Ins and Outs of the Atria

San Antonio Echocardiography Society

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UTHSCSA and STVAHCS
Atrial Echo: The Ins and Outs

- Atrial Anatomic review
- Atrial size
- Atrial function by echo
- Inflow and outflow
Atrial Anatomy
Connections of Atria

Right atrium

- IVC
- SVC
- Coronary sinus
- Thebesian veins
- (ASD)
- Tricuspid Valve

Left atrium

- Four pulmonary veins
- (ASD)
- Mitral Valve

Interatrial septum
LA is not seen in this anterior view

RA Appendage

Anterior AV groove

Clemente CD. Anatomy 3rd Ed, 1987, fig 188.
The Heart, Posterior View

Veins

Oblique pericardial sinus


Sobotta Atlas, 13th Ed, 2000, vol 2, p. 77
Sondegaard’s Groove, Waterston’s groove, interatrial groove
Base of Heart
Posterior View
Right Atrial Structures

- RA appendage
- Christa Terminalis
- Membranous Septum
- Fossa ovalis
- Eustachian valve
- Thebesian valve
sulcus terminalis and RA Appendage
Interatrial septum: Waterston’s groove
Right Atrium

Arrowheads indicate sulcus terminalis, the outside corresponding to the crista terminalis on the inside.


Figure 1  A. Panoramic view of the posterolateral wall of the right atrium based on the right oblique view of the fluoroscope (Heart 2). Arrowheads indicate the sulcus terminalis, the probable junction between the sinoatrial node and the sinus venosus. The frame containing the SVC, IVC, and the posterolateral free wall indicates the subject area of this study and is the area of the right atrium removed for tissue preparation. B. Endocardial aspect of the excised tissue based on the left oblique view of the fluoroscope. The crista terminalis is unfolded from its originally curved shape. The entire crista terminalis (arrowheads) lies between the pectinate muscles and the sinus venosus. The crista terminalis and its adjacent musculature were cut into sections 10-mm thick and perpendicular to the longitudinal axis, as shown. Because the inferior border of the crista terminalis was unclear in some cases, we defined it as the first bifurcation from the main trunk (dotted line). ANT = anterior, CT = crista terminalis, FO = foramen ovale, IVC = inferior vena cava, LAT = lateral, PM = pectinate muscle, POST = posterior, RA = right atrium, RAA = right atrial appendage, RSPV = right superior pulmonary vein, SVC = superior vena cava, SV = sinus venosus. Bar = 10 mm.
Left atrial appendage under the pulmonary artery and in front of pulmonary veins and over the LV
Arrow indicates Chiari network.
Fibrous Skeleton of the Heart
Right brachiocephalic vein
Right lung
Arch of aorta
Right auricle
Right atrium
Diaphragm
Liver

Left lung
Pulmonary trunk
Aortic valve
Circumflex branch of left coronary artery
Left ventricle
Right ventricle
Fundus of stomach
“Venous Cross”

Westberg’s space: the space between the pericardium and the beginning of the aorta (Dorland’s Medical Dictionary)
Echocardiography of the Atria
### Table 2 Sample acquisition protocol

<table>
<thead>
<tr>
<th>Red</th>
<th>Blue</th>
</tr>
</thead>
<tbody>
<tr>
<td>PLAx*</td>
<td>Ap5Ch (AV zoom)*</td>
</tr>
<tr>
<td>PLAx (MV/AV zoom)*</td>
<td>Ap2Ch*</td>
</tr>
<tr>
<td>RV inflow*</td>
<td>ApLAX*</td>
</tr>
<tr>
<td>RV outflow*</td>
<td>ApLAX (MV/AV zoom)*</td>
</tr>
<tr>
<td>PSAx (AV)*</td>
<td>SCLAX*</td>
</tr>
<tr>
<td>PSAx (MV)*</td>
<td>SCSAx</td>
</tr>
<tr>
<td>PSAx (LV)</td>
<td>SSAoArch*</td>
</tr>
<tr>
<td>PSAx (Apex)</td>
<td>PW: MV, LVOT, TV</td>
</tr>
<tr>
<td>Ap4Ch*</td>
<td>RVOT, PV, HV</td>
</tr>
<tr>
<td>Ap4Ch (MV zoom)*</td>
<td>CW: MV, AV, TV, PV</td>
</tr>
<tr>
<td>Ap4Ch (TV zoom)*</td>
<td>M-Mode sweeps</td>
</tr>
</tbody>
</table>

A total of 33 loops (15:1 JPEG ≈ 1.5 MB) + 10 stills (RLE, 200 kB); 50-MB/study × 180 studies/day = 9 GB/day = 2 terabytes/year.

