Cardiovascular imaging

Imaging is of paramount importance in assessment of cardiovascular disease. The diagnosis of disease has been revolutionized by the ability to gain high-resolution imaging of all aspects of the heart and vessels, and we are now able to visualize and assess function of everything 'from the heart to the capillary'. As a result multiple modalities and approaches are used and the area has matured to a stage where it is not possible for everyone—or anyone—to have the same high level of specialist knowledge across all modalities. For the newcomer the range of options can appear confusing. Fortunately, some common approaches to cardiovascular imaging have developed that are transferable across modalities and allow anyone to pick up an image and begin to interpret what is seen. The basic things to get to grips with are the follwoing.
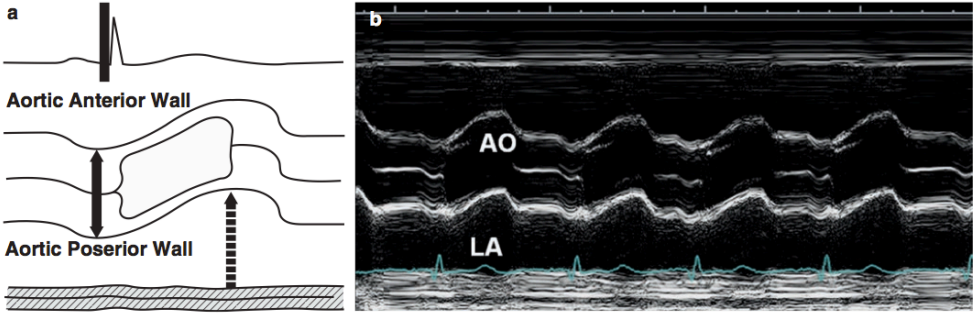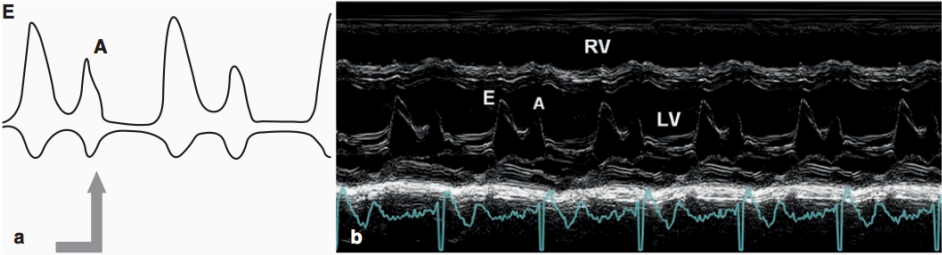
- Imaging planes—there is a recognizable series of imaging planes of the heart that allows anyone to orientate themselves to a particular structure based on some clues from the image.
- Diseases tend to relate to structures and areas—disease processes tend to affect a predominant area of the heart (although abnormalities in one area may affect other aspects). Different modalities are better at studying different aspects. In general:
  - myocardium—MR/SPECT/PET
  - cardiac function—Echo/CMR
  - valve structure and function—echo
  - coronaries—angiography/CT
  - central vessels—MR/CT
  - peripheral vessels—CT/MR/ultrasound.
- Advantages of particular modalities relate to the patient and the disease:
  - Echo—acute settings, high volume, real time
  - MR—unlimited by body habitus, any image plane
  - CT—rapid collection of volume dataset.
- Disadvantages of modalities relate to how the images are acquired:
  - Echo—range limited by penetration of ultrasound
  - MR—limited by need for magnetic field, having receivers close to the patient, acquisition over several cardiac cycles
  - CT—limited by need for radiation
 - SPECT—limited by resolution and need for radiation.

Echocardiography

- Ultrasound modality
- Multiple transducer frequencies and positions depending on patient
- Modes of Echocardiography

1- M-mode echocardiography

- The routine cardiac examination with M-mode shows images of four cardiac chambers and cardiac valves
- A better evaluation is obtained with the probe guided by 2D echo image in parasternal view, perpendicular to cardiac structure.
- The ECG signal will guide echo imaging http://safeshare.tv/w/uvsGAsbZSW

| Heart valves in M mode	
Aortic Valve	 **Fig. 1.3** **(a)** Diagram of aortic valve and left atrium. Cursor transects anterior aortic wall, aortic valve, posterior aortic wall, left atrium, and posterior wall of left atrium. **(b)** Aortic valve plane in M-mode. It is possible to show aortic leaflets as a box in systole and thin line in diastole. *AO* aorta; *LA* left atrium
Mitral Valve	 **Fig. 1.4** **(a)** Diagram of mitral valve. **(b)** Mitral valve in M-mode, opening in diastole in the centre of left ventricle. The leaflets of mitral valve separate widely with maximum early-diastolic motion of anterior leaflet called E point. The leaflets move together in the centre of left ventricle and then separate again after atrial systole (A wave). *RV* right ventricle; *E* early mitral diastolic wave; *A* late diastolic mitral valve wave; *LV* left ventricle
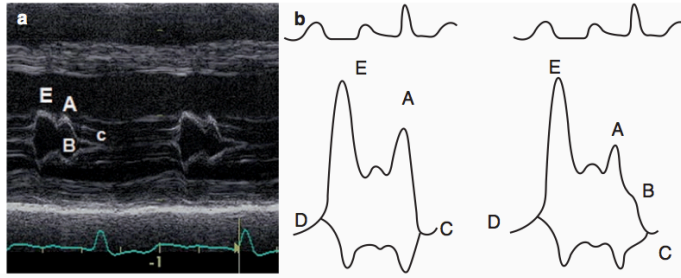
Fig. 1.5 Diagram of mitral valve opening in normal patient and in patients with ventricular dysfunction. In normal patients, the leaflets of mitral valve separate widely with maximum early-diastolic motion of anterior leaflet (E point). Distance between E point and septum is usually short. Leaflets move together in the centre of left ventricle and then separate again after atrial systole (A wave). The slope from A point to mitral closure (C point) is linear. In patients with left ventricular dysfunction and high left ventricular end-diastolic pressure, the slope from A to C presents a B bump or shoulder. M-mode (b) of a patient with left ventricular dysfunction and high end-diastolic pressure with characteristic shoulder on A-C line (B point). The distance between E wave and septum is greater. *D* opening point of mitral valve; *E* point is the maximum early-diastolic motion of anterior leaflet; *A* point is the late diastolic motion of anterior leaflet of mitral valve; *C* point is the closure of mitral valve; *B* point is the shoulder of A-C slope

