Cardiac and Cardiothoracic Anatomy in CT

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Contents

Modern cross-sectional imaging techniques such as echocardiography, magnetic resonance imaging (MRI), and multi-slice CT provide high-resolution visualization of cardiac morphology and function (Ooijen 2004). All of these modalities permit imaging of the heart in 2D and, at least to some extent, in 3D. While transthoracic echocardiography is dependent on an acoustic window, which sometimes permits imaging in every desired plane, MRI can be performed in any orientation. Multi-slice CT of the heart relies on an axial data acquisition; however, the high-resolution spiral data sets obtained with modern systems allow for display of small anatomical structures of the heart (Fig. 1.5) and for reformation in virtually any imaging plane. This chapter will introduce cardiac and cardiothoracic anatomy, as displayed by new multi-slice high-resolution CT scanners based on standard 2-dimensional views, which have been established with cardiac catheterization (Bittl 1997), echocardiography, and cardiac MRI and based on 3-dimensional surface reconstructions. The image data used for illustration have primarily been acquired with 4- and 16-slice CT with 0.5-s and 0.42-s rotation time, respectively. Of course, the described anatomical relations are also true for data obtained from multi-slice CT with more than 16-slices or from dual-source CT.

2.1 Topography

The human body can be viewed in three standard anatomic planes, which are oriented perpendicular to each other: sagittal, coronal, and transverse. These planes are aligned with the thoracic midline structures, the aorta and esophagus. In contrast, the heart is oriented obliquely in the chest and therefore imaging in standard anatomic planes is suboptimal to visualize cardiac anatomy and pathology (Edward 1984a, Edwards 1984b). The heart's three standard planes are its vertical and horizontal long axis and its so-called short axis. These cardiac axes are tilted against the standard anatomic planes, as shown in (Fig. 2.1).

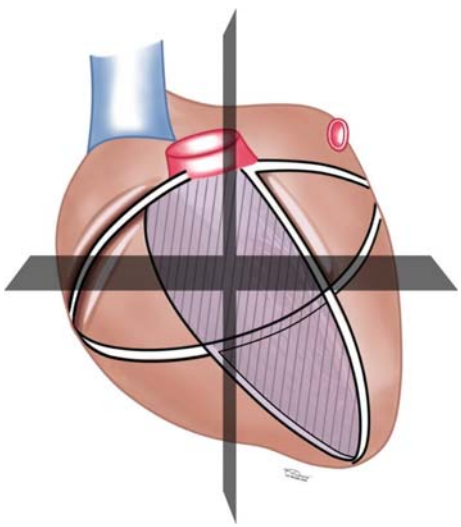

Fig. 2.1. Orientation of the vertical long axis and the short axis of the heart in relation to the standard anatomic planes of the body

The apex of the heart points to the left while the base of the heart is oriented dorsally and to the right, when viewed from above (Fig. 2.2). The right atrium and the right ventricle are to the right and anterior, and the left ventricle and left atrium are located to the left and posterior. A groove between atrium and ventricle marks the cardiac base. The right coronary artery (RCA) courses within the adipose tissue of the right atrioventricular groove. The left atrioventricular groove contains the left circumflex artery and great coronary vein. The interventricular septum, which separates right and left ventricles, is marked by less prominent indentations, the anterior and inferior interventricular grooves. The left anterior descending (LAD) coronary artery follows the anterior interventricular groove and the posterior descending artery courses along the inferior (posterior) interventricular groove (Fig. 2.2). Atrioventricular and interventricular grooves meet at the inferior base of the heart, the cardiac crux.

2.2 Standard Views

Even though the axial plane is not optimal for visualization of cardiac anatomy, it is the primary imaging plane in CT and usually gives a good overview of cardiac and coronary anatomy (Fig. 2.3). The angulations of the standard views for cardiac imaging correspond to the axis from base to apex and are oriented either parallel (horizontal or vertical long axis) or perpendicular (short axis) to this plane (Figs. 2.4–2.6).

Vertical Long Axis. The vertical long axis or two-chamber view is easily produced from the axial plane. It corresponds to a vertical plane through the cardiac apex and the middle of the mitral valve plane into the left atrium (Fig. 2.4) and is similar to the right anterior oblique view used with fluoroscopy or left ventriculography. The vertical long axis view displays the left ventricular inflow tract with the left atrium and the

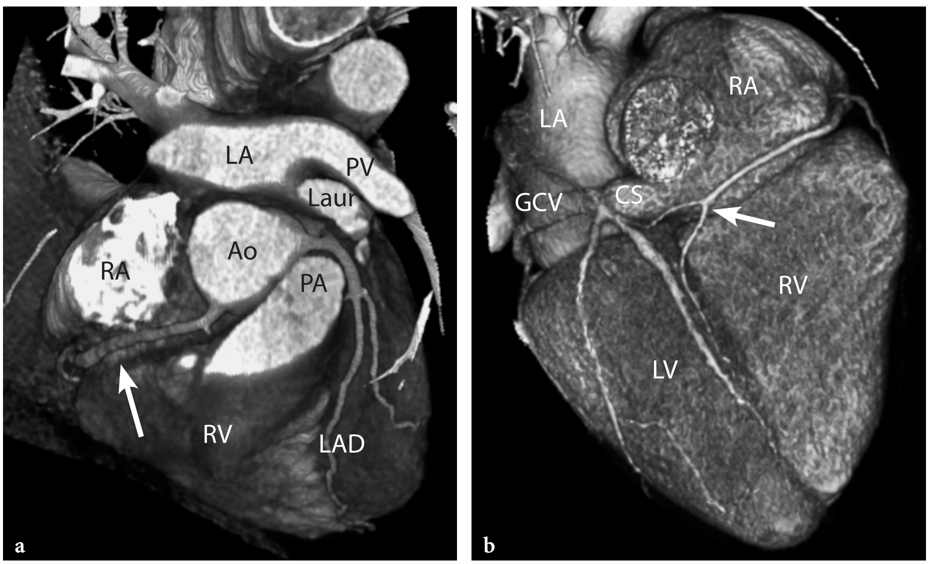

Fig. 2.2a, b. Three-dimensional display of the heart. **a** *Arrow* indicates right atrioventricular groove and right coronary artery. **b** Great cardiac vein (*GCV*) and posterior interventricular vein at the inferior aspect of the heart. The right coronary artery (RCA) bifurcates slightly proximal of the cardiac crux (*arrow* in **b**). *LA* left atrium, *RA* right atrium, *Ao* aorta, *PV* pulmonary vein, *Laur* left auricle, *PA* pulmonary artery, *D1* first diagonal branch, *RV* right ventricle, *LAD* left anterior descending coronary artery, *LV* left ventricle, *CS* coronary sinus

