THE LEFT ATRIUM – HOW CAN ECHO HELP US?

Dr. Dragos COZMA
BACKGROUND

- Left atrium (LA) dilation can occur in a broad spectrum of cardiovascular diseases including hypertension, left ventricular dysfunction, mitral valve disease and AF.

- In general, two major conditions are associated with LA dilation: pressure and volume overload.
• The pulmonary veins (PV) in the human heart enter the LA at the four “corners”

• “pillow shaped” human LA

LA muscular fibers extend to the PV !!!
BACKGROUND - LA dilation

dilation "stretch" of the PV – electroanatomical substrate for AF

WHERE?
BACKGROUND - LA dilation

- Altered load => changes in myocardial segment length => stretch and progressive geometrical rearrangement of myocytes, restructuring of the atrial wall and changing of atrial shape

- The electroanatomical substrate of dilated atria is characterized by increased non-uniform anisotropy and slowing of conduction, promoting reentrant circuits.

Cozma et al PACE 2005
CARDIAC PERFORMANCE AND LA

As the outer contour of the heart is relatively constant, as is the apex, and the atria is attached to the PV, the atrioventricular plane has to be the piston of a reciprocating pump expanding the atria while the ventricle shortens.

LA performance is complex and includes functioning as a reservoir, conduit, and booster pump at different stages of the cardiac cycle.
LA/LV VOL VARIATION & CARDIAC CYCLE

deformation of both chambers are reciprocating,

- **Rezervoir** LA filling during LV systole
- **Conduit** LA emptying while passive LV filling
- **Booster pump** LA emptying while active LV filling
WHY SHOULD WE MEASURE LA?

Close correlation between LA volume and the severity of diastolic dysfunction
WHY SHOULD WE MEASURE LA?

• LA enlargement is a significant predictor of death in both men and women.


• Patients with a severely increased LA (>40 ml/m²) have the highest risk for the development of cardiovascular events.

HOW TO EVALUATE LA dilation?
DIMENSIONS

PARASTERNAL LA

the Framingham Heart study. Circulation 1994

Long-axis section through heart approximating to the two chamber echocardiographic parasternal plane.
Other LA linear dimensions

- short- and long-axis (lateral and superoinferior) dimensions in apical four chamber view (inner edge to inner edge)
LA area

two-dimensional planimetry in the apical 4-chamber view by tracing the endocardial border cavity
LA VOLUME
The ellipsoid model assumes that the LA can be adequately represented as a prolate ellipse

\[ \frac{\pi}{6} (D_1 \times D_2 \times D_3) \]
LA VOLUME ellipsoid model

- Volume determined using linear dimensions is very dependent on selection of the location and direction of the minor axis dimensions.

- has been shown to significantly underestimate (~40%) LA volume.
**LA VOLUME**

**biplane area-length formula**

\[ 8\pi L/3 \times (A_1 \times A_2) \]

A1 and A2 represent the maximal planimetered LA area apical 4-2 C-views. L - LA long-axis length.

Rodevan O, Int J Cardiovasc Imaging 1999
The volume of the entire LA can be derived from the sum of the volume of the individual disks.

The formula is integrated with the aid of a computer and the calculated volume provided by the software package online.

Khankirawatana B, Am Heart J 2004
LA VOLUME

- Three-dimensional echocardiography should provide the most accurate evaluation of LA volume and has been validated against MRI.

  Khankirawatana B, J Am Soc Echocardiogr 2002

- However to date no consensus exists on the specific method that should be used for data acquisition and there is no comparison with established normal values.
### Limits Reference

