Volume Averaging
   - In-plane pixel size of 1.5-2 mm but slice thickness 6-8 mm
   - Results in lower peak velocities
3. Orientation - plane of imaging should be perpendicular to flow, if angle of intercept < 90 degree, inaccurate flow measurement

**AORTIC STENOSIS**

1. Estimate valve area
   - Continuity equation
   
   \[
   AV_{max} = \frac{A\ V_{max}}{max(V_{jet}) - min(V_{jet})}
   \]

2. Calculate Pressure Gradients
   - Peak pressure gradient: \(4V_{max}^2\)
   - Mean Pressure Gradient: \(4V_{avg}^2\)

  *Orientation of imaging plane should be parallel to flow jet to minimize error in peak velocity measurement*
PATIENT 1 - AORTIC STENOSIS

Multiple planes demonstrating jet of aortic stenosis and dilated ascending aorta

Area LVOT = 2.1 sq cm
Vm AV = 2.8 m/s

Peak Pressure Gradient
\[ \Delta P = 4 \times Vm^2 = 31.4 \text{ mm Hg} \]

Value area using Continuity equation
\[ A_{AV} = A_{LVOT} \times \left( \frac{Vm_{LVOT}}{Vm_{AV}} \right) = 1.55 \text{ sq cm} \]

Cardiac CMR imaging for valve disease. Circulation 2009

AORTIC STENOSIS

53 Aortic stenosis patients (severe to severe), 21 controls
TTE, PC-CMR same day
AVA continuity equation

Results:
Mean gradients and peak velocities: good agreement (r=0.92)
AVA CMR was lower than TTE, but there was good agreement between TTE and continuity equation calculated AVA (<0.05)

Comparison between cardiovascular magnetic resonance (CMR) and transthoracic Doppler echocardiography (TTE) aortic peak velocities

Delattre S et al. Circ Cardiovasc Imaging 2012;5:204-12
AORTIC STENOSIS

Specific advantages of MRI
- Direct measurement of LVOT area
- Angular aortic root (difficult to align US beam)

MITRAL STENOSIS EVALUATION

Pressure half-time (PHT) method
PHT: time for pressure gradient to decrease from peak pressure to zero pressure
PHT increases in patients with stenotic mitral valve

\[
PHT = \frac{V_{peak}}{0.77}
\]

MVA = \text{MVA} \times \text{PHT}^{-1}

MITRAL STENOSIS

Peak velocity = 4 m/s
Peak Pressure gradient = 64 mm Hg
MVA by DVI TDI = 0.77 cm²
Valve area by planimetry = 0.81 cm²

Impression: Severe Mitral stenosis
**PHT METHOD**

Underestimation of peak velocities by CMR.

Not all prolonged PHTs represent Mitral stenosis. Patients with abnormal myocardial relaxation also have prolonged PHT, however peak velocity is not increased.

Moderate to severe aortic Insufficiency: overestimation of MVA due to promoted decline of PHT.

---

**MITRAL STENOSIS**

Excellent visualization of mitral valve

Good correlation with echo

Reproducible

Not restricted by echo windows

CMR tends to over-estimate valve area compared with echo

*30-40% have atrial fibrillation. Problem with image acquisition

---

**REGURGITANT LESIONS**

Quantification of regurgitant fraction

For aortic and pulmonic valves:

(Reverse flow / forward flow volume) x 100%

Where aortic & pulmonic flow measured in proximal aorta & MPA respectively.

For mitral & tricuspid valves:

(stroke volume / forward flow) x 100%

---

**REGURGITANT VOLUME & FRACTION**

Can directly quantify antegrade and retrograde flow volume across semilunar valves

Phase contrast imaging of the mitral valve more difficult because of movement of mitral annulus during systole
AORTIC REGURGITATION

AORTIC REGURGITATION

DISCRIMINATORY ABILITY OF AORTIC REGURGITANT FRACTION.

113 patients with moderate to severe AI monitored for 9 yrs following CMR. Symptoms or other indications of surgery monitored.
Aortic regurgitation quantification by CMR can guide further management and predict need for surgery with high accuracy.

AORTIC REGURGITATION

Excellent correlation with other techniques

Good reproducibility

Good ability to predict symptom development and need for valve replacement surgery.
Mitral Regurgitation

Data from 141 patients who underwent CMR & echo were compared.
Mitrail & aortic regurgitation were calculated.
Repeated excellent correlation between CMR & echo.

Evaluation relies on a combination of 2 different techniques (volumetric and flow).
Direct quantification difficult due to highly mobile valve and often eccentric and mobile jets.
Good correlation with echo and angiography.
Good reproducibility.
Predicts patient’s need for surgery.

Comparison between Mitral regurgitation quantification with LVSV-RVSV (void technique) or LVSV-Ao flow volume (flow technique).
The flow technique maximized intra and inter-observer agreement.
Also independent of right-sided valvular dz.

28 patients.

Comparison between Mitral regurgitation quantification with LVSV-RVSV (void technique) or LVSV-Ao flow volume (flow technique).
The flow technique maximized intra and inter-observer agreement.
Also independent of right-sided valvular dz.
Wednesday

**PULMONIC REGURGITATION**

MRI especially useful because—

Challenging at echo due to poor acoustic window

Evaluation of pulmonic regurgitation on echo mainly qualitative based on

width of regurgitant jet & echodensities

Slope of continuous wave Doppler signal

---

**SECUNDUM ASD**

---

**SUMMARY**

VERSATILE TOOL

Robust sequence BUT

there still exist sources of error

Extends use of CMR into new avenues

---

**REFERENCES**
REFERENCES