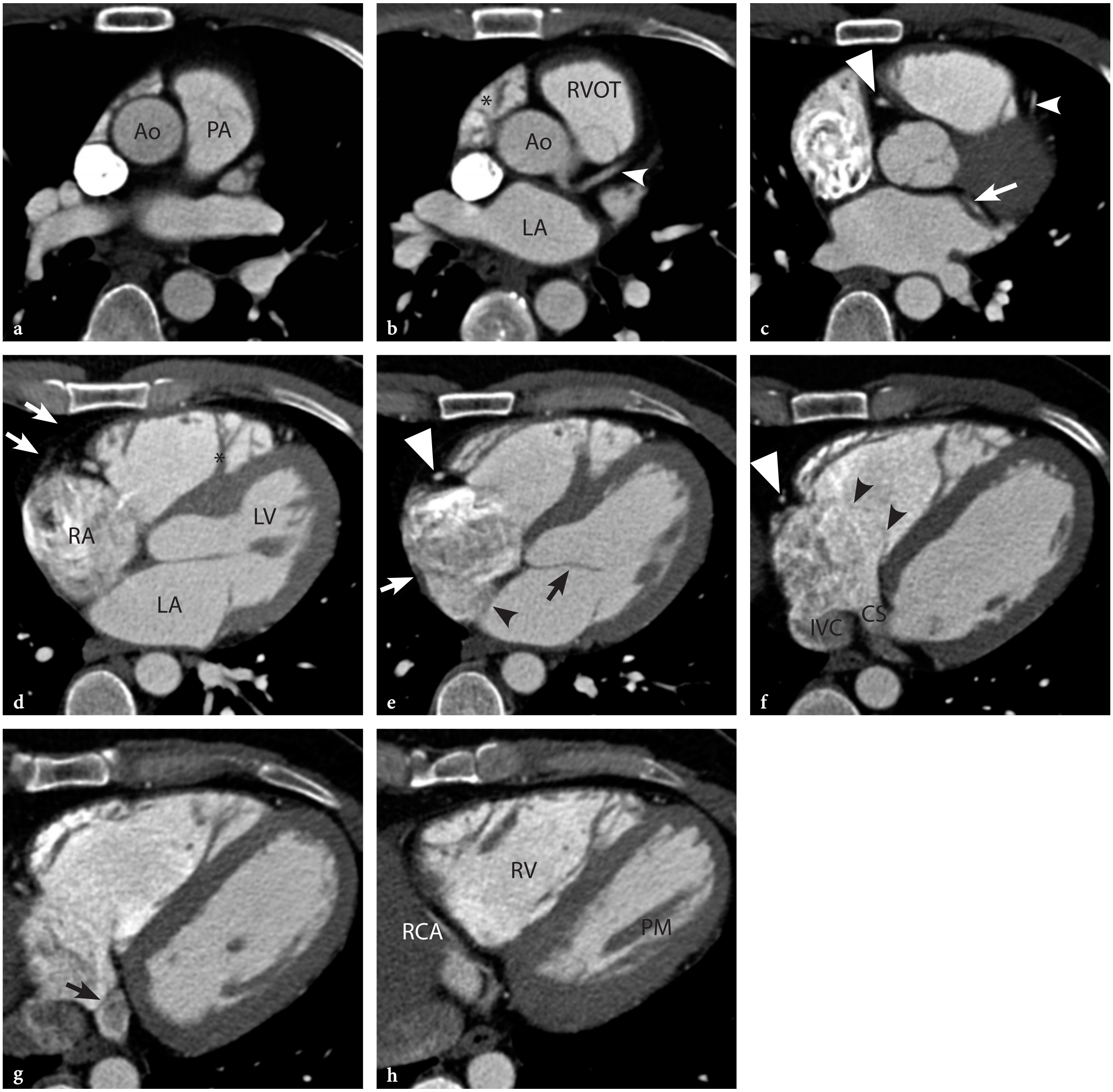

Fig. 2.3a–h. Axial anatomy of the heart in the craniocaudal direction. Visualization starts above the origin of the coronary arteries and displays the ascending aorta and pulmonary artery (*Ao* and *PA*, respectively, in **a**). The right atrial appendage (* in **b**) shows pronounced trabeculation. The LAD passes between the pulmonary trunk and the left atrial appendage and follows the anterior interventricular groove (*small white arrowhead* in **b** and **c**) down to the apex. The *RCA* (*large arrowhead* in **c**, **e**, and **f**) is depicted in the right atrioventricular groove, and the left circumflex artery is seen as a small vessel in the left atrioventricular groove (*small arrow* in **c**). The pericardium is identified as a thin tissue band (*small white arrows* in **d**). The mitral valve is well-delineated (*black arrow* in **e**) while the tricuspid valve is only faintly shown (*black arrowheads* in **f**). Also, separation of the right and left atria can be visualized (*black arrowhead* in **e**). The crista terminalis is seen in the right atrium (*white arrow* in **e**) and a small ridge at the orifice of the coronary sinus marks the thebesian valve (*black arrow* in **g**). Visualization of a slice at the apex of the heart reveals the distal segments of the *RCA* (**h**). *RVOT* Right ventricular outflow tract, *IVC* inferior vena cava, *PM* papillary muscle

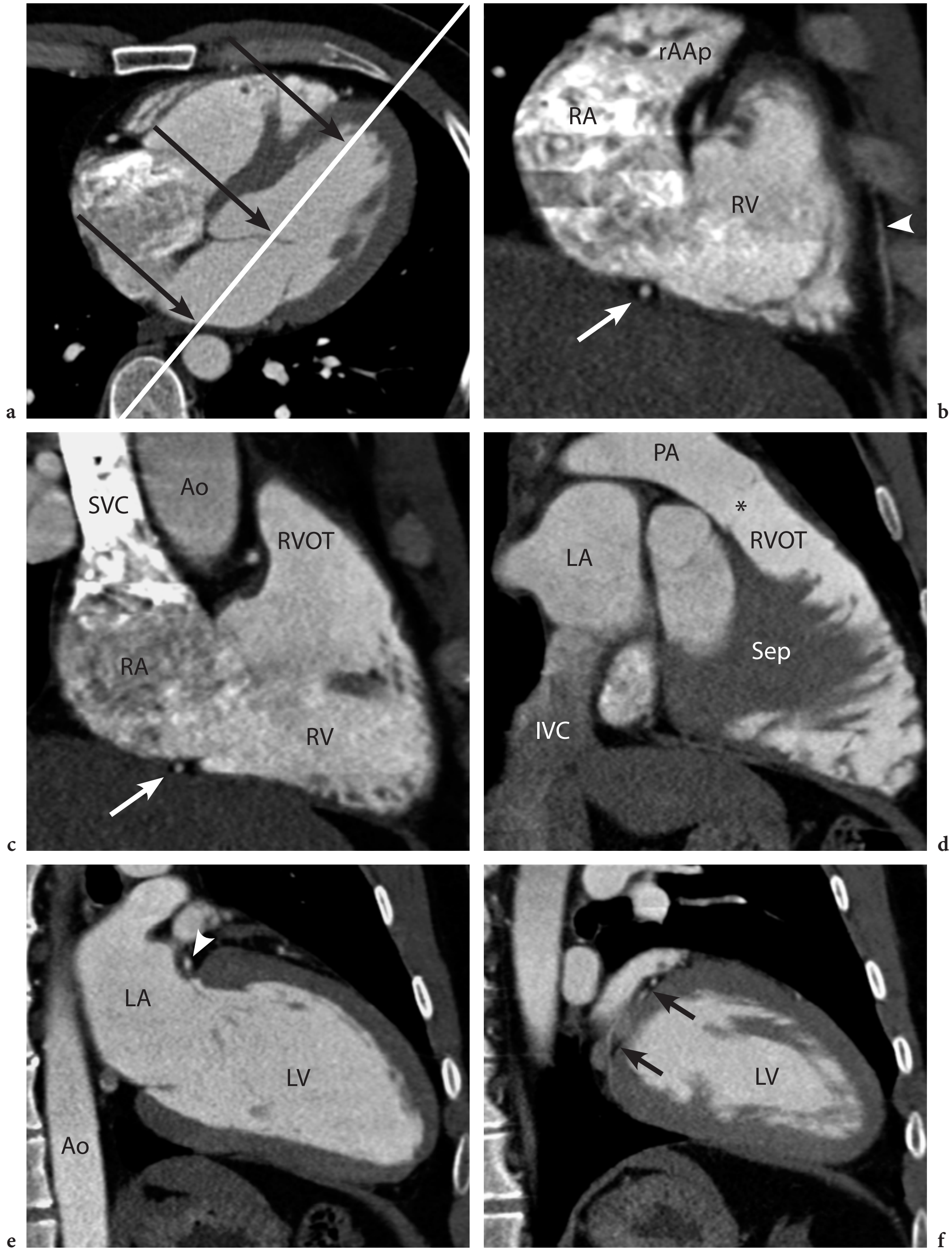

Fig. 2.4a–f. Vertical long axis views of the heart. **a** Vertical long axis orientation is shown as a line from the cardiac apex through the middle of the mitral valve plane. The tubular configuration of the *RA* and the more triangular shape of the RV are well-appreciated. Note the smooth appearance of the *RVOT* as opposed to the trabeculated inferior portion of the *RV* and the marked thinning of the left ventricular myocardium at the apex. *White arrow* in **b** and **c** *RCA*, *white arrowhead* in **e** left circumflex coronary artery, *black arrows* in **f** left atrioventricular groove, *white arrowhead* in **b** internal mammary artery. *rAAp* right atrial appendage, *SVC* superior vena cava, *Sep* septum

