Guidelines for the Echocardiographic Assessment of Atrial Septal Defect and Patent Foramen Ovale

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Disclosures

Medtronic & Philips Speakers’ Bureaus
ASE GUIDELINES & STANDARDS

Guidelines for the Echocardiographic Assessment of Atrial Septal Defect and Patent Foramen Ovale: From the American Society of Echocardiography and Society for Cardiac Angiography and Interventions

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Frank Silvestry
University of Pennsylvania
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ANATOMY & EMBRYOLOGY
Atrial septum & septal defects

ECHO IMAGING
2D/3D TTE & TEE

SHUNT ASSESSMENT
Color Doppler & contrast

PERCUTANEOUS CLOSURE
Echo guidance
EMBRYOLOGY OF ATRIAL SEPTUM

Septum primum

Ostium primum

Ostium secundum

Ostium secundum

Development of septum secundum

Foramen ovale
ATRIAL SEPTAL DEFECTS

Sinus Venosus SVC Type

Tricuspid Valve

Ostium Secundum

Ostium Primum

Sinus Venosus IVC Type

Unroofed Coronary Sinus
Atrial Septal Defects

- **Secundum ASD** (Fossa ovalis ASD)
- **Primum ASD** (AV canal spectrum)
- **Sinus venosus ASD** (SVC-type)
- **Common atrium**
AtriAL SEPTAL DEFECTS

~15% of ASDs

PRIMUM ASD (Left atrial perspective)

~80% of ASDs

SECUNDUM ASD (Left atrial perspective)

Amenable to percutaneous closure

~5% of ASDs

SVC-TYPE SINUS VENOSUS ASD (Right atrial perspective)
Atrial Septal Defects | Shape & Size Variability

**Secundum ASDs**
- Seen from RA perspective

- **Circular**
- **Triangular**
- **Ovoid**
- **Fenestrated**
  - Multiple holes
  - (< Lat. fenestra – window)
Echocardiographic Imaging of Atrial Septum
For best imaging of atrial septum, insonation angle should be as perpendicular as possible to the septal plane.

TTE | Subcostal View
ECHO IMAGING OF ATRIAL SEPTUM

As perpendicular as possible to the septal plane >>> **Coaxial** with Doppler flow.
Echo Imaging of Atrial Septum

For insonation angle is parallel (coaxial) with the septal plane, image dropouts must be differentiated from true atrial septal defects.

TTE | Apical 4-Chamber View

No ASD

Secundum ASD
TEE | ATRIOVENTRICULAR & POSTERIOR ASD RIM

LA

1

2

RA

RV

*
TEE | AORTIC & POSTERIOR ASD RIM
TEE | Superior & Inferior ASD Rim

LA

SVC

RA

5

6

*
3D TEE | Secundum ASD Rims

RA Perspective

LA Perspective

SVC

AV

IVC

TV

SVC

RUPV

AV

MV
Atrial Septum: Associated Findings
Atrial Septum Masqueraders

- Eustachian valve
- Chiari network
- Thebesian valve
EUSTACHIAN VALVE | PARTIAL VALVE OF IVC

BARTOLOMEO EUSTACHI
Latinized as Eustachius
(1514 - 1574)
Italian anatomist
**EUSTACHIAN VALVE | PARTIAL VALVE OF IVC**

**BARTOLOMEO EUSTACHI**  
Latinized as Eustachius  
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Italian anatomist
**Eustachian Valve | Partial Valve of IVC**

**Bartolomeo Eustachi**
Latinized as Eustachius
(1514 -1574)
Italian anatomist
HANS CHIARI
(1851 – 1916)
Austro-Hungarian anatomist
ATRIAL SEPTAL ANEURYSM

DEFINITION
• Redundancy or saccular deformity of the atrial septum
• Increased mobility of the atrial septal tissue.
• Excursion of the septal tissue (typically the fossa ovalis) of > 10 mm from the plane of the atrial septum into the RA or LA, or
• A combined total excursion right and left of ≥ 15 mm

