CT–based Essential Cardiac Anatomy for Radiology Residents to Understand Congenital Heart Disease

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Cardiac Anatomy for Congenital Heart Disease (CHD)

- **Anatomy and connections**: the first stage in understanding CHD

- **Basic terminology**: cardiac apex, base of the ventricles, crux cordis, cardiac imaging planes...
Visualization Techniques of Cardiac CT

- **2D:** multiplanar reformation (MPR), curved MPR, maximum intensity projection (MIP), minimum intensity projection (MinIP), cine

- **3D:** volume rendering (VR), merged VR, transparent-lumen VR, cine (4D)
Cardiac apex, the pointed end of the heart, is normally formed by the left ventricle (LV).

- When cardiac apex is formed by the right ventricle (RV) rather than the LV, the LV is likely “hypoplastic”.
The anatomic landmark is formed by the crossing of the atrioventricular sulcus (.....) and the conjunction (.....) of the posterior interventricular sulcus & interatrial sulcus.

When a hypoplastic ventricle touches the crux cordis, it is most likely the “morphological LV”.

**Definition & Significance**
Cardiac Silhouette
1. Superior vena cava; 2. right atrium; 3. aortic knob; 4. pulmonary conus; 5. left atrial appendage; 6. left ventricle
Posterior and superior view of left and right ventricles after removal of both atria

Useful to understand the detailed spatial relationships between cardiac valves, their leaflets, and commissures

AV: aortic valve
PV: pulmonary valve
MV: mitral valve
TV: tricuspid valve
Imaging Planes

‘Long axis’ imaging planes parallel to the long axis of the heart

‘Short axis’ imaging planes perpendicular to the long axis of the heart
Horizontal long axis
- 4-chamber view

Long axis
- LVOT view

Long axis
- RVOT view
SEGMENTS OF THE HEART

A-V JUNCTION

V-A JUNCTION

Atria

Ventricles

Great Arteries
Morphology

STEPS OF EVALUATION
Segmental and Sequential Approach

Atrial relationship (situs)

A-V connection

Ventricular relationship

V-A connection

Great arterial relationship

Associated anomalies
Cardiac Morphology

- Defined by specific morphologic features of cardiac segments rather than their spatial orientation in the body
- Atria → Ventricles → Great Arteries
ATRIA

RIGHT ATRIUM

- Triangular appendage with a broad junction
- Terminal crest
- Oval fossa with a limb
- Pectinate muscles extending to AV junction – *most accurate*

LEFT ATRIUM

- Finger-like appendage with a narrow junction
- No terminal crest
- No oval fossa
- Pectinate muscles not extending to AV junction – *most accurate*
**Fossa ovalis (FO)**

Normal apical attachment of TV < 8 mm/m²

**Coronary sinus (CS)**

**Thebesian valve**

*Courtesy of Dr. Shi Joon Yoo*
Anatomy of RA

- Koch triangle (▲): tendon of Todaro
  ( ], CS, TV annulus; AV node and bundle of His
- Eustachian valve: inferior vena cava
- Thebesian valve: CS
- Crista (Sulcus) terminalis: between RA proper & RA appendage; sinoatrial node in its superior part
- Chiari network: pseudo-lesion

Courtesy of Dr. Jung Im Jung
Patent Foramen Ovale (PFO)

**Definition & Significance**

- Incomplete fusion of the flap of the foramen ovale
- Commonly seen in newborns and gradually closed; remains patent in approximately 25% of people
- Increased risk for migraine headaches and cryptogenic stroke

A right-to-left jet (arrow) of less diluted contrast agent, which is administered through a leg vein, via PFO
Situs Solitus

Atrial Situs – method 1

Situs Inversus

Right Isomerism

mRA: morphological RA
mLA: morphological LA

Left Isomerism
Atrial Situs – method 2

Eparterial bronchus: superior to descending PA branch
Hyparterial bronchus: inferior to descending PA branch

Right Isomerism

Hyparterial

Eparterial

Left Isomerism

Hyparterial

Eparterial

Situs Solitus

Situs Inversus

Courtesy of Dr. Shi Joon Yoo
Bilateral trilobed lungs → Right Isomerism

Atrial Situs – method 3

Morphological right lung: 3 lobes; Morphological left lung: 2 lobes
VENTRICLES

**RIGHT VENTRICLE**
- Trabeculations: heavy and irregular
- Moderator band
- Septal attachment of AV valve: more apical

**LEFT VENTRICLE**
- Trabeculations: fine and regular
- No moderator band
- Septal attachment of AV valve: more cranial

The ventricle morphology determines the atrioventricular valve.
(TV ← morphologically right ventricle; MV ← morphologically left ventricle)
Perimembranous portion (\( \square \)) between right aortic sinus (R) and non-coronary aortic sinus (N)

