ASSESSMENT OF LV DIASTOLIC FUNCTION BY DOPPLER ECHOCARDIOGRAPHY

S Bakhoum, MD
Assistant Professor of Cardiology
Cairo University

PHYSIOLOGY OF DIASTOLE

- Normal diastolic function is defined as the ability of the LV to accommodate an adequate filling volume to maintain CO while operating at low pressure.
Doppler Indices of Diastolic Function

- Isovolumic relaxation time.
- Transmitral flow.
- Pulmonary vein flow.
Isovolumic Relaxation Time

LV
LVOT
MV
LA

Isovolumic Relaxation Time

IVRT
Isovolumic Relaxation Time
Clinical Applications

- Normal value: 65 ± 20 msec.
- Prolonged in various diseases (>90 msec) that result in impairment of myocardial relaxation.
- Non invasive predictor of:
  - Doxorubicin-induced cardiomyopathy.
  - Early cardiac transplant rejection
- Shortened in stages 2(<90 msec), 3 & 4 (<70 msec) diastolic dysfunction.

Isovolumic Relaxation Time
Limitations

- It measures the time taken by isovolumic relaxation and not the rate of relaxation.
- It is age dependent.
- It is sensitive to changes in HR and systolic function.
- It does not give information on LV filling.
**Doppler Indices of Diastolic Function**

- Isovolumic relaxation time.
- Transmitral flow.
- Pulmonary vein flow.

**Transmitral Flow**

- Transmitral blood flow velocities are representative of volumetric flow.
- The measured peak velocity is indicative of the relative instantaneous change in pressure between the LA and LV after the opening of the MV.
Technical Considerations
for optimal recording of TM flow

- Sample size should be relatively small, at the leaflet tips to yield higher flow velocities.

- Use color flow Doppler echocardiography to line up the sample volume parallel to flow in the 4-CH view.

- PW Doppler has superior temporal and range resolution than CW Doppler.

- Use the lowest filter settings possible.

- Ask patient to hold normal expiration, avoiding straining and average at least three beats.

Normal Transmitral Flow
Doppler Transmitral Flow

- Peak E wave velocity: 70 – 100 cm/sec.
- Peak A wave velocity: 45 – 70 cm/sec.
- E/A ratio: 1.0 – 2.0
- E deceleration time (DT): 160 – 240 msec.

Abnormal Transmitral Flow

- Stage I: Impaired Relaxation
- Stage II: Pseudo-normalization
- Stage III: Restrictive Filling (Reversible)
- Stage IV: Restrictive Filling (Irreversible)
Impaired LV Relaxation

Clinical Applications

- This pattern has been described in:
  - Patients with LVH due to HTN, AS, hypertrophic cardiomyopathy & obesity heart syndrome.
  - Patients with myocardial ischemic syndromes.
Pseudonormalization

The diagnosis can often be suspected by LA enlargement.

Confirmation of the diagnosis can be made on the basis of abnormal PV flow, abnormal TD annular motion or an abnormal response to the Valsalva maneuver.
Pseudonormalization

Restrictive Pattern
Restrictive Pattern
Clinical Applications

- This pattern has been described in patients with advanced heart failure & in patients with restrictive cardiomyopathy.

- Heart failure patients with this pattern have:
  - poor treadmill performance.
  - higher mortality.

Transmitral Flow
Limitations

- A large number of factors can affect the transmitral flow including age, heart rate, heart rhythm, loading conditions, LV systolic function, atrial function, and mitral valve disease.

- TM flow cannot be used in isolation to assess diastolic function.
Doppler Indices of Diastolic Function

- Isovolumic relaxation time.
- Transmitral flow.
- Pulmonary vein flow.

Normal Pulmonary Venous Flow
Normal Pulmonary Venous Flow

- Peak S wave velocity: 60 ± 15 cm/sec.
- Peak D wave velocity: 40 ± 15 cm/sec.
- Peak S / Peak D ratio: 1.3 – 1.5 (± 0.3).
- Systolic fraction= \( \frac{S_{TVI}}{D_{TVI}} \times 100 = 60 - 68 \pm 10\% \)
- Peak \( A_r \) wave velocity: -32 ± 10 cm/sec.
- \( A_r \) duration: 137 ± 31 msec.
Impaired LV Relaxation

- Higher $S_1$ and $S_2$ peak velocity.
- Lower $D$ peak velocity.
- Higher systolic fraction.
- Variable $Ar$.

Pseudormalisation Pattern

- Lower $S_1$ and $S_2$ peak velocity.
- Higher $D$ peak velocity.
- Lower Systolic fraction.
- Higher $Ar$
**Pulmonary Venous Flow**

Estimation of LA Pressure

\[ \text{LAP} = 35 - 0.39 \times (\text{systolic fraction}) \]

Systolic Fraction < 55% was 91% sensitive & 87% specific for predicting a mean LA pressure >15 mmHg

Kuecherer et al., Circulation 1990; 82: 1127

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**Pulmonary Venous Flow**

Estimation of LVEDP

- An Ar velocity >35 cm/sec & a difference in duration (Ar – A) >30 msec, is highly predictive of a LVEDP > 15 mm Hg.