AV, Aortic valve; Ap2Ch, apical 2-chamber; Ap4Ch, apical 4-chamber; Ap5Ch, apical 5-chamber; ApLAX, apical long axis; CW, continuous-wave; HV, hepatic veins; LV, left ventricle; LVOT, left ventricular outflow tract; MV, mitral valve; PLAx indicates parasternal long axis; PSAx, parasternal short axis; PV, pulmonic valve; PW, pulsed-wave; RV, right ventricle; RVOT, right ventricular outflow tract; SSAoArch, suprasternal notch aortic arch; SCLAX, subcostal long axis; SCSAx, subcostal short axis; and TV, tricuspid valve.

*2D + color.
Technical Aspects of Chamber Size Quantitation

• Reviews the technical aspects on how to perform quantitative chamber measurements
• Not intended to describe the standard of care of which measurements should be performed in individual clinical studies.
• However, evaluation of chamber size and function is a component of every complete echocardiographic examination and these measurements may have an impact on clinical management.

### Table 1. Elements of image acquisition and measurement for 2-dimensional quantitation

<table>
<thead>
<tr>
<th>Aim</th>
<th>Method</th>
</tr>
</thead>
<tbody>
<tr>
<td>Minimize translational motion</td>
<td>Quiet or suspended respiration (at endexpiration)</td>
</tr>
<tr>
<td>Maximize image resolution</td>
<td>Image at minimum depth necessary</td>
</tr>
<tr>
<td></td>
<td>Highest possible transducer frequency</td>
</tr>
<tr>
<td></td>
<td>Adjust gains, dynamic range, transmit, and lateral gain controls</td>
</tr>
<tr>
<td></td>
<td>appropriately</td>
</tr>
<tr>
<td></td>
<td>Frame rate $\geq 30$/s</td>
</tr>
<tr>
<td></td>
<td>Harmonic imaging</td>
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<tr>
<td></td>
<td>B-color imaging</td>
</tr>
<tr>
<td>Avoid apical foreshortening</td>
<td>Steep lateral decubitus position</td>
</tr>
<tr>
<td></td>
<td>Cut-out mattress</td>
</tr>
<tr>
<td></td>
<td>Avoid reliance on palpable apical impulse</td>
</tr>
<tr>
<td>Maximize endocardial border</td>
<td>Contrast enhancement delineation</td>
</tr>
<tr>
<td>Identify end diastole and end systole</td>
<td>Mitral valve motion and cavity size rather than reliance on ECG</td>
</tr>
</tbody>
</table>

*ECG, Electrocardiogram.*
Reporting Chamber Size

- **LA:** Normal, Mild, moderate, severe dilation, elongation, volume or dimensions
- **RA:** Normal, Mild, moderate, marked enlargement, or small
- **Summary echo report should include:**
  - Answer to the clinical question
  - Emphasis of abnormal findings
  - Comparison to prior studies if available or relevant

Right Atrium – Size

• Quantification of RA size is most commonly performed from A4C. The minor-axis dimension should be taken in a plane perpendicular to the long axis of the RA and extends from the lateral border of the RA to the interatrial septum. Although RA dimension may vary by sex, no separate male and female reference values can be recommended at this time.

Right Atrial Size

Report of the ASE Committee on Nomenclature and Standards in Two-dimensional echocardiography
Right Atrium – Volume

- There are no standard orthogonal RA views to use an apical biplane calculation, so the single plane area-length and method of disks formulas have been applied to RA volume determination in several small studies. There is too little peer-reviewed validated literature to recommend normal RA volumetric values at this time. However, limited data on a small number of healthy individuals revealed that indexed RA volumes are similar to LA normal values in men (21 mL/m\(^2\)) but appear to be slightly smaller in women.

