Basic Approach to the Echocardiographic Evaluation of Ventricular Diastolic Function

JAFTER ALI, MD
UNIVERSITY HOSPITALS CASE MEDICAL CENTER
STAFF CARDIOTHORACIC ANESTHESIOLOGIST
Introduction

• Independent component of overall cardiac performance

• Adequate ventricular filling depends on
  ○ ventricular relaxation
  ○ ventricular compliance
  ○ systolic function
  ○ atrial contraction
Clinical Relevance

- CHF – most common diagnosis amongst inpatients in the United States

- 50% have diastolic dysfunction with a normal EF

- Diastolic dysfunction increases with age
  - elderly patient with long standing HTN

- Prognosis
Clinical Relevance

- 30 to 70% of cardiac surgical patients

- Independently associated with
  - difficulty weaning from CPB
  - more frequent ionotropic support
  - increased morbidity
Clinical Relevance

• Following CPB, acute or progressive diastolic dysfunction can be associated with
  ○ ischemia-reperfusion injury
  ○ hypothermia
  ○ metabolic disturbances
  ○ myocardial edema

• Prophylactic Therapeutic Strategies
Diastolic Dysfunction

- Impaired capacity of the ventricles to fill at low pressure
  - ventricular relaxation
    - energy-dependent process
    - resequestration of calcium from cytosol to SR
  - chamber compliance
**Left Atrium**

- **Reservoir**
  - holds blood from venous circulation while MV is close

- **Conduit**
  - transmit of blood from LA to LV

- **Pump**
  - during contraction at end diastole to contribute to LVEDV

- **LA contribution to LV filling**
  - 20% young healthy patients
  - 50% patients early diastolic dysfunction
Echocardiographic Evaluation

- **Cardiac cath**
  - invasive intraventricular catheters

- **Pulmonary artery catheter**
  - useful for global LV function
  - cannot directly measure LV pressure, volume, or transmitral flow

- **Echocardiography**
  - safe
  - practical
  - noninvasive
TEE 2-D Clues

- **LV hypertrophy**
  - hypertension
  - aortic stenosis

- **Increased PA pressures**
  - evaluate for tricuspid regurgitation

- **LA enlargement (>4cm)**
  - associated with elevated LV filling pressures
Doppler Evaluation of LV Filling: Transmitral Inflow

- TMDF = transmitral doppler flow
  - fundamental to diastolic evaluation

- PWD sample volume at MV leaflet tips
Typical TMDF Profile

- Biphasic pattern
- E-wave
  - early diastolic filling
- Diastasis
- A-wave
  - atrial contraction
TMDF Schematic
TMDF Velocities

- Dependent on transmitral pressure gradient (TMPG), which is dependent on...
  - heart rate
  - heart rhythm (conduction disorder)
  - volume status
  - atrial contractility
  - mitral valve disease
  - ventricular septal interactions
  - intrinsic LV lusitropy
  - ventricular compliance
Practical Application Of TMDF Velocities

- Normal aging -> delayed LV relaxation at any given LV pressure -> lower initial TMPG -> less early filling (lower peak E wave velocity) and greater, compensatory late filling (higher peak A wave)

- Young adult -> efficient LV relaxation and elastic recoil -> predominant early LV filling with smaller atrial contribution
TMPG elevation in patients with decreased LV compliance is primarily due to progressively increasing LAP.

Thus, alterations in LV relaxation and compliance, along with changes in LAP, alter the TMPG and resulting TMDF profiles.
Grading Diastolic Dysfunction

Echocardiographic Classification of Diastolic Dysfunction

- Normal Diastolic Function
- Stage I Impaired Relaxation
- Stage II Pseudonormal
- Stage III Reversible Restrictive
- Stage IV Fixed Restrictive
Impaired Relaxation (Grade I)

- Occurs with myocardial ischemia/infarction, LVH, HCM, and early stages of infiltrative disorder

- **TMDF characteristics**
  - prolonged IVRT (more time required for LV to relax enough for MV to open) and decreased initial TMPG (causes decreased peak E wave)
  - E/A ratio < 1 (MV opens before LV relaxation complete)
  - prolonged DT (LA-LV pressure gradient takes longer to equilibrate)
  - increased A wave due to increased atrial preload

- “E/A reversal”
Impaired Relaxation (Grade I)
Grading Diastolic Dysfunction
Pseudonormal (Grade II)