PREVALENCE
• 2%–3% of humans

ASSOCIATIONS
• Increase prevalence of PFO
• Increased size of a PFO
• Increased prevalence of cryptogenic stroke
• Multiple septal fenestrations (fenestrated ASD)
ATRIAL SEPTAL ANEURYSM
Shunt Assessment
ATRIAL SEPTAL ANEURYSM | PFO SHUNT WITH SALINE CONTRAST
Intracardiac vs. Intrapulmonary Shunt

- **Provocative Maneuvers**
  Agitated saline injections should be performed at rest and provocative maneuvers to increase the right atrial pressure, such as cough and the Valsalva maneuver.

- **PFO**
  Within 3 cardiac cycles
  The presence of PFO is presumed when agitated saline contrast is noted in the left atrium within 3 cardiac cycles after complete opacification of the right atrium.

- **Intrapulmonary Shunt**
  After 5 cardiac cycles
  If the agitated saline contrast is noted after 5 cardiac cycles after complete opacification of the right atrium, pulmonary arteriovenous malformations (AVMs) must be considered.

- **Large Shunt**
  > 20 bubbles
  Various classification schemes have been proposed to assess the sizes of shunts, though none have been universally accepted yet. However, >20 bubbles crossing the PFO from the right to left atrium is considered to be a large shunt.
PFO VS. INTRAPULMONARY SHUNT

Intracardiac Shunt (PFO)

Intrapulmonary Shunt
Percutaneous Closure of Secundum ASD
2D/3D Echocardiography in ASD Closure

Before ASD Closure
- Appropriateness criteria for ASD closure (whether surgical or percutaneous)
- ASD details relevant to percutaneous ASD closure

During ASD Closure
- Visualization of guide catheters and ASD closure device as it is being deployed

After ASD Closure
- Assessment of device seatedness and residual shunt

Pre-procedural Imaging
CASE PRESENTATION

49-year-old woman with **progressive dyspnea on exertion** over the past year

- History of hypertension
- An atrial septal defect (ASD) and no pulmonary hypertension were seen on a transthoracic echocardiograph (TTE)
- Now referred for transesophageal echocardiogram (TEE)
Preprocedural TEE | View at 99°
Preprocedural TEE | Biplane View
PREPROCEDURAL TEE | 4-CHAMBER VIEW
**DIAGNOSIS**

- Secundum ASD with left-to-right shunt
- Dilated right heart
- No pulmonary hypertension
- Progressive dyspnea on exertion
QUESTION

Has the patient met the clinical & hemodynamic criteria for ASD closure?
ACC/AHA 2008 Guidelines for the Management of Adults With Congenital Heart Disease

2.5.2. Recommendations for Interventional and Surgical Therapy

Class I

1. Closure of an ASD either percutaneously or surgically is indicated for right atrial and RV enlargement with or without symptoms. (Level of Evidence: B)

2. A sinus venosus, coronary sinus, or primum ASD should be repaired surgically rather than by percutaneous closure. (Level of Evidence: B)

3. Surgeons with training and expertise in CHD should perform operations for various ASD closures. (Level of Evidence: C)
QUESTION

Has the patient met the anatomic criteria for percutaneous ASD closure?
PREPROCEDURAL TEE | ATRIOVENTRICULAR & POSTERIOR RIM
Preprocedural TEE | Aortic & Posterior Rim
PREPROCEDURAL TEE | SUPERIOR & INFERIOR RIM

LA

5

6

*S

RA

SVC

C

NYU Leon H. Charney Division of Cardiology
Preprocedural 3D TEE | Secundum ASD Rims

RA Perspective

LA Perspective
PREPROCEDURAL 3D TEE | RA PERSPECTIVE | ASD SIZING
**DIAGNOSIS**

- Secundum ASD with left-to-right shunt
- ASD Size: 1.85 x 1.25 cm
- Sufficient ASD rims
**Percutaneous ASD Occluders**

