Overview of Cardiac Anatomy with Echocardiographic Correlation

Douglas C. Shook, MD
Department of Anesthesiology, Perioperative and Pain Medicine
Brigham and Women’s Hospital
Harvard Medical School

Objectives

• Understand important anatomy seen in echocardiography
• Develop a better understanding of the anatomic relationships seen in 2D transesophageal echocardiography.

Orientation and important outer landmarks of the heart relevant to TEE

• Apex – It points anteriorly and inferiorly at about 60 degrees toward the left side of the patient.
• Base – The great vessels insert into the base of the heart. The aortic valve is in the center of the base of the heart. The pulmonic valve is the most anterior of the four valves, which makes it more difficult to visualize with TEE.
• Right Ventricle – It is an anterior structure of the heart in the chest.
• The right atrium and ventricle lie anterior to the left atrium and ventricle.
• Atrium - The chambers lie to the right and posterior to their corresponding ventricles. The left atrium is the window for the midesophageal TEE views and is closest to the esophagus.
• Sulcus Terminalis – The groove that separates the SVC from the base of the right atrium. It corresponds to the Crista Terminalis found in the right atrium which is seen regularly in the ME Bicaval View.

Arteries and Veins

• Aorta – begins at the base of the heart. The ascending aorta is examined using the ME AV LAX and ME Asc Aortic LAX views.
• Dominance – Refers to the artery from which the posterior descending artery originates. Patients are 85-90% right dominant (the right coronary artery supplies the PDA).
• Left Coronary Artery and Branches
  o Left Main – Originates from the left sinus of valsalva of the aortic root. Usually seen in the ME AV SAX view. Bifurcates into the left anterior descending and circumflex arteries.
  o LAD – It courses down the anterior interventricular groove to the apex of the heart. Branches include the septal perforators, diagonals, and right ventricular branches. It supplies the anterior 2/3 of the interventricular septum, anterior wall of the left ventricle, and anterior surface of the right ventricle. It is evaluated using the ME 4CV, ME 2CV, ME LAX, TG SAX, TG Basal SAX, TG 2CV, and TG LAX.
  o Circumflex – It courses in the left atrioventricular groove and its branches include the obtuse marginal arteries. It supplies blood to the lateral left ventricle, left atrium, and posteromedial papillary muscle. In 10-15% of patients, the circumflex gives rise to the PDA (left dominate circulation) and supplies the atrioventricular node. It supplies the SA node in 40-50% of hearts. It is evaluated using the ME 4CV, ME LAX, TG SAX, and TG LAX.
Right Coronary Artery and Branches
- **Right Coronary Artery** – Originates from the right sinus of valsalva of the aortic root. Commonly air from the left ventricle passes into the RCA because of the anterior position of its ostium in the aortic root. *It can be seen in the ME LAX view.* The RCA courses in the right atrioventricular groove giving rise to the acute marginal arteries. The RCA supplies the SA node in 50-60% of patients. It gives rise to the PDA and posterolateral artery in 85-90% of patients.
  - Acute marginal arteries – They supply the right ventricular anterior free wall. *Evaluated using the ME 4CV, ME RV inflow-outflow view, and TG SAX view.*
  - **Posterior Descending Artery** – Runs in the posterior interventricular groove giving off septal perforators that supply the inferior 1/3 of the interventricular septum. *Evaluated with the ME 4CV and TG SAX view.*
  - **Right Posterolateral Artery** – Supplies the inferior left ventricle. *Evaluated using the ME 2CV, TG SAX view, and TG 2CV.*

- **Superior and Inferior Vena Cava**
  - They both enter the right atrium at the base of the heart. *The coronary sinus is associated with the IVC on TEE.*
  - The SA node lies at the anterior superior extent of the terminal groove (sulcus terminalis) where the SVC enters the RA.