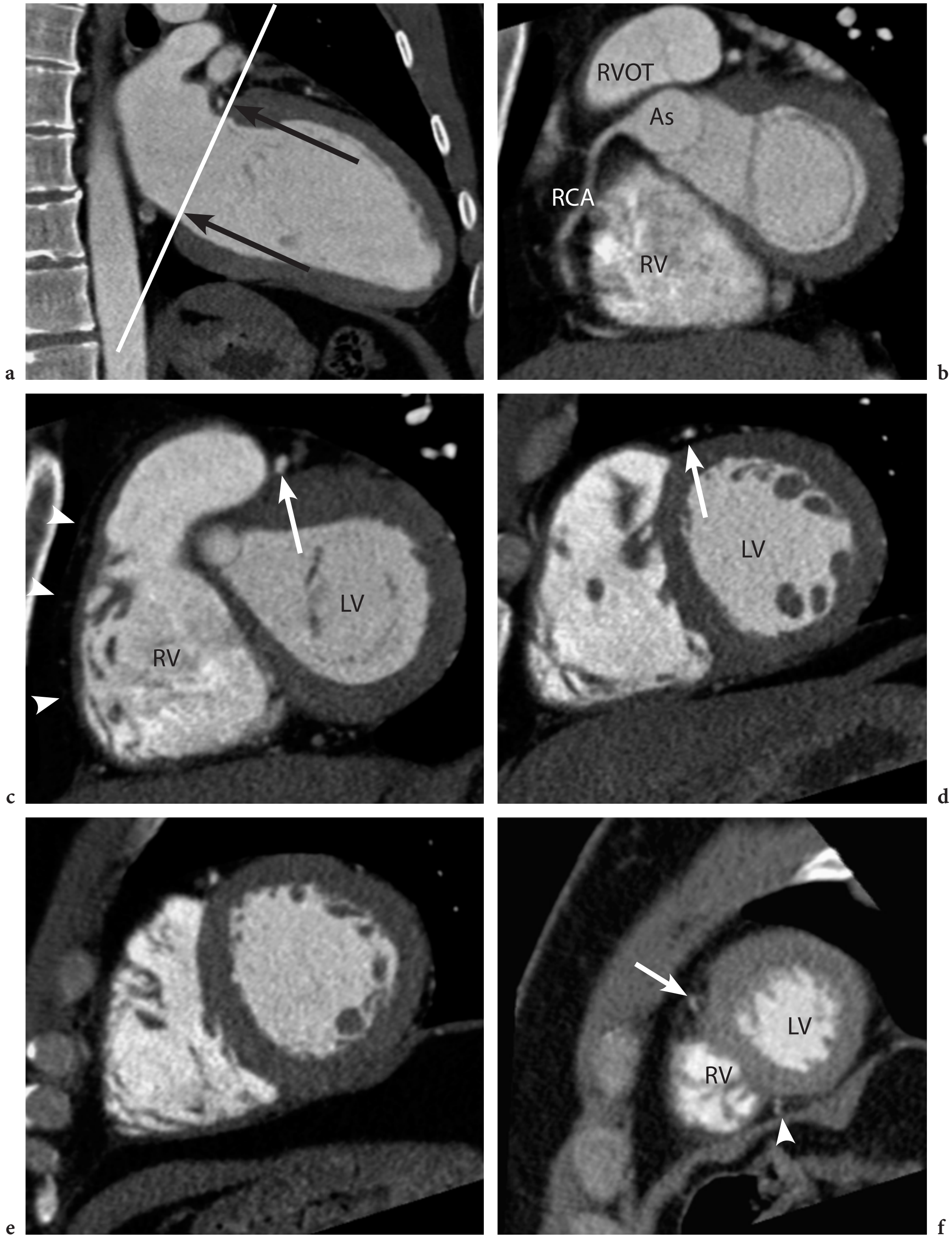

Fig. 2.5a–f. Short axis view of the heart. **a** Short axis orientation as planned from a vertical long axis view. The mitral valve is depicted as a thin soft-tissue structure in the left ventricular lumen in (**c**). Note the round configuration of the left ventricular cavity. *White arrow* (in **c**, **d**, and **f**) *LAD*, *white arrowhead* (in **f**) posterior descending artery. The *RCA* has an orientation parallel to the cardiac base and its descending segments are well-seen in this orientation. Note the anterior pericardium (*arrowheads* in **c**). *As* aortic sinus

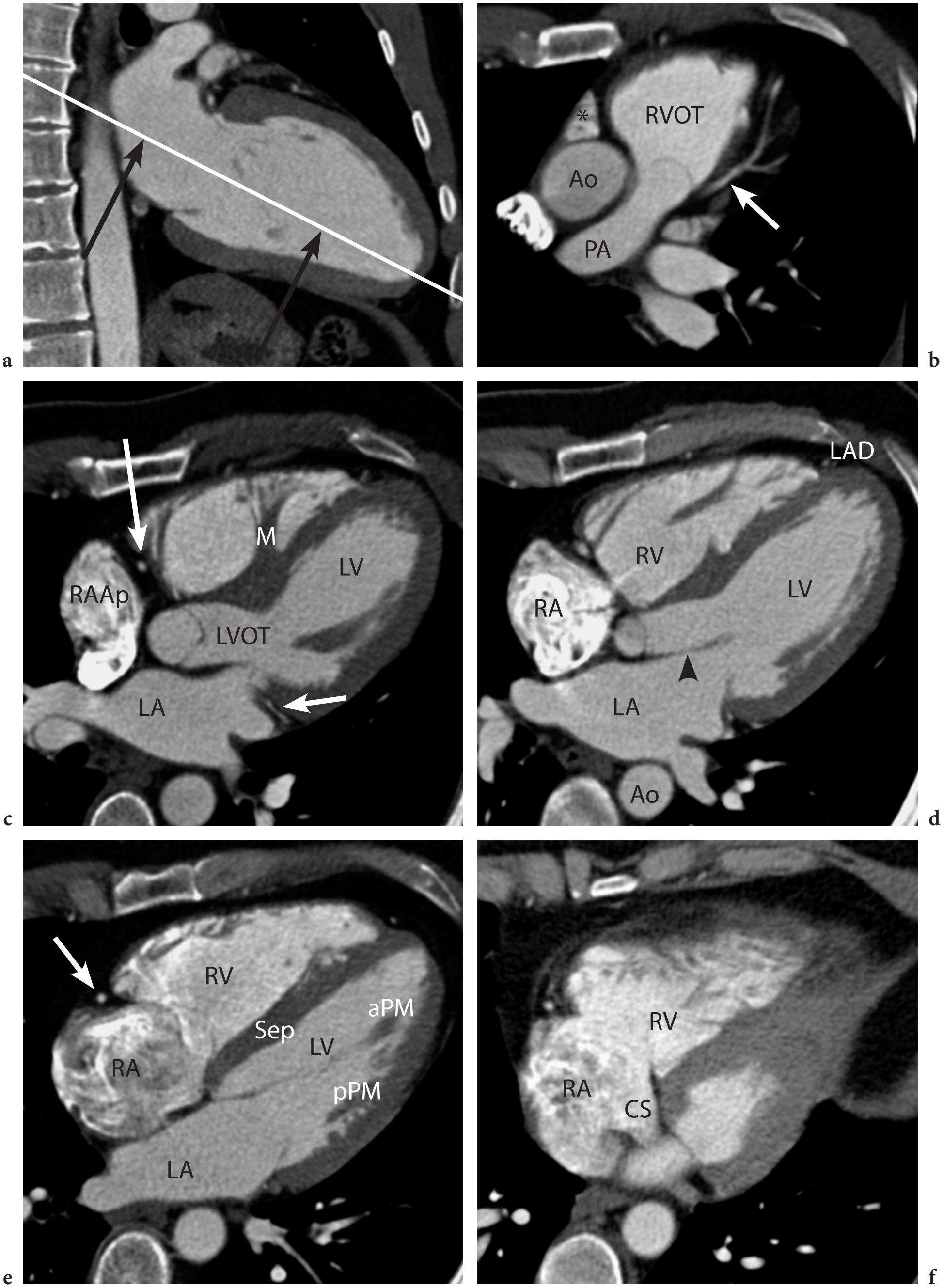

Fig. 2.6a–f. Horizontal long axis views of the heart. **a** Horizontal long axis orientation as planned from a vertical long axis view. Note the S-shape of the interventricular septum and the thin membranous part of the septum close to the cardiac base. The different coronary arteries can be delineated: *LAD* (*arrow* in **b**), *RCA* (*long arrow* in **c** and **e**), and *LCx* (*short arrow* in **c**). The moderator band (*M*) is well seen in the apical *RV* in (**c**). The anterior mitral valve leaflet (*white arrow* in **d**) forms part of the left ventricular outflow tract (*LVOT*)

mitral valve as well as parts of the left outflow tract; the right outflow tract is obliquely depicted. This view is particularly well-suited to delineate the configuration of the left ventricle and to assess the contraction of the anterior and inferior segments of the left ventricular myocardium. A vertical long axis view adapted to the course of the LAD along the anterior interventricular groove can be used to depict the LAD in almost its entirety. Maximum-intensity projection (MIP) images in this orientation also give an overview of the obtuse marginal branches of the left circumflex artery and the descending segment of the RCA.