- As early relaxation becomes further delayed, compensatory increase in LAP occurs
- Resembles normal LV filling!!
- TMDF characteristics
  - normal peak E, peak A, IVRT, and DT
Pseudonormal vs Normal

- Evaluate for 2-D clues
- Reduce preload -> will reveal impaired relaxation pattern on TMDF profile
  - valsalva
  - NTG
  - reverse trendelenburg
  - partial CPB
- Color M-mode
- Pulmonary venous flow profile
- Tissue Doppler Imaging
Pseudonormal (Grade II)

During peak valsalva
Grading Diastolic Dysfunction

Echocardiographic Classification of Diastolic Dysfunction

- Normal Diastolic Function
- Stage I Impaired Relaxation
- Stage II Pseudonormal
- Stage III Reversible Restrictive
- Stage IV Fixed Restrictive
Restrictive (Grade III)

- Markedly decreased LV compliance and severely increased LAP

- TMDF characteristics
  - E/A > 2 (elevated peak E relative to A due to elevated LAP)
  - IVRT shortened (<60ms, MV opens prematurely due to elevated LAP)
  - DT shortened (early transmitral flow into poor compliant LV results in rapid LA-LV pressure equilibration)
  - Decreased peak A wave velocity (poor atrial contractility and rapid increase in LV pressure)
Restrictive (Grade III)
Doppler Evaluation of LA Filling – Pulmonary Venous Flow
Doppler Evaluation of LA Filling – Pulmonary Venous Flow
Normal Pulmonary Vein Flow

- Predominant systolic flow
- Fused PVS1/PVS2 – 70%
- PVar duration should be same or less than transmitral AWD (LA contraction with net forward flow)
- PVar velocity that exceeds mitral A-wave by 35cm/s or PVar duration 30ms longer than AWD indicates increased LVEDP
PVF With Impaired Relaxation

- Reduced PV D wave velocity (parallels mitral E wave velocity)
- Compensatory increase in PV S wave velocity
- “Systolic predominance”
PVF As Diastolic Function Worsens

- As disease progresses, decrease in LV compliance with rise in LA pressure -> blocks LA systolic venous return

- Decreased PV S wave velocity
  - S/D ratio <1
  - Systolic VTI <40%
TMDF + PVF

- **Impaired Relaxation**
  - E/A <1
  - Systolic predominance of PVF

- **Pseudonormal**
  - normal mitral inflow
  - increased LAP compensates for increased LVEDP
    - blunted systolic component of PVF
    - increased velocity of PVar >35cm/s
TMDF + PVF

- **Restrictive**
  - E/A ratio >2, shortened DT and IVRT
  - Decreased LV compliance blunts PV S wave
  - Secondary to increased LAP and LVEDP -> PVar duration is greater than AWD
Pitfalls TMDF/PVDF Profiles

- affected by changes in preload, afterload, heart rate (tachycardia - E/A fusion), and rhythm (afib)

- increased preload -> increase in transmitral peak E wave velocity, shorter IVRT, steeper DT (ex. mitral regurgitation)

- location of PWD sample volume
Newer Techniques To Evaluate Diastolic Function

- Mitral Annular Motion Assessed with Doppler Tissue Imaging

- Color M-mode Transmitral Flow Propagation Velocity

- Advantage - LESS VUNERABLE TO ACUTE CHANGES IN LOADING CONDITIONS
Doppler Tissue Imaging (DTI)

- Low velocity, high amplitude signal (eliminate high velocities associated with blood flow)

- ME 4C – PWD sample (2.5-5mm) on lateral corner of mitral annulus (septal – velocities lower, blood flow velocity in LVOT can obscure DTI)

- PWD doppler beam alignment as parallel as possible to longitudinal axis (also translation and rotation)

- Low wall filter and minimal gain; also adjust nyquist limit, sweep speed, and scale
Doppler Tissue Imaging (DTI)
Doppler Tissue Imaging (DTI)

- **Systolic Component**
  - correlates with EF

- **Biphasic Diastolic**
  - mirrors TMDF
  - lower velocities

- **E’**
  - influenced by rate of myocardial relaxation and elastic recoil
  - **not load sensitive**
  - best discriminator between grade I and grade II
  - abnormal E’<8cm/s

- **A’**
  - reflects LA systolic function
Pitfalls DTI

- Technically difficult

- Abnormality in annulus/valve
  - calcium, ring, sutures
  - mitral stenosis
  - RWMA’s and scars
Color M-Mode Transmitral Propagation Velocity

