The importance of left atrium in LV diastolic function

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“The very essence of cardiovascular medicine is recognition of early heart failure.”
Sir Thomas Lewis 1933
**Diastole** is the period in which the myocardium loses its ability to generate force and returns to resting force and length.

**Normal diastolic function** allows the ventricle to fill adequately during rest and exercise, without an abnormal increase in diastolic pressures.

**Diastolic Dysfunction (DD)** refers to a condition in which abnormalities in mechanical function are present during diastole.
The LA *modulates* ventricular filling through its
- reservoir
- conduit
- pump functions

**Left Atrium (LA)**

**Mechanical function:**
is an important determinant of the left ventricular filling process
LA structural characteristics

- the LA wall consist of intermingling circumferential and longitudinal muscular bundles;
- abrupt changes in orientation, and mixed arrangements are common between bundles;
- the LA chamber show myocytes of smaller dimensions and are characterized by the presence of chains of myosine with fetal type expressions (shorter duration of the action potential);
- the LA chamber do not need to exert a particularly strong contractile activity.
Evalution methods of LA function

NON-invasive techniques

- ECG
- TTEcho/TOEcho
- M-mode/Dimension
- Doppler
- TDI
- B-mode/Volume
- 2D-strain
- CT/MRI

Invasive techniques

- Cardiac catheterization
- Pulmonary capillary wedge pressure (PCWP)
- LV end-diastolic pressure (LV EDP)
Left Atrium

Mechanical function

Reservoir ~40%

Conduit ~35%

Contractile ~25%

LA Vol max

LA Vol p

LA Vol min

A-L

SIMPSON
LA phasic function

- **Reservoir**
- **Conduit**
- **Contractile**

**LA Expansion Index (LA EI)**
\[
\text{Expansion index} = \frac{V_{\text{max}} - V_{\text{min}}}{V_{\text{min}}}
\]

**LA Passive Emptying Fraction (LA PEF)**
\[
\text{Passive fraction} = \frac{V_{\text{max}} - V_p}{V_{\text{max}}}
\]

**LA Active Emptying Fraction (LA AEF)**
\[
\text{Active fraction} = \frac{V_p - V_{\text{min}}}{V_p}
\]

LA remodeling and dilatation

I. Pressure and/or Volume overload

Pressure overload

Primary
“Stiff LA syndrome”

Secondary
- MV disease
- LV dysfunction

Volume overload

Acute
MR

Chronic
- Regurgitation
- Arteriovenous fistula
- Chronic anemia
- Athletic heart

II. Elevated LV filling pressure
(develops in most cardiac diseases)

Abnormal LV relaxation

Abnormal LV compliance

Effect of diastolic dysfunction grade on LA volume

- LA volumes and LA function indices vary according to the severity of diastolic dysfunction (DD);
- LA volumes increase;
- LA reservoir and conduit function decrease as the severity of LV DD progresses;
- LA contractile function shows a compensatory augmentation in patients with mild DD;
- As LV diastolic dysfunction worsens, LA contractile function is depressed, resulting in the reduction of LA total emptying volume.

Kyoko Otani et al., Impact of Diastolic Dysfunction Grade on Left Atrial Mechanics Assessed by Two-Dimensional Speckle Tracking Echocardiography. JASE 2010 Vol.23;(9), pp. 961-967.

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LA : dimension and volume (+)

- **LA volume** is a **barometer of LV filling** pressure and reflects the burden of DD;

- **LA max volume index \( \geq 34 \text{ mL/m}^2 \)** is an **independent predictor** of death, heart failure, atrial fibrillation, and ischemic stroke* (6657 patients);

- **Left atrial size** is certainly easy to assess and **LA volume** is superior to LA diameter as a measure of LA size*.

LA : dimension and volume (-) limitations

- LA size represents the integration of LV diastolic performance over time (!);

- ageing is associated with LA dilatation¹;

- LA max volume index provided excellent sensitivity and specificity for the detection of severe (grade III or IV) DD, BUT sensitivity and specificity for detection of mild or moderate (grade I or II) DD were less robust².

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Doppler echocardiography is widely used for the noninvasive assessment of diastolic filling of the left ventricle;

analysis of the mitral inflow, pulmonary vein flow velocity curves has provided useful information for determination of filling pressures;

In 1982, Kitabatake first described the transmitral flow velocity curves obtained with Doppler echocardiography in different disease states.
LA : Doppler-derived measurements (-)

- these techniques present **only a snapshot (at that moment)** view of diastolic function—the pattern would be altered if loading conditions changed;

- **mitral flow is dependent** on multiple interrelated factors, including the rate, age, loading conditions of the left ventricle. Different flow patterns may be seen only hours to days apart in the same person, depending on the left ventricular preload;

- **pseudonormal LV filling** (+ one major limitation of the Valsalva maneuver is that not everyone is able to perform this maneuver adequately, and it is not standardized);

- **pulmonary venous flow** may not be obtained on every patient;

- **too many** parameters.
• The ratio of mitral velocity to early diastolic velocity of the mitral annulus (E/E`) showed a better correlation with M-LVDP than did other Doppler variables for all levels of systolic function.