Short Axis. The short axis view is oriented perpendicular to the vertical long axis and is parallel with the mitral valve plane and the cardiac base (Fig. 2.5). The short axis therefore has a double-oblique angulation to account for the dorsoventral and medioleftlateral tilt of the heart. Due to the alignment of the short axis view with the atrioventricular grooves, it can be used to display the RCA down to the cardiac crux, the posterolateral branches of the distal RCA, and the left circumflex coronary artery in its course in the left atrioventricular groove. The inferior facet of the right ventricle is parallel with the diaphragm and thus the transverse plane has a sharp angle (also called the acute margin), with the anterior free wall and the outflow tract of the right ventricle giving the right ventricle an almost triangular shape in this view. The left ventricle has a circular aspect on short axis view. Right and left ventricular motion can also be visualized with the short axis view and it is the basis for volumetric measurements used in global ventricular function evaluation.

Horizontal Long Axis. The horizontal long axis corresponds to a tilted plane from cardiac apex through the middle of the mitral valve plane to the cardiac base. It is perpendicular to the vertical long axis and displays both ventricles and atria in their largest diameters. This view is a frontal view onto the heart from the anterior aspect directed to the inferior wall and thus gives a good overview of the size and configuration of both ventricles. It can be used to delineate the mitral and tricuspid valves. As shown in Figure 2.6, the horizontal long axis imaging plane displays the left main coronary artery and the LAD with its diagonal branches. The RCA, like the proximal left circumflex coronary artery, is depicted in an orthogonal cut plane.

Left Ventricular Outflow Tract. In addition to the standard cardiac planes, several other views are used to depict motion or special anatomic or pathologic features. The left ventricular outflow tract (LVOT) view delineates the left inflow and outflow tracts and is useful to assess motion of the mitral and aortic valves or septum changes in hypertrophic obstructive cardiomyopathy. The LVOT view can be planned on a coronal view by tilting the imaging plane according to the ascending aorta (Fig. 2.7).

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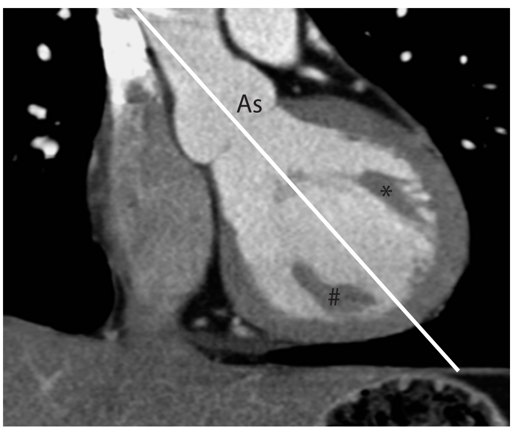


b


Fig. 2.7a, b. Left ventricular outflow tract view as planned from a true coronal view. Note the bulging of the aortic sinus (*As*) and the aortic valve in closed position (**a**). The anterior mitral valve leaflet is well-depicted (*black arrowheads* in **b**) with its relation to the *LV* inflow and outflow tracts

2.3 Coronary Arteries and Veins

This section gives an overview of the relevant anatomy for coronary artery angiography with CT. Figure 2.8 provides a schematic overview of the coronary artery anatomy and Table 2.1 summarizes the segmental nomenclature of the major coronary vessels according to AHA recommendations (Scanlon 1999) For a more detailed description of coronary artery anatomy, including its many variations, the reader is referred to the literature (Mc Alpine 1975).

Right Coronary Artery. The right and left coronary arteries arise from the right and left aortic sinus. The RCA arises from the aorta slightly caudal from the origin of the left coronary artery. The RCA takes its course down the right atrioventricular groove toward the cardiac crux, where it usually bifurcates into the posterior descending artery (PDA) and the right posterolateral ventricular (PLV) branches (Fig. 2.2b). The artery that crosses the cardiac crux and gives rise to the PDA represents the dominant coronary artery. In most people (>70%), the PDA arises from the distal RCA and supplies the inferior portion of the ventricular septum. Right PLV branches supply the inferior left ventricular wall and the inferior papillary muscle. A left dominance is found in 10% of persons, with the PDA arising from the left circumflex coronary artery. In this case, the RCA remains a very small vessel and terminates before it reaches the cardiac crux. In 20% of human hearts, there is an equal coronary distribution, so that the PDA arises from the RCA but the left coronary artery supplies the inferior segments of the left ventricle.

In a majority of people (50–60%), the first branch of the RCA is the conus artery. It passes upward and anteriorly to supply the right ventricular outflow tract. Otherwise, the conus artery arises as a separate vessel from the right aortic sinus just above the right coronary ostium. This vessel can be depicted with short axis MIP images (Fig. 2.9a). The second RCA branch in 60% of human hearts is the sinoatrial node artery. This vessel is rather tiny, but can be identified in a significant number of CT reformations as a vessel that courses dorsally toward the

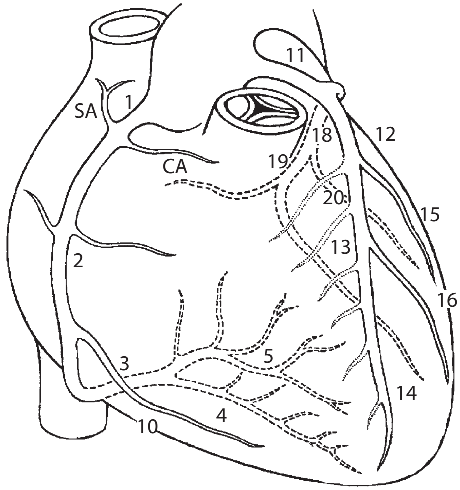


Fig. 2.8. Coronary artery anatomy and segmental classification as summarized in Table 2.1

Table 2.1. Coronary artery segments and corresponding anatomic names

Segment		Anatomic name and location
AHA 1999	AHA 1976	
1	1	RCA, proximal segment
2	2	RCA, middle segment
3	3	RCA, distal segment
4	4	PDA, right posterior descending artery
6		Right posterolateral branch
10		Acute marginal branch
11	5	LM, left main coronary artery
12	6	LAD, proximal segment
13	7	LAD, middle segment
14	8	LAD, distal segment
15	9	First diagonal branch
16	10	Second diagonal branch
18	11	LCx, proximal segment
19	13	LCx, middle/distal segment
20	12	First obtuse marginal branch
21		Second obtuse marginal branch
22		Third obtuse marginal branch
24	14	First left posterolateral branch
27	15	Left posterolateral descending artery
28		Ramus intermedius