**Values for Right Atrial Enlargement**

<table>
<thead>
<tr>
<th>Normal</th>
<th>Mild</th>
<th>Moderate</th>
<th>Severe</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.7-2.5</td>
<td>2.6-2.8</td>
<td>2.9-3.1</td>
<td>≥3.2</td>
</tr>
</tbody>
</table>

Right atrium minor axis dimension; men or women

Units: cm/M^2 (indexed for BSA)

Right Atrial Pressure
IVC Echocardiography

- Technique: Image in subcostal window, in long axis, measure about 1-2 cm from RA-IVC junction, with respiration or with brief sniff

- Findings
  - IVC<1.7 cm, >50% decrease with sniff – RA = 0-5 mmHg
  - IVC>1.7 cm, >50% decrease with sniff – RA = 6-10 mmHg
  - IVC>1.7 cm, <50% decrease with sniff – RA = 10-15 mmHg
  - IVC>1.7 cm, no decrease with sniff – RA = 16-20 mmHg

Left Atrium - Size
Measurement of LA volume from area-length \((L)\) method using A4C and A2C views at ventricular end systole (maximum LA size). \(L\) is measured from back wall to line across hinge points of mitral valve. Shorter \(L\) from either A4C or A2C is used in equation.

\[
\text{Left Atrial Volume} = \frac{8}{3\pi} [(A_1)(A_2)/(L)]^{*} \times 0.85 A_1 A_2 / L
\]

\(* (L)\) is the shortest of either the A4C or A2C length.

Left Atrium - Size

Measurement of LA volume from biplane method of disks (modified Simpson’s rule) using A4C and A2C views at ventricular end systole (maximum LA size). NOT PREFERRED.

Three-dimensional echocardiography should provide the most accurate evaluation of LA volume and has shown promise; 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.


Left Atrial Size

LA volume by biplane area–length (AL) method. \( A_{2C} = \) maximum planimetered area in apical 2-chamber view; \( A_{4C} = \) maximum planimetered area in apical 4-chamber view; \( L = \) average of \( L_{4C} \) and \( L_{2C} \); \( L_{2C} = \) length in 2-chamber view; \( L_{4C} = \) length in 4-chamber view.

\[
LA volume_{AL} = \frac{8 \times A_{4C} \times A_{2C}}{3 \pi L} \\
= \frac{0.85 \times A_{4C} \times A_{2C}}{L}
\]

Left Atrial Size

LA volume by Simpson’s method of disc summation. D1 and D2 = orthogonal major and minor axes of the discs; h = height of the discs

Left Atrial Size

LA volume by prolate-ellipsoid (PE) method. D1 = anteroposterior dimension measured from the parasternal long-axis view; D2 = width (or minor axis) of 4-chamber view; D3 = perpendicular length (major axis) of 4-chamber view

\[
\text{LA volume}_{PE} = \frac{4}{3} \pi \left( \frac{D_1}{2} \times \frac{D_2}{2} \times \frac{D_3}{2} \right)
\]

\[
= 0.523 \times D_1 \times D_2 \times D_3
\]

Left Atrial Size

A: Biplane Area-Length minus Simpson’s, mL/m²

B: Biplane Area-Length minus Prolate, mL/m²

Normal Values for Atrial Size

### Table 9 Reference limits and partition values for left atrial dimensions/volumes

<table>
<thead>
<tr>
<th></th>
<th>Women</th>
<th></th>
<th></th>
<th></th>
<th>Men</th>
<th></th>
<th></th>
<th></th>
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</thead>
<tbody>
<tr>
<td></td>
<td>Reference range</td>
<td>Mildly abnormal</td>
<td>Moderately abnormal</td>
<td>Severely abnormal</td>
<td>Reference range</td>
<td>Mildly abnormal</td>
<td>Moderately abnormal</td>
<td>Severely abnormal</td>
</tr>
<tr>
<td>Atrial dimensions</td>
<td></td>
<td></td>
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<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>
<td>3.0–4.0</td>
<td>4.1–4.6</td>
<td>4.7–5.2</td>
<td>≥5.2</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>
<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>
<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>
<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>
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<td></td>
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<td></td>
<td></td>
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<tr>
<td>LA area, cm²</td>
<td>≤20</td>
<td>20–30</td>
<td>30–40</td>
<td>&gt;40</td>
<td>≤20</td>
<td>20–30</td>
<td>30–40</td>
<td>&gt;40</td>
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<tr>
<td>Atrial volumes</td>
<td></td>
<td></td>
<td></td>
<td></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>
<td>18–58</td>
<td>59–68</td>
<td>69–78</td>
<td>≥79</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>
<td>22 ± 6</td>
<td>29–33</td>
<td>34–39</td>
<td>≥40</td>
</tr>
</tbody>
</table>

BSA, Body surface area; LA, left atrial; RA, right atrial.
Bold italic values: Recommended and best validated.