- **Coronary Sinus** - It predominately drains the left ventricle. It lies in the posterior atrioventricular groove and empties into the right atrium near the IVC. The thebesian valve guards the entrance into the right atrium. *Evaluated using a modified ME Bicaval view, ME 2CV and a deep ME 4CV.*

**Right Atrium**
- **Three components**
  - Right atrial appendage – It is filled with pectinate muscles. *Pectinate muscles (PM) can be seen in the ME Bicaval view.*
  - Venous component – Smooth walled portion of the atrium that receives blood from the IVC, SVC, and coronary sinus.
  - Vestibule – surrounds the orifice of the tricuspid valve.
- **Crista Terminalis (CT)** – Found at the junction of the appendage and the venous component (smooth walled) of the right atrium. *Seen in the ME Bicaval view.*
- **Eustachian Valve (EV)** – A fold of tissue located at the anterior border of the IVC. When very long it appears thin and perforated and is called a Chiari Network. *Seen in the ME Bicaval view and deep ME 4CV.*
- Atrial septum – It is obliquely oriented in the chest. The septum secundum is the superior rim of the fossa ovalis (FO). A patent foramen ovale, if present, is found at the anterior-superior rim of the fossa ovalis. 
  *See in the ME Bicaval view and ME 4CV.*
- Triangle of Koch – Demarcated by the tendon of Todaro (a fibrous structure formed at the junction of the Eustachian valve and the Thebesian valve), the septal leaflet of the tricuspid valve, and the orifice of the coronary sinus. The atrioventricular conduction system is located in the Triangle of Koch.
- Atrioventricular septum – *can been seen in the ME 4CV.*

**Tricuspid Valve – more apical compared to the mitral valve**
- Annulus – The right coronary artery circles the free wall portion of the annulus. The tricuspid annulus is larger than the mitral annulus.
- Three leaflets – Anterior, posterior, septal. The posterior leaflet is the lowest point of the valve. The anteroseptal commissure is the highest point of the valve. *These landmarks can be seen in the ME 4CV by advancing and withdrawing the probe.*
- Three papillary muscles – Anterior (largest), posterior, and medial (septal). They anchor the tricuspid valve to the right ventricle by fibrous strands called chordae tendineae.
- *Evaluated using the ME 4CV, ME RV Inflow-Outflow view, Modified Bicaval view, and TG RV inflow.*

**Right Ventricle**
- It has two separate openings and consists of three portions (inlet, apical, and outlet). The inlet consists of the tricuspid valve and its tension apparatus. The apex is thin and prone to perforation. In healthy hearts, the right ventricular apex doesn’t make up the true apex of the heart. *This can be seen on the ME 4CV.* The outlet portion of the right ventricle is a circumferential muscular structure. *Other views for the right ventricle include the ME RV inflow-outflow view, TG RV outflow view, and the TG SAX view.*
- Moderator Band – One of the trabeculae carneae in the right ventricle, it carries part of the right branch of the conduction system from the septum to the anterior papillary muscle. *Can be seen in the ME 4CV and TG SAX.*

**Pulmonary Valve – Farthest valve from the TEE probe**
- The pulmonary valve is supported by the muscular outlet portion of the right ventricle. It is in a 90 degree orientation to the aortic valve. You should never see the aortic valve and pulmonic valve in short-axis or long-axis together in a TEE view. *See the ME AV SAX view (AV is SAX and PV is LAX). In the ME AV SAX view the right and left aortic valve cusps point toward the pulmonic valve.* Other views for the pulmonic valve include the ME RV inflow-outflow, ME Ase Ao SAX, and UE aortic arch SAX view.
- Annulus – The pulmonary valve has semilunar attachments.
- Cusps of the PV – They are the Anterior, Right, and Left. *In the ME AV SAX view, typically you see the anterior cusp and either the right or left cusp.*
Left Atrium
- Most posterior portion of the heart. It lies next to the esophagus. The left atrium is at the top of the screen in midesophageal TEE views. It is tethered posteriorly by the four pulmonary veins. It has an appendage, venous, and vestibule components. Pectinate muscles are typically limited to the appendage.
- Coumadin Ridge – Seen in the left atrium on TEE. It is atrial tissue between the left upper pulmonary vein and the left atrial appendage.