Rossvol et al. JACC 1993; 21: 1687
Other Markers of Diastolic Function

- Non Invasive Assessment of Tau.
- Color M-mode Propagation Velocity.
- Tissue Doppler Mitral Annular Velocity.
- LA Volume
Non Invasive Measurement of Tau $\tau$

- Normal values: 25 – 40 msec.
- Higher values represent reduced early diastolic distensibility due to slow relaxation.
- It does not however describe events during phases of ventricular filling.
- It is only applicable in patients with a complete MR envelope.

Measurement of “Tau $\tau$ ($T_L$)”
Other Markers of Diastolic Function

- Non Invasive Assessment of Tau.
- Color M-mode Propagation Velocity.
- Tissue Doppler Mitral Annular Velocity.
- LA Volume

Color M-mode Flow Propagation Velocity
Color M-mode
Flow Propagation Velocity

- The slope of the early filling wave front “Vp” is a useful non invasive index of LV relaxation.

- “Vp” < 55 cm/sec in the young or < 45 cm/sec in older individuals identifies impaired LV relaxation.

- It is less affected by preload than TM or PV flow.

Color M-mode
Flow Propagation Velocity

- E/Vp ratio can be used to estimate PCWP.

- PCWP = [5.27 x E/Vp] + 4.6 (in mmHg)

- Positive and negative predictive values for E/Vp > 1.5 to predict PCWP >12 mm Hg were 93% and 70% respectively.
Other Markers of Diastolic Function

- Non Invasive Assessment of Tau.
- Color M-mode Propagation Velocity.
- Tissue Doppler Mitral Annular Velocity.
- LA Volume

Tissue Doppler Mitral Annular Velocity
TD Mitral Annular Velocity

Impaired LV Relaxation
TD Mitral Annular e’ Velocity

- Is related to LV relaxation.
- Reduced and delayed in impaired LV relaxation, relates inversely with the time constant of LV relaxation.
- It is relatively load independent.
- Patients with pseudonormal LV filling are separated from normal by an e’ < 8.5 cm/sec and an e’/a’ ratio < 1.

E/e’ Ratio

- E/e’ > 15 identifies patients with LVEDP >12 mm Hg.
- E/e’ < 8 identifies patients with normal LVEDP.
- PCWP (mm Hg) = 1.24 (E/e’) + 1.9

Nagueh et al., JACC 1997; 30: 1527
**E/e’ Ratio**

- E/e’ should not be used to estimate LV filling in:
  - Normal subjects.
  - Significant annular calcification.
  - Surgical rings.
  - Mitral stenosis.
  - Prosthetic mitral valves.
  - Moderate to severe mitral regurgitation.
  - Constrictive pericarditis.


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**$T_{E-e'} Interval**

- The time interval between the QRS complex and the onset of mitral E velocity is subtracted from the time interval between the QRS complex and e’ onset to derive ($T_{E-e'}$).

- It is advantageous to use:
  - subjects with normal cardiac function
  - those with mitral valve disease
  - when the E/e’ ratio is 8 to 15
\( T_{E-e'} \) Interval

- An IVRT/\( T_{E-e'} \) ratio < 2 has reasonable accuracy in identifying patients with increased LV filling pressures.

- \( \text{Tau } \tau \) (msec) = \( 32 + 0.7 \times (T_{E-e'}) \)


Other Markers of Diastolic Function

- Non Invasive Assessment of Tau.

- Color M-mode Propagation Velocity.

- Tissue Doppler Mitral Annular Velocity.

- LA Volume
LA Volume

- An increase in LA size is a morphologic expression of chronic diastolic dysfunction.

- Although non-specific, it reflects both the duration and severity of the disease.

- LA volume indexed to BSA has both diagnostic and prognostic value.

Novel markers of diastolic function
Global diastolic strain
Novel markers of diastolic function

- **Global diastolic myocardial strain rate:**
  - $\text{SR}_{\text{IVR}}$ has a strong correlation with time constant of LV pressure decay.
  - $\text{SR}_E$ is significantly related to LVEDP.
  - $E/\text{SR}_{\text{IVR}}$ is most useful in patients with $E/e’$ ratio: 8 to 15 and is more accurate than $E/e’$ in patients with normal EF and regional dysfunction.


- **Regional diastolic myocardial strain rate:**
  - to evaluate diastolic stiffness during stunning & infarction.
  - correlates with the degree of interstitial fibrosis.

- **LV twist:**
  - Both rate and extent of untwisting can be quantified.
CONCLUSION

- LV filling is the result of a variety of complex forces.

- No single parameter can be derived that will adequately describe diastolic function.

- Diastolic filling patterns do not remain static in either health or disease.
Thank You