Myocardial Tissue Velocity Imaging: Its Role in evaluation of Diastolic Dysfunction

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Outline

• Background on Diastolic Dysfunction & Diastolic Heart Failure.

• Review of Parameters used for evaluation of Diastolic Dysfunction & Diastolic Heart Failure.
  ✓ Morphological Parameters
  ✓ Functional Parameters
    o Transmitral flow
    o Pulmonary Vein flow
    o Myocardial tissue velocity imaging
      ▪ Definition
      ▪ What are the factors that affect it?
      ▪ How is it different than other functional parameters?
      ▪ How is it measured using Echo and CMR?
      ▪ What is the clinical utility of this parameter?
      ▪ Is there data to show its clinical value?
Why bother about Diastolic function & DHF?

• ‘Diastolic Heart failure’ [DHF] is a real clinical entity.

• Diagnostic Criteria:
  • signs and symptoms of Heart Failure;
  • normal or mildly abnormal systolic LV function; and
  • evidence of LV diastolic dysfunction.

• Heart failure with preserved ejection fraction represents approximately 40%-50% of all cases of heart failure, and its prevalence is increasing.

Why bother about Diastolic function & DHF?

- Diagnosis is difficult
  - Diastology is a complex subject
  - No single parameter is good enough short of invasive measurements

- Treatment is difficult
  - No effective cure
  - Frequently irreversible

- Mortality and morbidity is similar to systolic heart failure.
What are the ways we can diagnose Diastolic Dysfunction or DHF?

- Invasive
- Non Invasive
What are the ways we can diagnose Diastolic Dysfunction or DHF

- **Invasive**
  - Elevated LV end diastolic pressure (>16mmHg).
  - Elevated mean PCWP >12mmHg.
  - Increased time constant of LV relaxation $\tau > 48\text{ms}$.
  - Increase in the constant for LV chamber stiffness $b > 0.27$. 
What are the ways we can diagnose Diastolic Dysfunction or DHF

- Invasive
- Non Invasive
  - Clinical [Signs of HF, EKG (A fib.), BNP]
  - Morphological
  - Functional
    - Flow
      - Transmitral Flow (TMF)
      - Pulmonary vein flow
      - Left ventricular filling
    - Tissue motion
Can we use MRI to study these parameters?
Morphological Parameter: LA Vol

- LA volume:
  - Morphological expression of LV diastolic dysfunction
  - Biomarker of the chronicity of diastolic dysfunction.

- Provides significant insight into an individual’s risk of the development of adverse cardiovascular events, including MI, stroke, AF and heart failure*.

- LA volume is graded relative to risk as
  - mild (28-33ml/m²),
  - moderate (34-39ml/m²) or
  - severe (>40ml/m²)

Morphological parameter:
How to calculate LA Vol. on CMR?

Biplane Area-Length method used for MR evaluation of
Left atrial volume on Cine-true FISP 4-CH and 2-CH views

LA Volume = \((0.85 \times A1 \times A2)/ L\)

- L = LA length
- A1 = LA area in 2-CH view
- A2 = LA area in 4-CH view

2819 mm²

57 mm

2697 mm²

62 mm
Left Atrial Volume

**Strength**

- Provides morphologic and physiologic evidence for chronic elevation in filling pressure
- **Severity scale based on clinical outcomes**

**Weakness**

- May be enlarged in other medical conditions including chronic anemia, athletic heart, chronic valvular disease without increase in LV filling pressure.

**Tsang TS, et al., Am J Cardiol, 2002;90(12):1284–9.**
How can we use MRI to study functional parameters?
The cardiac cycle consists of four phases shown in the diagram.

Notice the pressure-vol. changes during the cycle, in particular during IVRT and ventricular filling.
Functional Parameters: Transmitral Flow

- Diastole, in turn, is divided into four stages:
  1. Isovolumetric relaxation
  2. Early rapid diastolic filling
  3. Diastasis
  4. Late diastolic atrial filling

- Notice that the Transmitral Pressure Gradient (TMPG) is the actual determinant of LV filling.

- TMPG is influenced by:
  - LV relaxation
  - LV compliance (which affects LA pressures)
Functional Parameter: Transmitral Flow

- Mitral inflow is quantified by measuring the E-wave, the A-wave, the E/A ratio and the Deceleration Time (DT):
  - **E-wave** represents early mitral inflow velocity and is influenced by the relative pressures between the LA and LV;
  - **A-wave** represents the atrial contractile component of mitral filling and is influenced by LV compliance and LA contractility; and
  - **DT** represents the interval from E-wave peak to a point of intersection of the deceleration of flow with the baseline.
    - It correlates with time of pressure equalization between the LA and LV.
    - As the early LA and LV filling pressures either evolve toward or away from equivalence, the DT either shortens or lengthens, respectively.
Mitral Valve evaluation:
How to obtain Mitral Flow and Velocity Curves on CMR?
Mitral TMF evaluation:
How to calculate EA ratio, DT and E-wave upslope from the flow / velocity curves?
Mitral valvular flow: E/A ratio, E-wave upslope and DT

**Strength**
- Can be obtained in all patients
- Provides diagnostic and prognostic information
- Been validated to be consistent across modalities.

**Weakness**
- Highly preload dependant
- Difficult to obtain without good EKG tracing
- Problematic at high heart rates, atrial fibrillation, heart block.
Functional Parameter # 2: Pulmonary vein flow

- The normal pulmonary vein flow pattern reflects changes in LV compliance. It consists of the:
  - **S-wave**, occurring during LV systole, and dependent on atrial relaxation and mitral annulus motion;
  - **D-wave**, occurring during LV diastole and reflecting LV filling; and
  - **A-wave**, which is below the baseline as opposed to the S and D waves, occurs during atrial contraction.
Pulmonary vein evaluation: How to obtain pulmonary vein flow curve on CMR?