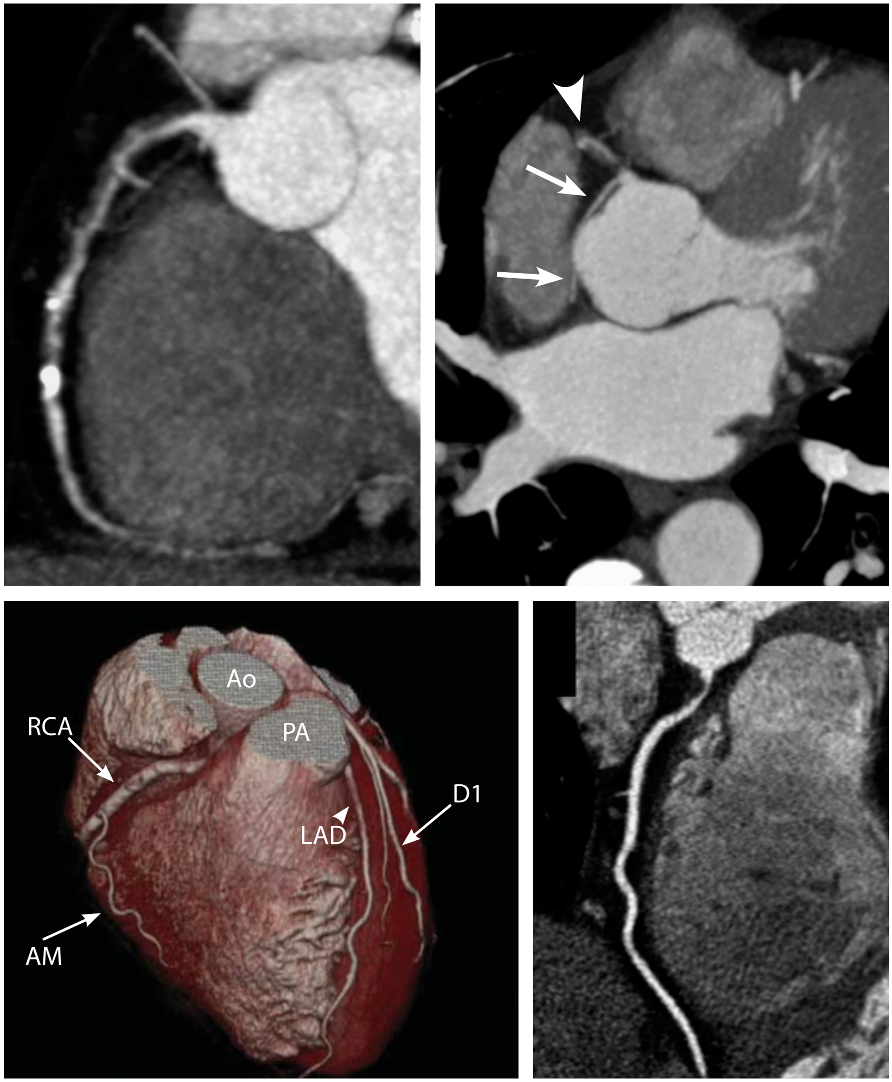


Fig. 2.9. a Right coronary artery displayed with curved maximum intensity projection (MIP) over its entire course. The conus artery is seen as the first branch of the RCA (*arrowhead* in **b**). The sinus node artery passes between the *Ao* and right atrial appendage (*arrows* in **b**). Proximal and middle segment including the acute marginal branch (*AM*) in 3D display is shown in (**c**). Curved multiplanar reformation (MPR) allows display of all four main segments in one view (**d**)

lateromedial aspect of the right atrium (Fig. 2.9b). Several marginal (or right ventricular) branches supply the anterior free wall of the right ventricle. The right ventricular branch originates from the middle RCA segment (Fig. 2.9c). The largest marginal branch usually travels along the acute margin from base to apex and thus is called the acute marginal branch. Despite the tortuous course of the RCA, the entire vessel can be displayed in one view using curved multiplanar reformations (Fig. 2.9d).

Left Coronary Artery. The left main coronary artery takes a short course along the epicardium, between the pulmonary trunk and left atrium. It then divides into the LAD and the left circumflex (LCx) arteries. A third artery, the intermediate artery, may also arise at this division, thus forming a trifurcation in 20–30% of hearts (Figs. 2.9c, 2.10). This ramus intermedius is analogous to a diagonal branch and it usually supplies the anterolateral free wall.

The LAD passes down the cardiac midline along the anterior interventricular groove to the cardiac apex. Its major branches are the septal and diagonal branches. The septal branches, which supply the anterior and apical septum, vary in size, but they are rarely identified on CT. There is a wide variability in the number and size of the diagonal branches. Unlike the septal branches, one to three diagonal branches, which supply the anterior left ventricular free wall, are usually well seen on CT (Figs. 2.9c, 2.11).

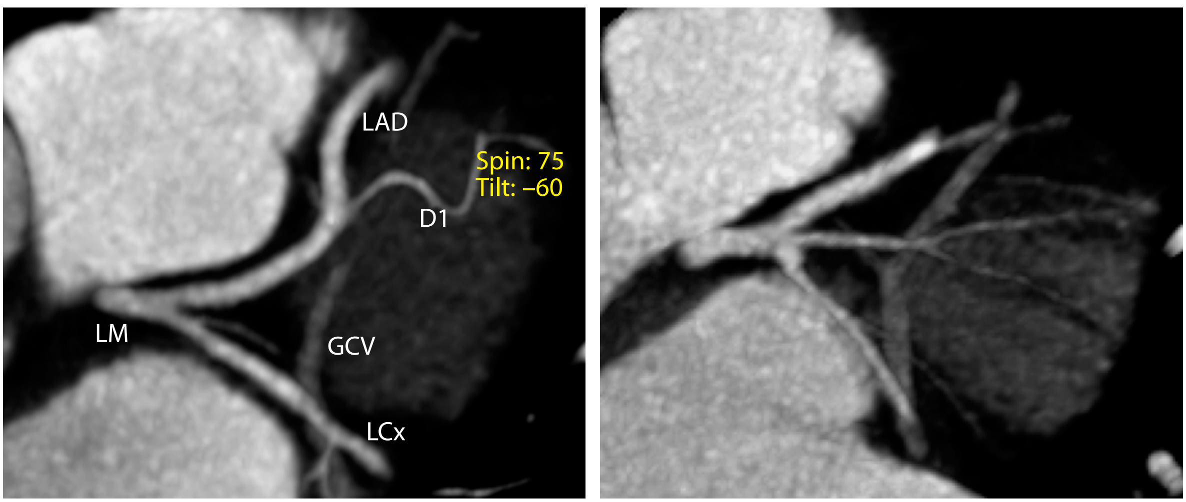
The left circumflex artery follows the left atrioventricular groove and gives off one to three large obtuse marginal branches. The distal LCx beyond the obtuse marginal branch tends to be a rather small vessel that is difficult to delineate on CT. The LCx and its obtuse marginal branches supply the lateral left ventricular wall. This artery commonly terminates beyond its large obtuse marginal branch. The length and caliber of the LCx coronary artery varies with the caliber and distribution of the right coronary artery, as described above.

Coronary Veins. The coronary venous circulation comprises the cardiac veins, coronary sinus, and thebesian veins (venae cordis minimae). The great cardiac vein courses in the anterior interventricular groove along the LAD and then follows the LCx coronary artery in the left atrioventricular groove. The great cardiac vein and the left posterior and middle cardiac veins drain into the coronary sinus (Fig. 2.2b). The coronary sinus drains the coronary blood into the right atrium.

2.4 Pericardium

The parietal pericardium is a fibrous sac that envelops the heart and attaches onto the great vessels. The visceral pericardium forms the serous inner lining of the fibrous pericardium as well as the outer lining of the heart and great vessels. The pericardium is usually seen as single thin layer of a soft-tissue-density structure (Fig. 2.3d). It contains the epicardial coronary arteries and veins, autonomic nerves, lymphatics, and adipose tissue. The junctions between the visceral and parietal pericardium lie along the

a



b

Fig. 2.10a, b. Normal left coronary artery. The left main coronary artery (*LM*) bifurcates and gives off the *LAD* and left circumflex (*LCx*) coronary arteries. An intermediate ramus is depicted in **b**. The *GCV* is seen adjacent to the *LAD* (**a**) and in the atrioventricular groove (**b**)

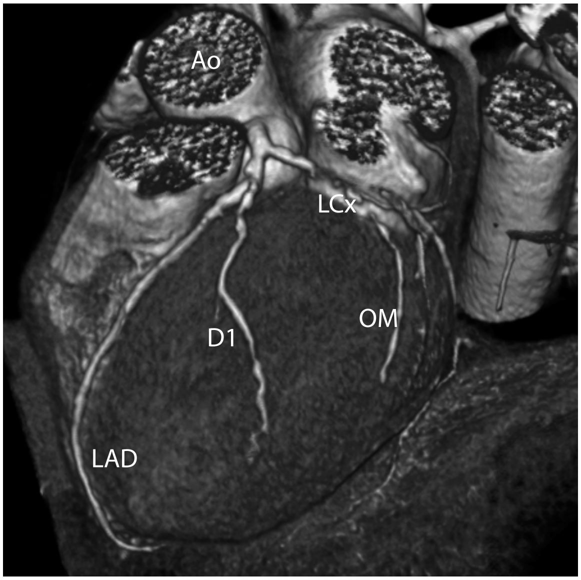


Fig. 2.11. Three-dimensional display of the left coronary system. Note a proximal occlusion of the *LCx* artery. *OM* Obtuse marginal branch

great vessels and form the pericardial reflections. Almost the entire ascending aorta and main pulmonary artery as well as portions of both venae cavae and all four pulmonary veins are intrapericardial.