Mitral Valve
- Mitral apparatus – It is made up of the fibrous skeleton of the heart, annulus, leaflets, chordae tendineae, papillary muscles, and left ventricle. All of these components are essential to the proper functioning of the mitral valve.
- Annulus – It is denser than the tricuspid annulus. It extends from the left and right trigones parietalement. Between the trigones is the aortic-mitral curtain (fibrous continuity between the left and non-coronary cusps of the aortic valve and the anterior leaflet of the mitral valve). The right trigone is close to the AV node. The circumflex artery is associated with the anterior portion of the annulus and the coronary sinus is associated with the posterior portion of the annulus. The ME 2CV shows this relationship.
- Anterior Leaflet – It comprises about 60-70% of the total mitral surface area, but only 1/3 of the annular circumference. It is in fibrous continuity with the aortic valve. The anterior leaflet is always associated with the aortic valve in all TEE views (eg, ME LAX).
- Posterior Leaflet – It comprises about 30-40% of the total mitral surface area and makes up 2/3 of the annular circumference. Generally there are three scallops on the posterior leaflet.
- Papillary Muscles – There are two papillary muscles, the anterolateral and posteromedial papillary muscle.
- Chordae Tendineae – They extend from the papillary muscle to the mitral leaflets. Primary chordae attach to the leaflet tips (ruptured in flail mitral leaflets) and secondary chordae attach to the mid-portion of the leaflets. Tertiary chordae attach to the base of the posterior leaflet only and arise from the ventricular wall. There are usually two thickened secondary chordae referred to as “stay” chordae that play an important role in LV geometry and function.
- Insertion of the Chordae – A line draw down the middle of the anterior leaflet (A2) through the posterior leaflet (P2) marks the dividing point for chordae insertion. Chordae from the anterolateral papillary muscle insert into the lateral halves of both the anterior and posterior leaflets. Chordae from the posteromedial papillary muscle insert into the medial halves of both the anterior and posterior leaflets.
- Terminology for the Mitral Valve – The Carpentier classification is used to describe anatomic relationships of the anterior and posterior leaflets.
- Views for the Mitral Valve – ME 4CV, ME Commissural view, ME 2CV, ME LAX view, TG Basal SAX view, TG 2CV, TG LAX view.
Left Ventricle
- Inlet – It consists of the mitral valve and its tension apparatus.
- Apical – Fine trabeculations make up the apical portion of the left ventricle. The left ventricle is thinner at the apex.
- Outlet – It has both a muscular and fibrous components. This is in contrast to the right ventricle which is entirely muscular. The anterior leaflet of the mitral valve is one of the boundaries of the left ventricular outflow tract. This plays an important role in LVOT obstruction in pathologic states.
- Views for the Left Ventricle - ME 4CV, ME 2CV, ME LAX view, TG Basal SAX view, TG Mid SAX view, TG 2CV, TG LAX view.

Aortic Valve – Central and related to all cardiac chambers
- Aortic Root – It is not a single structure but is comprised of the aortic annulus, valve cusps, sinuses of valsalva, the sinotubular junction, and the proximal ascending aorta. An abscess in the aortic root can produce fistulas to any chamber in the heart.
- Annulus – The aortic valve has semilunar attachments. There is no discrete annulus for the aortic valve.
- Cusps – There are three valve leaflets named for the coronary artery that may or may not arise from the corresponding sinus of valsalva. The commissure of the left and right aortic valve cusps point toward the pulmonic valve. Seen in the ME RV inflow-outflow view. The commissure of the left and non-coronary cusps point toward the anterior mitral leaflet. The left and non-coronary cusps are in fibrous continuity with the anterior leaflet of the mitral valve. The body of the non-coronary cusp is adjacent to the atrial septum.
- Views for the Aortic Valve – ME AV SAX, ME AV LAX, TG LAX, Deep TG LAX.

Bibliography
ASE/SCA 20 Views with Labels

a. ME four chamber
b. ME two chamber
c. ME LAX
d. TG mid SAX
e. TG two chamber
f. TG basal SAX
g. ME mitral commissural
h. ME AV SAX
i. ME AV LAX
j. TG LAX
k. deep TG LAX
l. ME bivocal
m. ME RV inflow-outflow
n. TG RV inflow
o. ME asc aortic SAX
p. ME asc aortic LAX
q. desc aortic SAX
r. desc aortic LAX
s. UE aortic arch LAX
t. UE aortic arch SAX