- **Amplatzer**
  - For ASDs up to 38-mm in diameter

- **Gore-Helex**
  - For ASDs up to 18-mm in diameter

LA Disc > RA Disc

RA Disc = LA Disc
PERCUTANEOUS ASD CLOSURE PEARLS

1. SIZING ASDs
   a. Method #1 – While imaging the ASD by TEE, start inflating the sizing balloon inside an ASD. Turn on color Doppler. Keep inflating the balloon until trans-ASD flow around the balloon is no longer seen. Measure the balloon diameter at the ASD level (stop-flow balloon diameter) and use this diameter to choose appropriate ASD occluder size. This is typically done for Amplatzer septal occluder type devices.
   b. Method #2 - Measure ASD diameters by echo. Add 25% to those diameters and you will approximate the stop-flow balloon diameter.
2. AMPLATZER ASD OCCLUDER
   --Amplatzer waist should be the same size as the stop-flow diameter (or its echo diameter + 25% approximation).
   --Maximum Amplatzer waist diameter in the United States is 38 mm.
   --ASD 5ims should be at least 5 mm except the aortic rim which can even be absent. The 5-mm limit is determined by the size of the overhanging edge of the right atrial disc past the waist.
3. GORE HELEX ASD OCCLUDER
   --Gore Helex device has no waist; just a wire
   --Device size = stop-flow diameter x 2
   --Device size is the size of the disc (RA and LA discs have the same size).
   --Maximum disc size is 36 mm; the maximum ASD stop-flow diameter closable by Gore Helex is 18 mm
4. POST PROCEDURAL DEVICE LEAKS
   --Leaks through the device or through its waist are expected and are not pathologic
   --Pathologic flows are between the atrial rim and the device
   --Large residual leaks are defined as 4 mm or more in width on color Doppler at atrial rim level
Intra-procedural Imaging

ASD BALLOON SIZING
After obtaining a peripheral venous access, a sizing balloon is inflated inside the ASD.
INTRAPROCEDURAL TEE | ASD BALLOON SIZING
INTRAPROCEDURAL TEE | ASD BALLOON SIZING

![Ultrasound Image](image)

FR 21Hz
7.0cm

2D
60%
C 50
P Off
Gen

CF
59%
4.4MHz
WF High
Med

LA

RA

PAT T: 37.0°C
TEE T: 38.7°C

M4 M4
+23.1

85 bpm
ASD SIZING | STOP-FLOW DIAMETER
ASD Occluder Sizing

19-mm Amplatzer ASD occluder was chosen
Intra-procedural Imaging

ASD OCCLUDER DEPLOYMENT
INTRAPROCEDURAL 3D TEE | DEPLOYMENT OF LA DISC
**INTRAPROCEDURAL 3D TEE | DEPLOYMENT OF LA DISC**

![3D TEE Image]

- VR 5Hz
- 5cm
- 60 180
- Live 3D
- 3D 27%
- 3D 31dB

2013/12/11 11:02:43AM
NYULMC 6BLY

63 bpm
INTRAPROCEDURAL 3D TEE | DEPLOYMENT OF LA DISC
INTRAPROCEDURAL 2D TEE | AMPLATZER OCCLUDER DEPLOYMENT
INTRAPROCEDURAL ICE| AMPLATZER OCCLUDER DEPLOYMENT
INTRAPROCEDURAL FLUOROSCOPY | AMPLATZER OCCLUDER DEPLOYMENT
Post-procedural Imaging

ASD OCCLUDER DEPLOYMENT
POST-PROCEDURAL 3D TEE | AMPLATZER DEPLOYED

RA Perspective

LA Perspective
Check for para-device leak.
POST PERCUTANEOUS ASD OCCLUDER

Complications are rare...
...but you must check for them proactively!
Check for complications.
POST-PROCEDURAL CATH | RETRIEVAL OF ASD OCCLUDER
Thank You!