• E/E` < 8 accurately predicted normal M-LVDP

• E/E` > 15 identified increased M-LVDP.
TISSUE DOPPLER VELOCITY IMAGING and LA VOLUME

- In patients with **preserved LVEFs**, adding **LAVi > 31 mL/m2 to E/e’** (when E/e’ was in the gray zone, but not when E/e’ was >13) significantly increased the accuracy of E/e’ alone for the estimation of LV filling pressure. (sensitivity 87%, specificity 88%)

\[ E/E' = 8-13 + \text{LA max vol ind} >31 \text{ ml/m}^2 \]

\[ \uparrow \text{LV filling pressure} \]

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Hisham Dokainish et al. Do Additional Echocardiographic Variables Increase the Accuracy of E/e’ for Predicting Left Ventricular Filling Pressure in Normal Ejection Fraction? An Echocardiographic and Invasive Hemodynamic Study

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TISSUE DOPPLER VELOCITY IMAGING (-)

- **Wide variability** with E/E' of 8 to 15 (grey zone).
- **E` velocity** is usually **reduced** in patients with significant annular calcification, surgical rings, mitral stenosis, and prosthetic mitral valves.
- **In patients** with advanced systolic heart failure (EF<35%), mean E/E' ratio may not be a useful index to estimate filling pressures;

**Figure 6.** M-LVDP versus groups defined by values of septal E/E'. ○ Indicates patients with EF <50%; ●, patients with EF >50%.

Matteo Cameli et al. *Left atrial longitudinal strain by speckle tracking echocardiography correlates well with left ventricular filling pressures in patients with heart failure.* Cardiovascular Ultrasound 2010, 8:14.
LA Myocardial deformation

- An **alternative method** of exploring LA function;

- **Strain and strain rate (SR)** imaging have emerged as a quantitative technique to accurately estimate myocardial function and contractility*.

### LA myocardial deformation assessment

#### Doppler vs. Non-Doppler

<table>
<thead>
<tr>
<th>Feature</th>
<th>Doppler</th>
<th>Non-Doppler</th>
</tr>
</thead>
<tbody>
<tr>
<td>Angle independency</td>
<td>+</td>
<td>-</td>
</tr>
<tr>
<td>Frame rate</td>
<td>115-300 fps</td>
<td>35-90 fps</td>
</tr>
<tr>
<td>«tethering»</td>
<td>+</td>
<td>-</td>
</tr>
</tbody>
</table>

**Diagram:**
- **Doppler Tissue Velocity Imaging (TVI):**
  - Ultrasound beams visualized.
  - Color scale indicating tissue velocity.
- **Non-Doppler 2D Strain Imaging:**
  - Different visualization method.
  - Color scale showing strain.

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**TDI**

- **regional** LA deformation (+)
- only **longitudinal** function (-)
- suboptimal reproducibility (-)
- time-consuming: ~ 10 min./1 pat. (-)

**2D-strain**

- **regional** and **global** LA deformation (+)
- **longitudinal** and **radial** function (+)
- good reproducibility (+)
- time: ~ 1-3 min./1 pat. (+)
- no special software for LA analysis (-)
Two-dimensional Speckle Tracking (2D-strain): LA longitudinal function

6 LA segments
Left atrial longitudinal strain curves (%)

- peak atrial longitudinal strain (regional - PALS)
- peak averages strain (for 6 LA segments - averages PALS)
- global strain (4CH and 2CH averages ε – global PALS)
Correctness of 2D-strain

- This study demonstrates that 2D-strain is not influenced by global heart motion and tethering from adjacent segments.
Correlation between LV end-diastolic pressure (LVEDP) and Peak LA strain during reservoir phase

- > 45 % PALS (cut-off value) : normal LVEDP
- <30 % PALS (cut-off value) : ↑ LVEDP

- 101 patients (Age (y) 66±9 (31-84))
- EF 58 ± 16 % (19-84)

LA longitudinal strain by 2D-strain correlates well with LV filling pressures in patients with heart failure.

• 36 patients c EF ≤ 35 %

Matteo Cameli et al. *Left atrial longitudinal strain by speckle tracking echocardiography correlates well with left ventricular filling pressures in patients with heart failure.* *Cardiovascular Ultrasound* 2010, 8:14.

Strain cut-off value 15.1%.

**Figure 2.** Pulmonary capillary wedge pressure (mmHg) vs. Global Atrial Longitudinal Strain (%)

- Sensitivity 100%
- Specificity 93%

**Figure 3.** Pulmonary capillary wedge pressure (mmHg) vs. E/E ratio

- R = -0.8070
  - p < 0.0001

- R = 0.1487
  - p = ns
LA longitudinal strain (reservoir phase): physiological or pathological left ventricular hypertrophy

- Controls (25)
- Athletes (45)
- Hypertensive (40)

41-46 y

LA diameter 40-42 мм

Peak LA longitudinal strain (lateral wall LA)

- 47,3 % ±15,6
- 51,3 % ±17,9
- 37,2 %* ±15,6

*p<0.0001: Patients with hypertension vs controls and athletes.

Left atrial myocardial function in either physiological or pathological left ventricular hypertrophy: a two-dimensional speckle strain study.

Conclusions

- **LA function** is an important determinant of the **LV filling process**.

- **The E/E` ratio** was the single best predictor of LV filling pressure but **did not** have adequate discriminatory power to be used in isolation.

- **The LA volume** is a biomarker of chronic diastolic dysfunction and cardiovascular disease risk.

- **Strain** measurements **by speckle tracking** appear to have good reproducibility and can be applied to study segmental and global deformation and to address mechanistic issues.

- The report should include a conclusion on LV filling pressures and the presence and grade of diastolic dysfunction.
No Diastole, No Sistole

dr. Kalinin :-)

Thanks for Your Attention