Values for Left Atrial Enlargement

<table>
<thead>
<tr>
<th></th>
<th>Normal</th>
<th>Mild</th>
<th>Moderate</th>
<th>Severe</th>
</tr>
</thead>
<tbody>
<tr>
<td>Units: mL/M$^2$</td>
<td>≤22±6</td>
<td>29-33</td>
<td>34-39</td>
<td>≥40</td>
</tr>
</tbody>
</table>

Left atrium; men or women

Left Atrial Size

NI, mild, mod, severe

16-28, 29-33, 34-39, ≥40 mL/m²

Atrial Ins and Outs in Heart Failure


Atrial Function

• Poorly defined
• Atrial systolic wall motion
  – Afterload, preload, contractility
  – M-mode aortic root
  – Atrial ejection fraction
  – Atrial filling fraction of LV
• Inflow tract atrial velocity
  – P wave required for atrial systolic function
  – Peak A wave
  – A wave VTI

Atrial Function

- Atrial Active transport
- Atrial conduit

Figure 1  Left atrial pressure-volume loops from three variably loaded beats in a control dog (A) and in a dog with pacing induced heart failure (B). The A loop represents active atrial contraction. The V loop represents passive filling and emptying of the left atrium. Loops are computer smoothed for clarity.

Atrial Function

- In Humans
- LA area by echo

Atrial Inflows and Outflows
Comparing Atrial Inflow Patterns

- Hepatic vein
- IVC
- SVC
- Coronary sinus
- ASD
- Pulmonary vein

Pulmonary Venous Flow

From Rossvoll O et al. (Hatle) J Am Coll Cardiol 1993;21:1687
Pulmonary Venous Flow Pattern

- **LV preload and systolic and diastolic function**
  - Increased LA pressure - lower S if LV systolic dysfunction, (more S if LV systolic function is preserved)
  - Impaired relaxation – larger S and lower D, corresponding to lower MV E
  - Pseudonormal – lower S and dominant D wave and larger Ar wave (lower LV compliance)
  - Restrictive – low S and large D and rapid D deceleration, Ar is variable

- **Age** increases systolic dominance and maybe Ar
- **Mitral regurgitation*** reduces S wave, reverses if severe MR
- **Large ASD** causes single continuous antegrade wave and diminished AR wave**

Normal Pulmonary Vein PW Doppler Patterns

S - systolic
D - diastolic
$S_E$ - early systolic atrial relaxation
$S_L$ - late systolic descent of MV annulus
$A_r$ - atrial reversal
$S_i$ - systolic integral
$D_i$ - diastolic integral

Smith, MD, in Otto, 2002, p. 123
Comparing Atrial Outflow Patterns

- Mitral flow
- Tricuspid flow
Right Atrial Normal Variants

- Eustachian valve (RVIT view)
- Chiari network
- Prominent crista terminalis
Right Atrial Abnormalities - 1

• Tumor – primary or metastatic
  – Primary – myxoma (15% of myxomas are in the RA, typical origin from atrial septum near fossa ovalis), sarcoma
  – Metastatic – hypernephroma, hepatoma, testicular sarcoma

• Thrombus (native or on catheter)
Right Atrial Abnormalities - 2

• Congenital
  – (cor triatriatum dexter)
  – Prominent drainage from coronary sinus due to persistent left SVC
  – Anomalous pulmonary venous connection (partial or complete)
  – IVC interruption with azygous continuation
  – Tricuspid atresia
Left Atrial Abnormalities

- Tumor (primary or metastatic)
- Thrombus (appendage or other)
- Congenital
  - cor triatriatum (sinister)
  - Supravalvular mitral stenosis
  - Congenital mitral stenosis (Shone’s syndrome)
Interatrial Septum

- Atrial septal defect – secundum, primum, sinus venosus (absent septum – single atrium)
- Patent foramen ovale
- Atrial septal aneurysm
- Lipomatous hypertrophy of the interatrial septum
- Myxomas usually arise from the interatrial septum
- ATRIAL SEPTAL CURVATURE as a pressure indicator
Right Atrium - Mass

Asymptomatic giant RA myxoma

Yuce M. et al. *International J Cardiol.* 2007;114:405
Biattrial Mass

Tavil Y et al. Cardiovascular Pathology. 2006;15:354. Large rhabdomyosarcoma
Biaatrial Mass

Tavil Y et al. Cardiovascular Pathology. 2006;15:354. Large rhabdomyosarcoma
Biatrial Mass

(A) Histopathologic examination shows a tumor composed of round cells with atypical mitoses and rhabdomyoblasts (H&E, ×100).

(B) Immunohistochemical study demonstrating that the tumor cell showed strong positive staining for actin (×40).