New York University Medical Center
Bonus Slides

ASD BALLOON SIZING
Before ASD Closure: Guidelines for ASD Closure

- **Class I Recommendations**
  - RA or RV enlargement with or without symptoms
  - Sinus venosus, coronary sinus or primum ASDs should be repaired surgically rather than percutaneously

- **Class II Recommendations**
  - Paradoxical embolism
  - Orthodeoxia-platypnea
  - Net left-to-right shunt when PVR < 2/3 SVR and PAP < 2/3 systemic BP

- **Class III Recommendations**
  - Patients with severe irreversible pulmonary arterial hypertension and no evidence of a left-to-right shunt should NOT undergo ASD closure

**ACC/AHA Guidelines for Adult Congenital Heart Disease,** *Circulation* 2008;118:e714-833.

NYU Leon H. Charney Division of Cardiology
Assessment Before ASD Closure

**RIGHT HEART DILATATION**

**NET LEFT-to-RIGHT SHUNT**

Apical 4-Chamber View
SECUNDUM ASD

Left-to-Right Shunt
SECUNDUM ASD

ASE/EAE/CSE Guidelines for Right Heart Assessment
*J Am Soc Echocardiogr* 2010;23:685-713.
Secundum ASD: Left-to-Right Shunt

Spectral Doppler
ASD Flow in Sinus Rhythm

Color Doppler
2D TEE at 30 Degrees

PEAK 1
End-ventricular systole

PEAK 2
Atrial kick

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Before ASD Closure: Right Heart Pressures

TR Jet

- TR Jet speed: 3 m/s

PI Jet

- PI Jet speed: 1.5 m/s

IVC

- RAP = 3 mm Hg

PASP = 4 \times (3 \text{ m/sec})^2 + \text{RAP} = 39 \text{ mm Hg}

PADP = 4 \times (1.5 \text{ m/sec})^2 + \text{RAP} = 12 \text{ mm Hg}
Before ASD Closure: Pulmonary Vascular Resistance

\[ PVR = 0.16 + 10 \times \frac{V_{max_{TR jet}}}{VTI_{RVOT}} \]

Resistance = \( \frac{\Delta P}{\text{Flow}} \)

PVR = 0.16 + 10 * (3 m/sec) / (17 cm)

PVR = 1.8 Wood units [or, 1.8 * 80 = 144 SI units]

Abbas Method

Closure of ASD is usually NOT done when:

\[
PVR > \frac{2}{3} \times SVR
\]

**Normal Resistance Values**

- PVR = 1-2 Wood units
- SVR = 11-16 Wood units

**Paul Wood**
British invasive cardiologist (1907–1962)
Died of acute LAD infarct
Diagnosis of ASD Per Se

ASD Shape

* ASD Orifice and Rim Size

* Relationship of ASD to surrounding structures
Secundum ASDs: Variety of Shapes

SECUNDUM ASDs
Seen from RA perspective

- Circular
- Triangular
- Ovoid
- Fenestrated
  - Multiple holes
  - (Lat. fenestra – window)
Relationships of Secundum ASDs

RA Perspective

LA Perspective

SUFFICEINT ASD RIMS
Aortic rim > 3 mm
Other rims > 7 mm
Orienting 3D TEE Images of Atrial Septum

TUPLE Maneuver: Tilt Up Then Left

Acquisition at 0 Degrees

Acquisition at 120 Degrees

Orienting 3D TEE Images of Atrial Septum

Acquisition at 0 Degrees

TUPLE (tilt-up-then-left) Maneuver

TUPLE maneuver is now featured in the latest edition of Braunwald textbook of cardiology.
Sizing Secundum ASDs: The OLD Way

Method #1: Rectangular Grid (2 mm)

Method #2: Multiplane Reconstruction (MPR)