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Reference Range</th>
<th>Mildly Abnormal</th>
<th>Moderately Abnormal</th>
<th>Severely Abnormal</th>
</tr>
</thead>
<tbody>
<tr>
<td>Atrial dimensions</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>LA diameter (cm)</td>
<td>2.7 – 3.8</td>
<td>3.9 – 4.2</td>
<td>4.3 – 4.6</td>
<td>≥4.7</td>
</tr>
<tr>
<td>LA diameter/BSA (cm/m²)</td>
<td>1.5 – 2.3</td>
<td>2.4 – 2.6</td>
<td>2.7 – 2.9</td>
<td>≥3.0</td>
</tr>
<tr>
<td>RA minor axis dimension (cm)</td>
<td>2.9 – 4.5</td>
<td>4.6 – 4.9</td>
<td>5.0 – 5.4</td>
<td>≥5.5</td>
</tr>
<tr>
<td>RA minor axis dimension/BSA (cm/m²)</td>
<td>1.7 – 2.5</td>
<td>2.6 – 2.8</td>
<td>2.9 – 3.1</td>
<td>≥3.2</td>
</tr>
<tr>
<td>Atrial area</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>LA area (cm²)</td>
<td>≤20</td>
<td>20 – 30</td>
<td>30 – 40</td>
<td>&gt;40</td>
</tr>
<tr>
<td>Atrial volumes</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>LA volume (ml)</td>
<td>22 – 52</td>
<td>53 – 62</td>
<td>63 – 72</td>
<td>≥73</td>
</tr>
<tr>
<td>LA volume /BSA (ml/m²)</td>
<td>22 ± 6</td>
<td>29 – 33</td>
<td>34 – 39</td>
<td>≥40</td>
</tr>
</tbody>
</table>

Lang et al, Eur J Echocardiography 2006
Indexed LA volume is a more robust cardiovascular risk marker than LA area or diameter in patients who are in sinus rhythm. However, in patients with AF, the predictive utility of LA size for future cardiovascular events seemed unsatisfactory.

Why?
LA real shape
Real border LA - PV
PV antrum
LA real shape?
LA size-shape & vulnerability to AF

D. Cozma, B.A. Popescu et al
PACE 2007
WHEN IS LA IMPORTANT?

• in the presence of a normal LV, impairment of LA contraction has little effect on cardiac output, because conduit function compensates for atrial and ventricular filling.

In contrast, 

• in the presence of early LV dysfunction, when atrial booster pump and reservoir functions are increased, impairment of atrial contraction causes a decrease in cardiac output because atrial conduit function is unable to provide compensatory atrial and ventricular filling.
HOW TO EVALUATE LA FUNCTION?
CONVENTIONAL MITRAL Doppler

ECG

Doppler mitral

LV pres

Contractie VS

Relaxare VS

Suctiune

LV filling

DT

A dur

Contractie AS

R

C

B
• Ratio E/A (N. V. 1-2)
• VTI mitral / VTI A
• A wave Deceleration Time (N.V. 60-100ms) LV EDP >18 mmHg if A DT wave < 60ms; (sens: 89% - spec: 100%)
• Duration mitral A wave (Am)

Tenenbaum A, J Am Coll Cardiol. 1996
- S/D ratio
- (normal > 1)

- PV A wave (normal < 35 cm/s)
- Duration A wave PV flow (normal Ap < Am)
- Ap > Am coresponds to LV EDP > 15 mmHg, sens 85%, spec 79%

Rossvoll O, Hatle LK J Am Coll Cardiol. 1993
TDI mitral anulus / LA walls

N. V. E’> A’
LV DYSFUNCTION PROGRESSION

Cheuk-Man Yu  Progression of Systolic Abnormalities in Patients With "Isolated" Diastolic Heart Failure and Diastolic Dysfunction  Circulation. 2002
Recommendations for the Evaluation of Left Ventricular Diastolic Function by Echocardiography

Estimation of Filling Pressures in Patients with Normal EF

- **E/e’ ≤ 8** (Sep, Lat, or Av.)
- **E/e’ 9-14**
- **Sep. E/e’ ≥ 15** or **Lat. E/e’ ≥ 12** or **Av. E/e’ ≥ 13**

**LA volume < 34 ml/m²**
- Ar – A < 0 ms
- Valsalva Δ E/A < 0.5
- PAS <30 mmHg
- IVRT/TE-e’ > 2
- Normal LAP

**LA volume ≥ 34 ml/m²**
- Ar – A ≥ 30 ms
- Valsalva Δ E/A ≥ 0.5
- PAS >35 mmHg
- IVRT/TE-e’ < 2
- ↑ LAP
Practical Approach to Grade Diastolic Dysfunction