- Early LV relaxation -> suction force -> intraventricular pressure gradient initiated at level of mitral orifice

- PG maintained in the mid LV during early diastole -> responsible for accelerating flow -> sequential filling towards LV apex

- Propagation rate of LV peak inflow velocity (secondary to rapid LV relaxation) can be evaluated using color M-mode doppler

- $V_p =$ velocity at which flow propagates within the ventricle
Color M-Mode Transmitral Propagation Velocity
## Essentials of Doppler Echocardiography

### Table 7.2 Doppler echocardiographic values for indices of left ventricular diastolic dysfunction

<table>
<thead>
<tr>
<th></th>
<th>Normal (young)</th>
<th>Normal (adult)</th>
<th>Impaired relaxation</th>
<th>Pseudonormal filling</th>
<th>Restrictive filling</th>
</tr>
</thead>
<tbody>
<tr>
<td>E/A (cm/s)</td>
<td>&gt; 1</td>
<td>&gt; 1</td>
<td>&lt; 1</td>
<td>1–2</td>
<td>&gt; 2</td>
</tr>
<tr>
<td>DT (ms)</td>
<td>&lt; 220</td>
<td>&lt; 220</td>
<td>&gt; 220</td>
<td>150–200</td>
<td>&lt; 150</td>
</tr>
<tr>
<td>IVRT (ms)</td>
<td>&lt; 100</td>
<td>&lt; 100</td>
<td>&gt; 100</td>
<td>60–100</td>
<td>&lt; 60</td>
</tr>
<tr>
<td>S/D</td>
<td>&lt; 1</td>
<td>≥ 1</td>
<td>≥ 1</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>PVAR (cm/s)</td>
<td>&lt; 35</td>
<td>&lt; 35</td>
<td>&lt; 35</td>
<td>≥ 35</td>
<td>≥ 25*</td>
</tr>
<tr>
<td>Vp (cm/s)</td>
<td>&gt; 55</td>
<td>≥ 45</td>
<td>&lt; 45</td>
<td>45</td>
<td>45</td>
</tr>
<tr>
<td>E' (cm/s)</td>
<td>&gt; 10</td>
<td>&gt; 8</td>
<td>&lt; 8</td>
<td>≤8</td>
<td>8</td>
</tr>
</tbody>
</table>

*Unless atrial mechanical failure is present.

E/A, early-to-late left ventricular (LV) filling ratio; DT, early LV filling deceleration time; IVRT, isovolumic relaxation time; S/D, systolic-to-diastolic pulmonary venous flow ratio; PVAR, pulmonary venous peak atrial contraction reversal velocity; Vp, transmitral color M-mode propagation velocity; E', peak early diastolic mitral annular velocity.


Echocardiographic techniques for diagnosing diastolic dysfunction will hopefully facilitate the development of perioperative therapeutic intervention.
Echocardiographic Classification of Diastolic Dysfunction

Mitral Inflow
- Normal Diastolic Function: $0.75 < E/A < 1.5$, $DT > 140$ ms
- Stage I: Impaired Relaxation
- Stage II: Pseudonormal
- Stage III: Reversible Restrictive
- Stage IV: Fixed Restrictive

Mitral Inflow at Peak Valsalva Maneuver
- $E/A < 0.5$
- $E/A < 0.5$
- $E/A = 0.5$
- $E/A = 0.5$
- $E/A < 0.5$

Pulmonary Venous Flow
- $S > D$
- $AR > AD$
- $AR > AD$
- $AR > AD$
- $AR > AD$

Color M-Mode Propogation Velocity
- $V_p > 45$
- $V_p < 45$
- $V_p < 45$
- $V_p < 45$
- $V_p < 45$

Doppler Tissue Imaging of Mitral Annular Motion
- $E/ea < 10$
- $E/ea < 10$
- $E/ea = 10$
- $E/ea = 10$
- $E/ea = 10$

LV Relaxation
- Normal
- Impaired
- Impaired
- Impaired
- Impaired

LV Compliance
- Normal
- Normal to $↓$
- $↓↓$
- $↓↓↓$
- $↓↓↓↓$

Atrial Pressure
- Normal
- Normal
- $↑↑$
- $↑↑↑$
- $↑↑↑↑$
THANKS FOR PAYING ATTENTION!!