Courtesy of Dr. Shi Joon Yoo
Crista Supraventricularis = ventriculoinfundibular fold (VIF) + outlet of infundibular septum (OS) + anterior limb of trabecular septomarginalis

MPM: medial papillary muscle
Trabecula Septomarginalis

= body + anterior limb (AL) + posterior limb (PL)

A big trabecula at RV septal surface; moderator band at its apical portion; the right bundle branch of conduction system beneath it
Papillary Muscles

Along with chordae tendinae, they are belonged to subvalvular apparatus, crucial for preserving atrioventricular valve coaptation.

- Two (antero-lateral [A] and postero-medial [P]) for the LV;
- Three (anterior, posterior, & septal) for the RV
“Tiny” papillary muscle (if visible) that may be served as an anatomic landmark for peri-membranous ventricular septal defect (*; OE [outlet extension], TE [trabecular extension], IE [inlet extension]) and right bundle branch (commonly posterior to it)
VENTRICLES

 Balanced vs. Unbalanced or Hypoplastic

 Spectrum

 Balanced ventricles

 Normal

 Unbalanced AVSD

 Hypoplastic left heart syndrome (HLHS)

 Biventricular repair ↔ Univentricular repair

 RV  LV  LA  RA

 Balanced ventricles

 Hypoplastic LV
Septum of the Heart

Three Components

1) Interatrial (IAS)
2) Atrioventricular (AVS; between the tricuspid and mitral valves; between LV and RA): even a small defect → surgical indication
3) Interventricular (IVS)

* Perimembranous portion (PM; “[”)

IAS
AVS
IVS
PM
RV
LA
LV
Muscular VSDs

Swiss-Cheese type

1) Full extent: essential for treatment planning; best visualized at diastolic phase
2) Transparent-lumen volume rendering: the best visualization technique; back cut, useful to distinguish a pseudo lesion (arrow) from a true defect (black)
Types of Atrioventricular Connection in Biventricular Heart

- **Concordant:**
  - LA $\rightarrow$ LV
  - RA $\rightarrow$ RV

- **Discordant:** congenitally-corrected (cc) transposition of the great arteries (TGA)
  - RA $\rightarrow$ LV
  - LA $\rightarrow$ RV

- **Twisted:** superoinferior ventricle or criss-cross heart
Modes of Atrioventricular Connection

- **Imperforate or absent**: tricuspid or mitral atresia; RCA, deep in right AV sulcus (characteristic finding)

- **Common (○)**: complete atrioventricular septal defect

- **Overriding**: one AV valve positioned over both ventricles

- **Straddling**: one AV valve papillary muscle attached to the opposite side of the interventricular septum; an impact on surgical planning
Modes of Atrioventricular Connection

- **Double inlet left ventricle (DILV):**
  - Two AV valves connecting to a dominant ventricle (usually LV)
  - Dominant inferior LV → VSD (*) → small superior RV
**Ventriculoarterial Connection**

- **Concordant**: aorta from LV, pulmonary trunk from RV
- **Discordant**: TGA; aorta from RV, pulmonary trunk from RV
- **Double-outlet**: DORV; 50% rule; the one GA from RV, the other (> 50%) also from RV
- **Overriding**: TOF; 50% rule; pulmonary trunk from RV, aorta (> 50%) from LV
- **Single-outlet**: truncus arteriosus, pulmonary atresia
GREAT ARTERIES

PULMONARY ARTERY

- Branches to the lungs
- No branch to the body

AORTA

- Branches to the body
- Coronary artery

The great artery determines the semilunar valve.

(PV ← Pulmonary trunk; AV ← Aorta)

spiral relationship
Relationship of Great Arteries

Spectrum

D-Malposition ↔ Normal ↔ L-Malposition

cc-TGA with dextrocardia

DORV with subpulmonic VSD

Commissural malalignment

cc-TGA with dextrocardia

Right (Dextro-) Anterior (Malposition)

Left (Levo-) Anterior (Malposition)

A: Aorta
P: Pulmonary trunk
3D Printed Heart Model

- High-resolution isotropic 3D CT data
- Data transformation: DICOM file → STL file
- Data segmentation: requiring a high level of expertise in CHD
- 3D printing

Anatomic Fidelity
True Heart > Imaging > 3D Printing

CT-based Virtual Reality
External & internal cardiac anatomy
CONCLUSION

- Cardiac CT can provide high-quality cardiac anatomic details.
- CT-based cardiac anatomy illustrated in this exhibit helps radiology residents understand CHD.
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