An Integrated Approach to Study LV Diastolic Function

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LV Diastolic Dysfunction

- Normal diastolic function

- LV diastolic dysfunction

Impaired relaxation (early diastole) and ↓ compliance (mid – late diastole) lead to LV resistance to filling, causing LV filling pressures to increase.
Echocardiography in LV Diastolic Dysfunction

Doppler indices

and

2D/M-mode parameters
Echocardiography in the LV Diastolic Dysfunction

- **Diagnosis of the LV diastolic dysfunction**
- Evaluation of LV filling pressure
- Diagnosis of HFNEF
Mitral inflow

Normal values in adults:

- E > A
- DT 140 - 240
- IVRT 70 - 90

Pressure

LV Apex

Normal values age-dependent

LV Filling Rate

Vmax E

Vmax A

IVRT

DT

A dur

Early Filling

Diastasis

Atrial Systole

Pressure (mmHg)

LV Apex

Vmax E

Vmax A

Early Filling

Diastasis

Atrial Systole

LV Filling Rate (ml/sec)

200 msec
Mitral inflow - LV filling patterns

Abnormal Relaxation
- Grade I Mild
- Grade II Moderate
- Grade III Severe

Pseudonormal
- Grading diastolic dysfunction

Restrictive Filling

Worsening diastolic function
Mitral inflow - LV filling patterns

Mitral inflow is load dependent

- **Normal**
- **Pseudonormal**
  - \( \uparrow \text{Tau} \)
  - \( \uparrow \text{LAP} \)
- **Impaired relaxation**
  - \( \downarrow \text{E} \)
- **Worsening diastolic function**
  - \( \uparrow \text{E} \)

\( \text{E} \) and \( \text{A} \) represent early and atrial filling components, respectively.
Mitral annulus velocities – TDI

Ea or e’ is significantly related with LV relaxation
Early mitral annulus velocity – $e'$

$e'$ – can be used as non-invasive index of LV relaxation

Mitral annulus velocities – TDI

- **Limitations of e’**
  - Heavy annular calcification
  - Prosthetic mitral valves
  - Mitral stenosis and regurgitation

- e´ lateral < 10 cm/sec
- e´ septal < 8 cm/sec
Intraventricular colour M-mode flow propagation velocity in early diastole - $V_p$

Colour M-mode - High temporal and spatial resolution
Intraventricular colour M-mode flow propagation velocity - $V_p$

Limits:
small LV volumes / normal EF
Interobserver variability

$V_p < 50$ cm/sec – impaired relaxation

$R = -0.78$

$Y = 592.21x^{-0.6838}$

$p < 0.001$

Pulmonary Venous Flow
Pulmonary venous flow

- S > D
- S < D and Ar > A
- S << D and Ar > A

Abnormal Relaxation
Pseudonormal pattern
Restrictive pattern

Limits: load dependent cannot be obtained in all patients

Appleton CP et al, Heart Failure Clinics 2000
Preload reduction - Valsalva Maneuver

**Normal filling pressure**

Before | After
---|---
\( E \) | \( A \) | \( E \) | \( A \)

\[ \Delta E/A < 0.5 \]

**Delayed relaxation + ↑ LAP**

Before | After
---|---
\( E \) | \( A \) | \( E \) | \( A \) | \( E \)

\[ \Delta E/A > 0.5 \]

Limits: smaller magnitude of change ≠ normal LV diastolic function difficult to obtain

HurrellD et al., J Am Coll Cardiol 1997
Left Ventricular and Left Atrial Remodelling

- LV Hypertrophy
- LA volume index > 34 ml/mp

Dilated LA in the absence of diastolic dysfunction:
- Mitral valve disease
- Atrial fibrillation
- Anemia/high output states
LV Diastolic Dysfunction

- Diagnosis of the LV diastolic dysfunction
- Evaluation of LV filling pressure
- Diagnosis of HFNEF
- Challenging situations
Evaluation of LV filling pressure