- **Septal e' ≥ 8**
  - **Lateral e' ≥ 10**
  - **LA < 34 ml/m2**
    - Normal function
- **Septal e' ≥ 8**
  - **Lateral e' ≥ 10**
  - **LA ≥ 34 ml/m2**
    - Normal function, Athlete’s heart, or constriction
- **Septal e' < 8**
  - **Lateral e' < 10**
  - **LA ≥ 34 ml/m2**
    - E/A < 0.8
      - DT > 200 ms
      - Av. E/e' ≤ 8
      - Ar-A < 0 ms
      - Val ∆E/A < 0.5
      - Grade I
    - E/A 0.8-1.5
      - DT 160-200 ms
      - Av. E/e’ 9-12
      - Ar-A ≥ 30 ms
      - Val ∆E/A ≥ 0.5
      - Grade II
    - E/A ≥ 2
      - DT < 160 ms
      - Av. E/e’ ≥ 13
      - Ar-A ≥ 30 ms
      - Val ∆E/A ≥ 0.5
      - Grade III
Currently, Doppler echocardiography is used for LA function definition.

But there are significant limitations concerning the relation between LA dilation and booster pomp.

R / C / B phases descriptions are incomplete.
LA VOLUME VARIATION - ABD

Automatic Border Detection

Limitations: accuracy of LA borders.

Advantages:
- LA vol variation curves (complete evaluation R C B)
- Good temporal resolution (better than manual measurement which is time consuming)

K T Spencer et al *Heart* 2001
LA VOL VARIATION derived parameters:

**Total LA EF**
(max vol − min vol / max vol),

**Active LA EF**
(atrial presystolic vol − min vol /atrial presystolic vol).

MAX VOL - MIN VOL = reservoir
MAX VOL − PRESYST VOL = conduit
Active LA EF − informations concerning LA contractility
66% LA emptying is passive / 34% active
LA VOL VARIATION

Parox AF pts: increased LA active contractile function, with upward shift of the volume variation curves suggesting pseudonormal mitral pattern

D. Cozma et al, Eur J Echocard 2004 (abstr)
STRAIN – *is the mean relative deformation*

\[ \frac{\Delta v}{L_0} = \frac{v_1 - v_2}{L_0} \]

Strain - = shortening
Strain + = lengthening

*strain rate = speed at which deformation - strain occurs*
LA STRAIN / STRAIN RATE & R/C/B

Strain + = lengthening

Strain - = shortening

because of its thin wall, strain rate imaging in the atria is extra prone to artifacts due to low lateral resolution
LA STRAIN & R/C/B

left atrial longitudinal strain is reduced in HCM patients

I A Paraskevaidis, et al Heart 2009
Reduced LA reservoir function markedly increases the propensity for first AF episode, independent of LA volume, left ventricular function, and clinical risk factors.

Abhayaratna WP, Am J Cardiol. 2008
LA PROGNOSTIC ROLE
85% of strokes occur in SR!!

American Heart Association. Heart Disease and Stroke Statistics–2005 Update

LA vol – predictor of first ischemic stroke

LA and HF

Increased LA size is associated with the new development of HF in old subjects without valvular heart disease and normal ejection fraction

Gottdiener JS, et al Am J Cardiol 2006
LA & heart surgery

LA dilation is predictor of postoperative mortality

- after mitral valvular replacement in symptomatic pts with mitral regurgitation
  Reed D, et al Circulation 1991

- LA size has predictive value for outcome in pts with Ao stenosis
  Rossi A et al Am J Cardiol 2000
LA in patients with low EF

Pts EF ≤ 35%,
LA dilation = independent predictor of mortality of any cause
and has prognostic value additional to demographic, clinical, and conventional ecocardiographic data

LA size & DCM /AMI

Restrictive and Dilated CM - prognostic value for survival

Ammash N Met al Circulation 2000

Increased left atrial volume is a powerful predictor of mortality after acute myocardial infarction and provides prognostic information incremental to clinical data and conventional measures of LV systolic and diastolic function.

• Single measurement of LA parasternal dimension is not acceptable to assess LA dilation

• It is generally recommended to measure LA volume

• LA function may be assessed using conventional mitral Doppler / TDI / strain / volume variation

• LA has prognostic value and correlates to LV dysfunction
“LA size represents the integration of LV diastolic performance over time”

“Drawing a parallel to two of the most commonly used diagnostic tests in diabetes is nearly irresistible. Just as serum glucose is used to assess transient diabetic control, LV filling pressure is used to assess transient loading conditions. In turn, the diastolic function corollary of measurement of hemoglobin A1C (a long-term biomarker of average metabolic state) is LA size (a long-term biomarker of average LV diastolic pressure, and hence, when increased, of diastolic dysfunction).”

Pamela S. Douglas