Phase contrast cine MR image through the pulmonary vein
Pulmonary vein evaluation: How to calculate pulmonary vein SD ratio, A-wave amplitude & duration on CMR?

![Graph showing flow vs time with labels for Systolic Peak, Diastolic Peak, A-wave Amplitude, and A-wave Duration.](image)
Pulmonary Vein Flow

**Strength**

- Complements mitral flow parameters especially when fusion of E and A wave.
- In differentiating normal vs. pseudo-normal pattern.
- The relationship of PV-A reversal (PVAR) duration to mitral A duration is the only marker specific for elevation in LVEDP

**Weakness**

- Can be difficult to obtain especially in a patient who cannot breath hold (especially on Echo).
- Like mitral inflow, this parameter is dependent on the myocardial rhythm.
Interplay of Functional Parameters: Transmitral & Pulmonary vein flow in DHF
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Functional Parameter # 3: Myocardial Tissue Motion

- **Definition:** It is the velocity of the myocardial tissue during systole and diastole expressed in cm/sec.

  ✓ Myocardial motion NOT blood pool.
  ✓ It can be conveniently divided into:
    - Motion during systole
    - Motion during diastole
Factors affecting myocardial tissue velocity

- Systolic myocardial velocity depends on:
  - Contractility

- Diastolic myocardial Velocity depends on
  - Myocardial relaxation
  - Is independent of LV filling pressure
Myocardial Velocity Vs. Trans-mitral flow

- **Myocardial Velocity**
  - Early diastole
    - LV relaxation
  - Late Diastole
    - LV relaxation &
      - LV distention due to LA contraction

- **Transmitral Blood Vel**
  - Early Filling (E wave)
    - LA-LV pressure Gradient
    - LV relaxation
    - LV stiffness
    - Mitral Valve inertness
  - Late Filling (A wave)
    - LV stiffness
    - LA contractility
Need for this parameter?

- Non-invasive
- Is not a dynamic parameter like TMF; depends predominantly on LV relaxation.
- In conjunction with TMF can be used to estimate the LV pressure gradient.
Factors affecting myocardial tissue velocity in health and disease

Adapted from Paelinck BP et al, A, JACC 45(7), 2005
Normal Diastolic Function
Grade 3 Diastolic Heart Failure
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Tissue Doppler Imaging

SYSTOLE

DIASTOLE

E'

A'
Transmitral Flow
Myocardial Tissue Velocity
Velocity vs Time

Legend:
- Data
- Spline (+/- 1)

Slice Position: SP L60.1  Venc Adjustment -30 : 30
Check contours. Computer generated contours may not correspond to anatomy.
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Adapted from Journal of American Society of Echocardiography Feb 2009 - Recommendations for the evaluation of left ventricular diastolic dysfunction by echocardiography.

**Grading**

- **Septal E' > 8 & Lateral E' > 10**
  - **Grade 0 Normal**

- **Septal E' < 8 & Lateral E' < 10**
  - **ABNORMAL**
Clinical Utility of Myocardial Tissue Velocity Imaging in diastolic Dysfunction
Clinical Utility of Myocardial Tissue Velocity Imaging

Mitral Valve Flow

Tissue Doppler Imaging

PSEUDONORMAL
Clinical Utility of Myocardial Tissue Velocity Imaging

Transmitral Flow

Myocardial Tissue Velocity

PSEUDONORMAL
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Clinical Validity of Myocardial Tissue Velocity Imaging

Feasibility of Tissue Magnetic Resonance Imaging
A Pilot Study in Comparison With Tissue Doppler Imaging and Invasive Measurement

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OBJECTIVES
This research was intended to determine the feasibility of tissue magnetic resonance (MR) imaging in comparison with tissue Doppler imaging and its potential implications for the estimation of filling pressure, in comparison with invasive measurement.

BACKGROUND
Evaluation of diastolic function using MR imaging is commonly confined to the study of transmitial flow. However, transmitial flow is unreliable for the estimation of left ventricular (LV) filling pressures in hypertrophy and normal systolic function. Normalizing early mitral velocity (E) for the influence of myocardial relaxation by combining E with early diastolic mitral septal tissue velocity (Ea) provides better Doppler estimates of filling pressures.

METHODS
Eighteen patients with hypertensive heart disease (LV mass index: 114 ± 21 g/m²), absence of valvular regurgitation, and with normal or mildly reduced systolic function (LV ejection fraction: 57.6 ± 6.5%) referred for cardiac catheterization, underwent consecutive measurement of mitral flow and septal tissue velocities with phase-contrast MR and Doppler. These data were compared with mean pulmonary capillary wedge pressure (PCWP).

RESULTS
There was a strong relation between MR (11.6 ± 4.3) and Doppler-assessed (12.1 ± 3.5) E/Ea (95% confidence interval of -1.5 to 0.5) (r = 0.89, p < 0.0001). In addition, E/Ea related strongly to invasively measured PCWP (MR: r = 0.80, p < 0.0001 and Doppler: r = 0.85, p < 0.0001).

CONCLUSIONS
Tissue MR imaging is a feasible method to assess Ea. Combining E and Ea allowed similar estimation of filling pressure by MR and Doppler, in good agreement with invasive measurement. The potential confounding effect of valvular regurgitation needs further study. (J Am Coll Cardiol 2005;45:1109–16) © 2005 by the American College of Cardiology Foundation
Future Directions

• Further large validation studies are needed.

• Clinical studies in different patient subsets is needed.

• What is a true imaging gold Std?

• Role of ‘Radial’ Myocardial velocities?
Thank you for your attention...