2.5 Cardiac Chambers

Right Atrium. The right atrium has a tubular shape and with its smooth-walled posterior portion forms an almost straight continuation of the upper and inferior venae cavae. The posterior component that receives the venae cavae and the coronary sinus is separated by a prominent muscle ridge, the crista terminalis (Fig. 2.3e), from a muscular anterior region from which the right atrial appendage emanates. The right atrial appendage lies in close proximity to the right aortic sinus and overlies the proximal right atrioventricular groove and the RCA.

Right Ventricle. The right ventricle occupies the sternocostal surface of the heart. It is made up of inlet and trabecular outflow components. The myocardium of the right ventricular free wall ranges between 1 and 3 mm in CT and is much thinner than that of the left ventricle. The inlet portion extends from the tricuspid annulus to the insertions of the three papillary muscles. A trabecular zone extends beyond the attachments of the papillary muscles toward the ventricular apex. There, an intracavitary muscle, the moderator band, forms a prominent trabecular structure that connects the septum with the anterior tricuspid papillary muscle (Fig. 2.3d). The right outflow tract, or conus, is a smooth-walled muscular subpulmonary channel.

Left Atrium. The left atrium is dorsally located and collects the blood from the valveless pulmonary veins. Anterolaterally, the left atrial appendage overlies the LCx coronary artery and sometimes the left main coronary artery. The left atrial appendage is tubular in shape and less trabeculated than the right atrial appendage. The atrial septum consists of the interatrial and atrioventricular regions. The interatrial portion is characterized by the fossa ovalis, a shallow depression at the position of the former foramen ovale, which is usually not delineated with CT.

Left Ventricle. The left ventricle has an inlet component and a subaortic outflow component. The interventricular septum bulges towards the right ventricle, which results in the round configuration of the left ventricular cavity seen on short axis views (Fig. 2.5). The left ventricular free wall is normally thickest toward the base, where it measures between 6 and 12 mm, and thinnest toward the apex, where it averages only 1–2 mm in thickness (Fig. 2.4). The trabeculae of the left ventricle are more densely packed than those of the right ventricle, which result in a rather smooth appearance of the left ventricular cavity. The two papillary muscles are distinct soft-tissue structures seen in the cavity of the left ventricle. The anterior papillary muscle attaches to the anterior leaflet of the mitral valve, while the inferior muscle extends to the posterior leaflet. The ventricular septum may be divided into the muscular septum and a short membranous portion at the base. The membranous septum lies beneath the right and posterior aortic cusps and contacts the mitral and tricuspid annuli. The septum has a slightly S-shaped configuration due to the different orientations of the infundibular and ventricular components, which is well-appreciated on images in the axial plane or the horizontal long axis view. The majority of clinically significant ventricular septal defects involve the membranous septum.

The left ventricle can be divided into specific segments with reference to the long axis and short axis views (Cerqueira 2002). The location of a segment along the long axis is defined as basal, mid-cavity, and apical. In the short axis view, the basal and mid-cavity slices are further subdivided into six equal segments: anterior, anteroseptal, inferoseptal, inferior, inferolateral, and anterolateral. The appropriate names for each segment are the combination of the long axis location and the circumferential position, e.g., basal anteroseptal or mid-inferolateral. The apical slices are dived into only four segments, the apical anterior, apical septal, apical inferior, and apical lateral segments. The apical cap, which represents the left ventricular myocardium of the extreme tip of the left ventricle, is called the apex. Using this scheme, the left ventricular myocardium can be divided into 17 segments, which are used for bulls-eye plots of the left ventricular myocardium (Fig. 2.12). Although there is tremendous variability in the coronary artery blood supply to myocardial segments, individual segments have been assigned to specific coronary artery territories. The LAD usually supplies the anterior and anteroseptal segments, the RCA is assigned to the inferior and inferolateral segments, while the LCx supplies the anterolateral and inferolateral segments. The apex may derive its supply from any of the three vessels.

2.6 Cardiac Valves

The four cardiac valves are anchored to fibrous rings, which comprise their annuli at the base of the heart. The annuli join to form the fibrous skeleton of the heart. The aortic valve is located centrally, and its fibrous ring extensions abut each of the other three valves (Fig. 2.13).

Tricuspid Valve. The tricuspid valve consists of the anterior, septal, and posterior leaflets. The anterior leaflet is the largest and forms an intracavitary separation of the inflow and outflow tracts of the right ventricle. The septal leaflet has many direct chordal attachments to the ventricular septum, and the posterior leaflet is usually the smallest. The tricuspid valve is a rather thin structure and, due to either small attenuation differences between blood

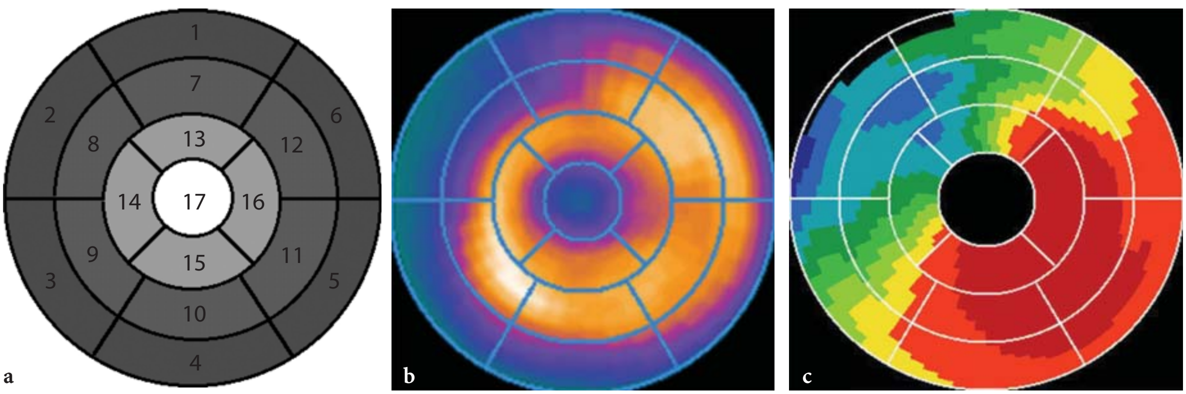


Fig. 2.12. a Bulls-eye plot of the left ventricle segments. *1* basal anterior, *2* basal anteroseptal, *3* basal inferior, *4* basal inferior, *5* basal inferolateral, *6* basal anterolateral, *7* mid-anterior, *8* mid-anteroseptal, *9* mid-inferior, *10* mid-inferior, *11* mid-inferolateral, *12* mid-anterolateral, *13* apical anterior, *14* apical septal, *15* apical inferior, *16* apical inferior, *17* apex. **b**, **c** Examples of color coded bulls-eye plots. **b** PET perfusion study, **c** MR regional ejection fraction

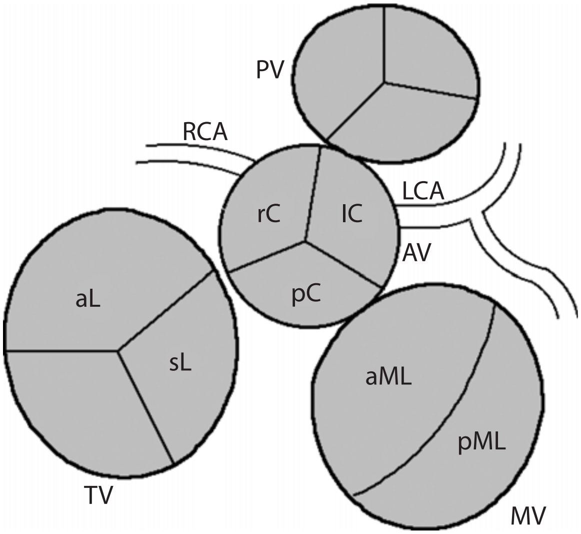


Fig. 2.13. Anatomy of the cardiac base and cardiac valves. The aortic valve (*AV*) is centrally located. The coronary arteries rise at the right (*rC*) and left (*lC*) aortic cusps. The posterior cusp is the non-coronary cusp. *TV* Tricuspid valve with anterior (*aL*) and septal (*sL*) leaflets. *MV* Mitral valve with anterior (*aML*) and posterior (*pML*) leaflets. *LCA* Left coronary artery

and valve tissue or streak artifacts related to high-density contrast agent in the right atrium, it is rarely well-delineated on CT images (Fig. 2.3f).