Combined indices

- $E/e'$
- $E/Vp$
- $Ar - A$
E/e' and PWCP

E/e’ ratio = most important combined indice to estimate LV filling pressure

Y = 1.9 + 1.24 x
R = 0.87
N=60

Independent of EF
Sinus tachycardia
Atrial fibrillation
HOCM

Nagueh SF et al. J Am Coll Cardiol 1997
E/e' and PWCP

The majority of patients with elevated filling pressure and normal EF were in the group of E/e' between 8-15.
E/Vp and PCWP

E/Vp > 2.5

y = 0.039x + 1.02
r = 0.81
p < 0.001

Lower accuracy in normal EF / small LV

$\Delta$ Time $Ar - A$ and LVEDP

- Duration of $Ar - A$ difficult to measure
- $Ar - A > 30$ msec
- LVEDP $> 15$ mmHg
- Independent of EF and age

Rossvoll, Hatle, J Am Coll Cardiol 1993
GUIDELINES AND STANDARDS

Recommendations for the Evaluation of Left Ventricular Diastolic Function by Echocardiography

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Estimation of filling pressures in patients with depressed EF

Mitral E/A

- E/A < 1 and E ≤ 50 cm/s
  - E/e’ (average e’) < 8
    - E/Vp < 1.4
    - S/D > 1
    - Ar – A < 0 ms
    - Valsalva Δ E/A < 0.5
    - PAS < 30 mmHg
    - IVRT/T_{E-e’} > 2
  - Normal LAP

- E/A ≥ 1 - < 2, or
  - E/A < 1 and E > 50 cm/s
  - E/e’ (average e’) > 15
    - E/Vp ≥ 2.5
    - S/D < 1
    - Ar – A ≥ 30 ms
    - Valsalva Δ E/A ≥ 0.5
    - PAS > 35 mmHg
    - IVRT/T_{E-e’} < 2
  - ↑LAP

- E/A ≥ 2, DT < 150 ms
  - ↑LAP

Nagueh SF et al, JASE and Eur JL Echocard 2009
Estimation of filling pressures in patients with normal EF

E/e' ≤ 8
(Sep, Lat, or Av.)

E/e' = 9-14

LA volume < 34 ml/m²
Ar – A < 0 ms
Valsalva Δ E/A < 0.5
PAS < 30 mmHg
IVRT/T_E-e' > 2

Normal LAP

LA volume ≥ 34 ml/m²
Ar – A ≥ 30 ms
Valsalva Δ E/A ≥ 0.5
PAS > 35 mmHg
IVRT/T_E-e' < 2

↑ LAP

Sep. E/e' ≥ 15
or
Lat. E/e' ≥ 12
or
Av. E/e' ≥ 13

↑ LAP

Nagueh SF et al, JASE and Eur JL Echocard 2009
LV Diastolic Dysfunction

- Diagnosis of the LV diastolic dysfunction
- Evaluation of LV filling pressure
- **Diagnosis of HFNEF**
Diagnosis of Heart Failure with Normal EF

Symptoms or signs of heart failure

Normal or mildly reduced left ventricular systolic function
LVEF > 50%
and
LVEDVI < 97 ml/m²

Evidence of abnormal LV relaxation, filling, diastolic distensibility and diastolic stiffness

Echocardiography – E/e’

E/e’ > 15

- Echo – Doppler
  - E/A < 0,5 and DT > 280 ms
  - Ard-Ad > 30 ms
  - LAVI > 40 ml/m²
  - LVMI > 122 g/m² women
  - >149 g/m² men
  - Atrial fibrillation

15 > E/e’ > 8

↑Natriuretic peptides

HFNEF

Adapted from Paulus WJ, Eur H J 2007
Atrial Fibrillation and Diastolic Dysfunction

- E/e' > 11
- E/Vp > 1.4

Mitral inflow
- DT < 150 ms
- IVRT < 65 msec

PVF
- DT < 220 msec
Diastolic stress test

Normal

Exertional dyspnea and Impaired relaxation/normal filling pressures

Heart failure

 millennials
Conclusions

Comprehensive evaluation of LV diastolic dysfunction consists of the assessment of LV filling and filling pressure together with the left atrial and left ventricular size, morphology and function.

The diagnosis of HFNEF remain challenging and the LV diastolic function can be assessed during exercise stress.

The emerging techniques assessing myocardial deformation and ventricular-arterial coupling will add new insights into the left ventricular and left atrial function.