Single Atrium

Measurement of TV Annulus and TV Displacement

An apical 4-chamber view demonstrating techniques for measuring TV deformations. The TV annular dimension (dashed line) and tethering height (solid line) were determined by the distance between the tips of the arrowhead, respectively. LA, Left atrium. Fukuda S et al. Am Heart J. 2006;152:1208.
A, TV viewed from the atrium. The valve relative to anatomic structures is displayed, demonstrating the location of high and low points.

B, Dilation along the free wall aspect of the TV with functional TR (dashed lines).

Carcinoma from Adrenal to RA

Carcinoma from Adrenal to RA

Carcinoma from Adrenal to RA

MR and Normal PA Pressure and Large LA

LA Dissection

LA Appendage spontaneous inversion

Images taken from 4 views demonstrating the inverted left atrial appendage (LAA) (green arrow), in the left atrium (LA) yellow arrow is pointing to mitral valve (MV). Parasternal long-axis (A), parasternal short-axis (B), apical 4-chamber (C), and subcostal sagital (D) views

LA Appendage spontaneous inversion

Apical 4-chamber view in the same patient with laminar color Doppler demonstrated in left atrium (LA) indicating no obstruction. This was later confirmed with pulsed Doppler. LV, Left ventricle; RA, right atrium; RV, right ventricle

LA Appendage spontaneous inversion

Parasternal short-axis view, in the same patient 9 days after cardioversion. Left atrial (LAA) appendage (green arrow) has returned to its normal, everted position. AO, Aorta; RA, right atrium; LA, left atrium

RA Ball Valve
Thrombus

(A and B) Transthoracic two-dimension echocardiography in the four chamber view showing a large mobile thrombus moving like pong pong ball within the right atrium.

Tricuspid stenosis is present.

RA Ball Valve
Thrombus

A large mobile thrombus removed from the right atrium at emergency surgery.

Giant Atrial Septal Aneurysm Simulating RA Tumor

75 yo man pre CABG with AFib, and intraoperative TEE.

Initial picture appears as tumor or thrombus in RA.

Doppler shows flow across the interatrial septum.

Giant Atrial Septal Aneurysm Simulating RA Tumor

75 yo man pre CABG with AFib, and intraoperative TEE.

Agitated saline opacifies the RA and leaves the atrial septal aneurysm unopacified.

Spontaneous echocontrast in aneurysm disappeared with lower blood pressure.

30 yo man with severe hypotension after surgery for extensive burn injury.

Multiplane transesophageal echocardiography images (top). Large membrane divides right atrium (RA) into 2 subchambers (bottom). Hole (0.9 × 1 cm) permitted forward flow. LA, Left atrium

Cor Triatriatum Dexter

30 yo man with severe hypotension after surgery for extensive burn injury.

Right atrial (RA) angiography (top). Large membrane divides right atrium into 2 subchambers (bottom); balloon dilation of RA membrane. IVC, inferior vena cava; RV, right ventricle; SVC, superior vena cava

Metastatic Hepatocellular Carcinoma Extending into RA

66 yo man with cirrhosis

2D-E A4C reveals the mass (arrows) in the RA.

TEE of RA shows mass protruding into the RA

Metastatic Hepatocellular Carcinoma Extending into RA

66 yo man with cirrhosis

Abdominal CT illustrates an infiltrating structure in the left lobe of the liver.

Apical 4C reveals the tumor mass (arrows) extending through the tricuspid valve into the right ventricle

LA Anomalous Band Causing MR

43 yo woman with dyspnea.

TEE view showing the anomalous band in the LA, connecting the atrial side of the anterior MV leaflet and atrial septum.

TEE view showing the anomalous band in the left atrium, causing prolapse and moderate-to-severe mitral regurgitation.

43 yo woman with dyspnea.

Pathological specimen of the removed band.

TEE view showing improvement in the regurgitation after resection of the band.

Pulmonary Vein Anatomy

- Pulmonary venous Diameter
- Distance to first bifurcation

Pulmonary Vein Stenosis

Transthoracic echocardiogram in apical 4-chamber view demonstrating large rounded mass projecting in right atrial (RA) position (arrow). It was unclear whether it was inside or adjacent to RA.

Transesophageal echocardiography showing 5.7- × 5.2-cm extracardiac mass in pericardial space, with compression of right atrium (RA). Note thick contour surrounding mass and heterogeneous content (arrows), with echodense areas causing acoustic shadowing (A). After injection of agitated-saline solution, note microbubbles in RA without contrast into mass (arrows), confirming absence of blood flow (B).