ASD 1.6 x 1.4 cm
Sizing Secundum ASDs: The NEW Way

**Method #3**: ASD Sizing Directly on 3D TEE Image

**ASD Diameters**: 1.6 x 1.4 cm

**ASD Area**: 1.8 cm²

**ASD Circumference**: 5.0 cm
Sizing Secundum ASDs: 2D vs. 3D

**3D TEE**

**MPR** = Multi Plane Reconstruction

\[\chi\rho\delta\nu = \text{gut, string of a musical instrument (made of gut)}\]

**2D TEE**

Tends to UNDERESTIMATE the size of ASD

Often geometric **chord** rather than true **diameter** is measured.
ASD Occluders

Approved for use in the United States

Device #1: Amplatzer

Device #2: Gore-Helex
St. Jude Amplatzer ASD Occluder: Sizing based on \textbf{WAIST} size
### TABLE 12: GORE® HELEX® Septal Occluder Device Sizing

<table>
<thead>
<tr>
<th>Labeled Occluder Diameter (mm)</th>
<th>Nominal Defect Size (mm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>15</td>
<td>7.5</td>
</tr>
<tr>
<td>20</td>
<td>10</td>
</tr>
<tr>
<td>25</td>
<td>12.5</td>
</tr>
<tr>
<td>30</td>
<td>15</td>
</tr>
<tr>
<td>35</td>
<td>17.5</td>
</tr>
</tbody>
</table>

Gore-Helex: Sizing based on **DISC** size
Part 2

During ASD Closure
Percutaneous ASD Closure

**STEP 1**
Passage of wires & catheters across ASD

**STEP 2**
Sizing of ASD with balloon

**STEP 3**
Deployment of ASD closure device

Femoral venous access
Percutaneous ASD Closure

Balloon Sizing (Stop-flow diameter)
Percutaneous ASD Closure

ASD Closure Device Deployment

Amplatzer Device Still Attached to Delivery Catheter

RA Perspective

LA Perspective
Percutaneous ASD Closure

ASD Closure Device Deployment

Tugging the device

Residual Leak
ASD Closure Device: LA Perspective

Gore-Helex ASD Occluder
Residual Leak

Repositioned Gore-Helex Device:
No Leak
ASD Closure: Intracardiac Echo (ICE)
Post ASD Closure
After percutaneous ASD closure, check for complications (e.g. pericardial effusion).
Primum ASD
Primum ASD

Part of the endocardial cushion (AV canal) disease spectrum

Associated with Down syndrome (trisomy 21) disease spectrum

John Langdon Down (1828-1896) British physician
ENDOCARDIAL CUSHION DISEASE SPECTRUM

Normal AV Canal

Partial AV Canal

Complete AV Canal
PRIMUM ASD | AV CANAL
PRIMUM ASD
PRIMUM ASD + SOMETHING ELSE

Peculiar
Mitral Regurgitation
Primum ASD + Cleft Mitral Valve

Cleft Mitral Valve
(LV perspective)

Relationship between
cleft mitral valve and primum ASD
CLEFT MITRAL VALVE: LA PERSPECTIVE
TEACHING POINTS

• Primum ASD is located near the atrioventricular valves

• Rarely an isolated lesion

• Typically associated with elements of endocardial cushion defect disease spectrum
  • Cleft mitral valve
  • Inlet VSD
Sinus Venosus ASD
Sinus Venosus ASDs

Sinus venosus is an embryologic venous reservoir proximal to the right atrium.

**SVC-type**
Sinus venosus ASD

**IVC-type**
Sinus venosus ASD
Markedly dilated right heart without apparent septal defect
SVC-TYPE SINUS VENOSUS ASD
SVC-TYPE SINUS VENOSUS ASD | ANOMALOUS PULMONARY VENOUS RETURN

SVC

RUPV
**SVC-type Sinus Venosus ASD**

- ASD
- SVC
- Aortic Valve
- True Atrial Septum
- RA Aspect
SVC-TYPE SINUS VENOSUS ASD + PAPVR
Thank You!

New York University Medical Center