Mitral Valve. In contrast to the other cardiac valves, the mitral valve has only two leaflets. The anterior leaflet is large and semicircular, and, like the anterior tricuspid leaflet, it partially separates the ventricular inflow and outflow tracts. Unlike its right-sided counterpart, the mitral valve leaflets are usually well-depicted on CT. Beneath the two mitral commissures – the separations of the leaflets – lie the anterior and inferior papillary muscles, which arise from the left ventricular free wall. Commissural chords arise from each papillary muscle and extend in a fan-like array to insert into both leaflets adjacent to the commissures.

Aortic Valve. The aortic valve comprises the annulus, cusps, and commissures and, like the pulmonary valve, has no tensor apparatus. The left, right, and posterior half-moon-shaped (semilunar) aortic cusps form pocket-like tissue flaps. The commissures between the cusps reach the level of the aortic sinotubular junction, where the sinus and tubular portions of the ascending aorta meet. The components of the aortic valve are well-visualized by CT and may be depicted in open and closed positions with appropriate reconstructions. There is a close relation between the mitral valve and the aortic valve as the intervalvular fibrosa at the level of the left and posterior aortic cusps is merged with the anterior mitral leaflet.

2.7 Great Vessels

Vena Cava. The right and left subclavian veins merge with the corresponding internal jugular veins to form the right and left brachiocephalic veins. The left brachiocephalic vein is longer than its right-sided counterpart and travels anterior to the aortic arch and the ascending aorta until it merges with the right brachiocephalic vein to form the superior vena cava. The superior vena cava lies anterior to the right pulmonary artery and receives the azygos vein posteriorly before it drains into the right atrium (Fig. 2.14). A left superior vena cava may persist. This vessel then usually drains into the coronary sinus (Fig. 2.15a).

Pulmonary Artery. The pulmonary trunk arises from the conus of the right ventricle and ascends obliquely ventral and then to the left of the ascending aorta (Fig. 2.15b). It bifurcates near the undersurface of the aortic arch into right and left branches. The left pulmonary artery courses over the left bronchus, whereas the right pulmonary artery, which is longer and slightly larger than the left, travels horizontally beneath the aortic arch and ventral to the right bronchus. At the root of the lung, it divides into the upper lobe artery and the intermediate artery. The upper lobe artery divides into the apical and posterior segmental branches and the anterior branch. The intermediate artery, or interlobar trunk, gives rise to the middle lobe artery and the segment artery of the apical seg-

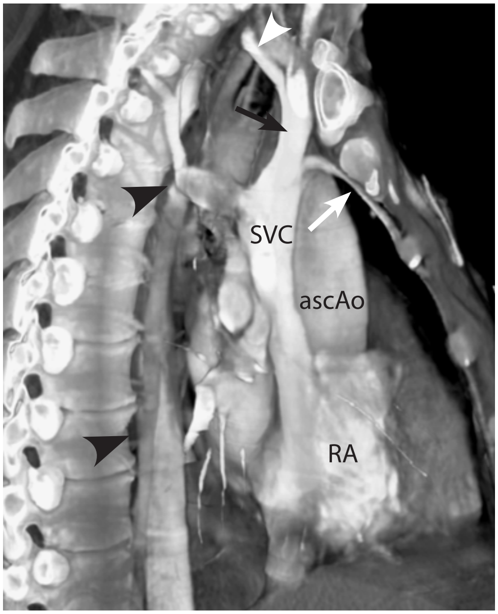


Fig. 2.14. Anatomy of the superior vena cava. The internal jugular (*white arrowhead*) and right subclavian veins form the short right brachocephalic vein (*black arrow*). The azygos vein (*black arrowheads*) courses over the right bronchus and drains into the SVC from posterior. Note the right internal mammary vein (*white arrow*) draining into the cranial vena cava

ment of the right lower lobe. The continuation of the intermediate artery divides into the four basal segment arteries. The left pulmonary artery gives rise to the apical and posterior arteries of the apicoposterior segment and the anterior segment artery of the left upper lobe. The lingular artery and the superior segmental artery of the lower lobe arise from the interlobular portion of the left pulmonary artery. The remainder of the artery divides into the four basal segment arteries.

Pulmonary Veins. In conventional normal anatomy, single right and left superior and inferior pulmonary veins drain into the left atrium (Fig. 2.16). Their orifices lie on the posterior aspects of the left atrial cavity and are well-visualized using 3D volume-rendering technique (Lacomis 2003). A large atriovenous junction is created when upper and lower lobe veins merge proximal to the left atrium. This variant is found more frequently on the left than on the right. Accessory pulmonary veins with independent junctions with the left atrium are seen more frequently on the right (Fig. 2.17). A vein that drains into a structure other than the left atrium is termed an anomalous pulmonary vein. With the

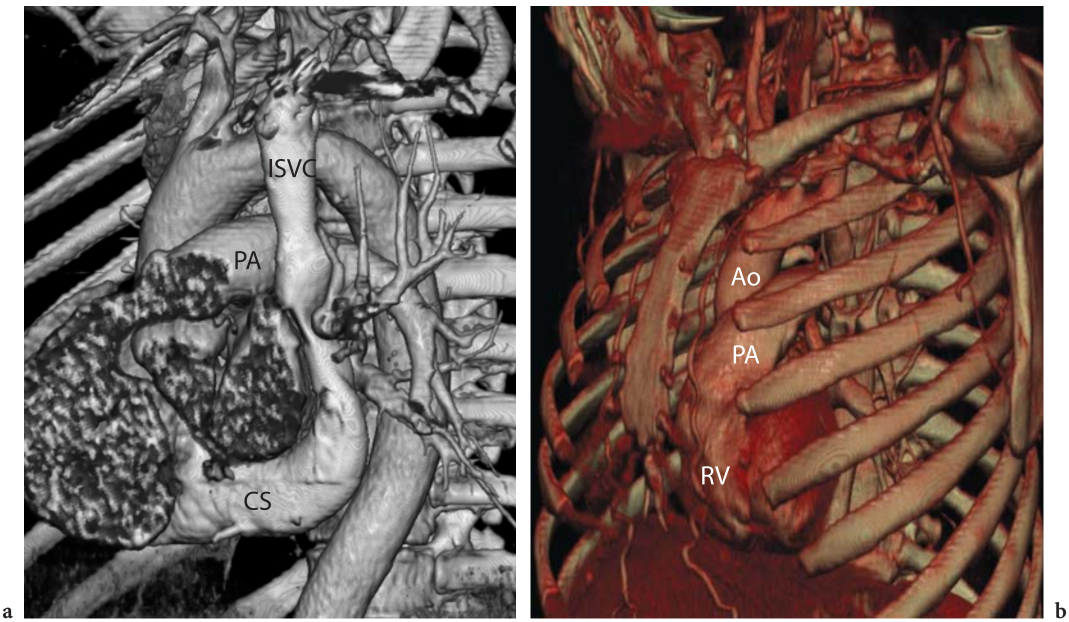


Fig. 2.15. 3D volume-rendering displays of a persistent left-sided vena cava draining into the enlarged coronary sinus and **b** the *PA* originating from the conus of the *RV*

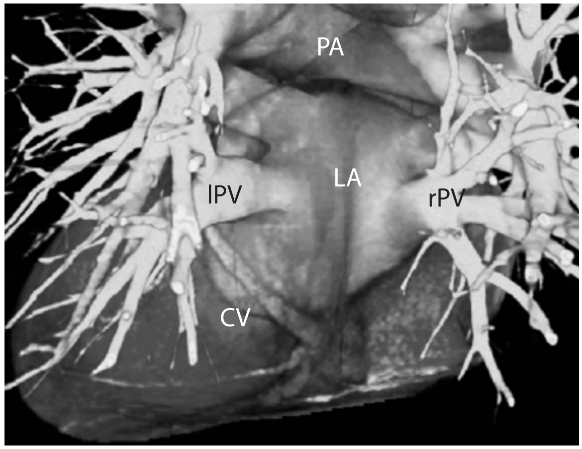


Fig. 2.16. Pulmonary venous anatomy as seen from a left posterior view. Single inferior and superior pulmonary veins are seen on the left and right. *lpV*, *rPV* Left and right pulmonary veins, *CV* coronary vein

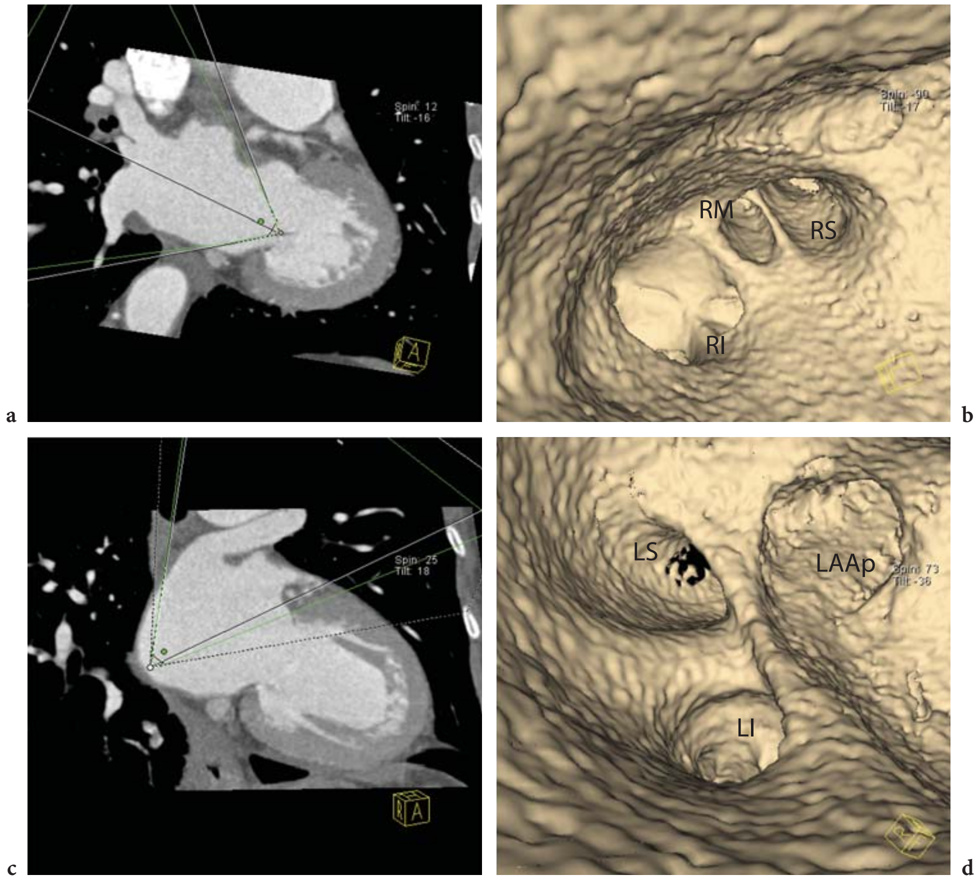


Fig. 2.17a–d. Endocardial views and corresponding reference images of the LA with pulmonary ostia. **a**, **b** A small intervenous saddle separates the accessory right middle vein from the right superior vein. *RI* Right inferior vein. **c**, **d** On the left, the superior and inferior veins are depicted with the adjacent orifice of the left atrial appendage (*LAAp*)

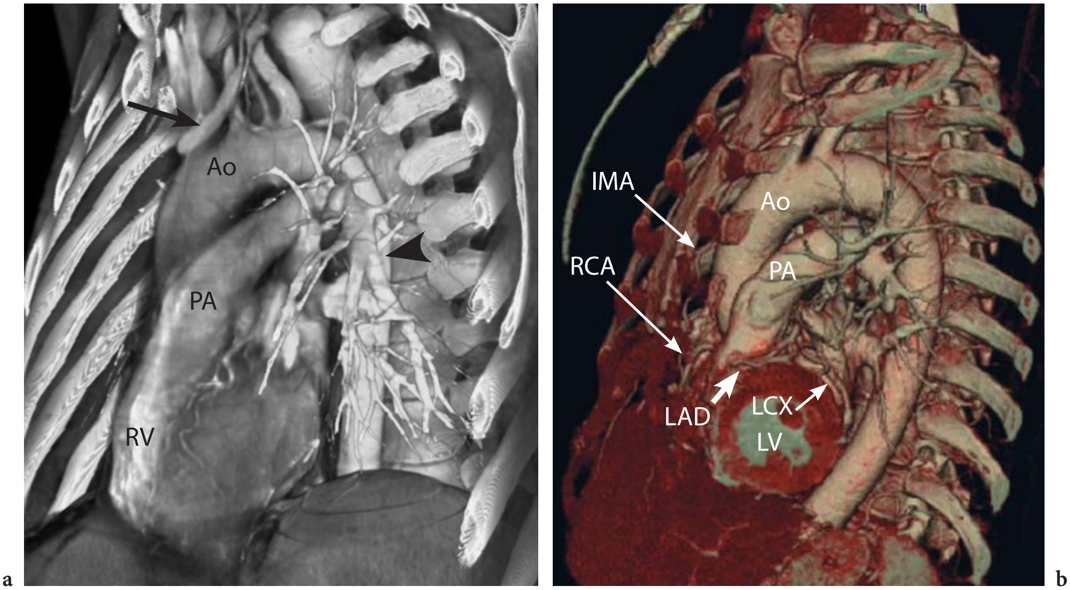


Fig. 2.18. a 3D volume rendering of the thoracic vessels from an ECG-gated spiral *CT*. The left brachiocephalic vein passes ventral to the aortic arch to drain into the SVC. The aortic arch gives off the brachiocephalic trunk, the left common carotid, and subclavian arteries, and a variant left vertebral artery. The *PA* ascends from the RVOT and rises ventral to the ascending aorta to bifurcate underneath the aortic arch. The left *PA* branches (*arrow*) are posterior to the left PVs. **b** An ECG-gated spiral scan of the chest using the latest 64-slice CT scanners reveals the great thoracic vessels, the internal mammary arteries (*IMA*), the greater cardiac anatomy, and the coronary arteries from the same scan

evolution of pulmonary vein ablation therapy for atrial fibrillation, precise demonstration of pulmonary vein anatomy is becoming increasingly important. Virtual endoscopic views can easily be generated to display pulmonary vein anatomy as seen from the left atrium (Fig. 2.17) and may help to guide catheter ablation.

Aorta. The thoracic aorta arises at the level of the aortic valve and is divided into three segments: ascending aorta, aortic arch, and descending thoracic aorta. The ascending aorta is about 3 cm in diameter and consists of sinus and tubular portions, which are demarcated by the sinotubular junction. The entire ascending aorta is covered by the visceral pericardium. The aortic arch travels over the left main bronchus and the right pulmonary artery and gives rise to the brachiocephalic (innominate), the left common carotid, and the left subclavian arteries. In about 10% of persons, the innominate and left common carotid share a common ostium; in 5%, the left vertebral artery arises directly from the aortic arch in between the left common carotid and the left subclavian artery instead of from the subclavian artery (Fig. 2.18a). The remnant of the ductus arteriosus botalli, which, when patent, connects the proximal left pulmonary artery with the aortic arch, forms the ductal artery ligament. The descending thoracic aorta lies adjacent to the left atrium and the vertebral column. An ECG-gated scan of the entire chest using the latest 64-slice CT scanners enables display of the great thoracic vessels, the greater cardiac anatomy, and the coronary arteries from a single scan (Fig. 2.18b).

Abbreviations used in figure legends	
aL	Anterior leaflet
AM	Acute marginal branch
aML	Anterior mitral valve leaflet
Ao	Aorta
As	Aortic sinus
AV	Aortic valve
CS	Coronary sinus
CV	Coronary vein
D1	First diagonal branch
GCV	Great coronary vein
IMA	Internal mammary arteries
IVC	Inferior vena cava
LA	Left atrium
LAAp	Left atrial appendage
LAD	Left anterior descending artery
Laur	Left auricle
lC	Left aortic cusp
LCA	Left coronary artery
LCx	Left circumflex coronary artery
lPV	Left pulmonary vein
LV	Left ventricle
LVOT	Left ventricular outflow tract
M	Moderator band
MV	Mitral valve
OM	Obtuse marginal branch
PA	Pulmonary artery
PM	Papillary muscle
pML	Posterior mitral valve leaflet
PV	Pulmonary vein
RA	Right atrium
rAAp	Right atrial appendage
rC	Right aortic cusp
RCA	Right coronary artery
RI	Right inferior vein
rPV	Right pulmonary vein
RV	Right ventricle
RVOT	Right ventricular outflow tract
Sep	Septum
sL	Septal leaflet
SVC	Superior vena cava
TV	Tricuspid valve

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