Left Ventricle

Fig. 1.6 **(a)** Diagram of left ventricle. The *arrows* show measures of end-systolic and end-diastolic diameters of left ventricle and thickness of septum and posterior wall. For evaluation of left ventricular diameters, the ventricular border of septum and ventricular border of posterior wall are used as *anterior line* and *posterior lines*, respectively. **(b)** Left ventricle measures in M-mode. Diastolic measures are taken at the beginning of QRS and systolic measures are taken where higher excursion of posterior wall endocardium can be seen. The *long and short lines* show left ventricle end-diastolic diameter and left ventricle end-systolic diameter, respectively
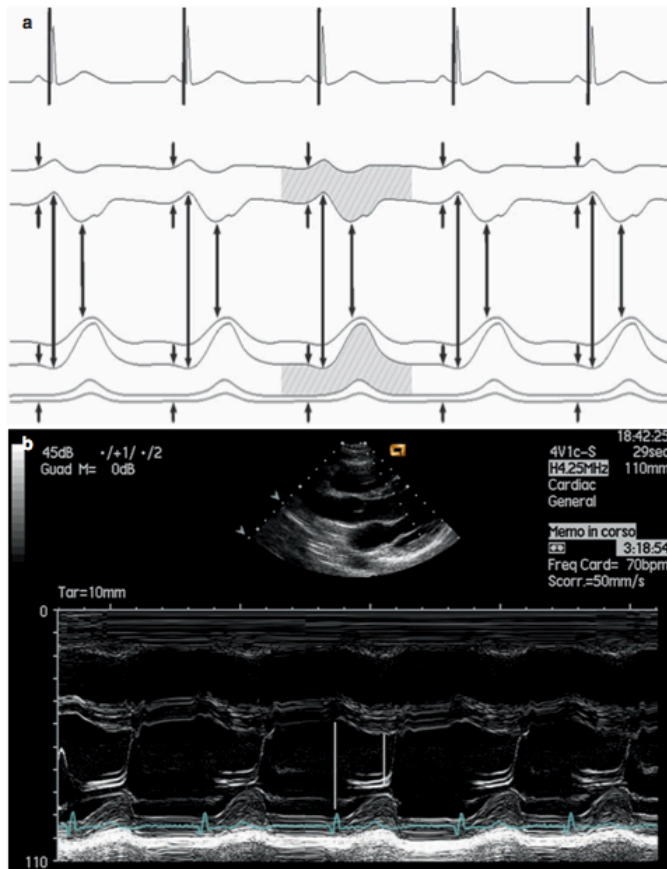
| Tricuspid Valve	Fig. 1.8 Tricuspid valve M-mode image is similar to mitral valve image and uses the same nomenclature. E point is the maximum early-diastolic motion of tricuspid valve. A-point is the late diastolic motion of tricuspid valve
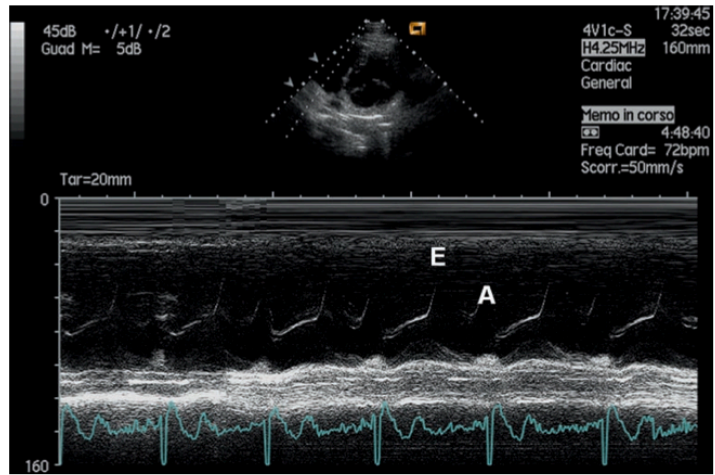
2- Two-dimensional echocardiography
http://www.yale.edu/imaging/echo_atlas/contents/index.html

Nuclear cardiology (PET and SPECT)

- Radionuclide imaging of the heart is well established for the clinical diagnostic and prognostic workup of coronary artery disease (CAD).
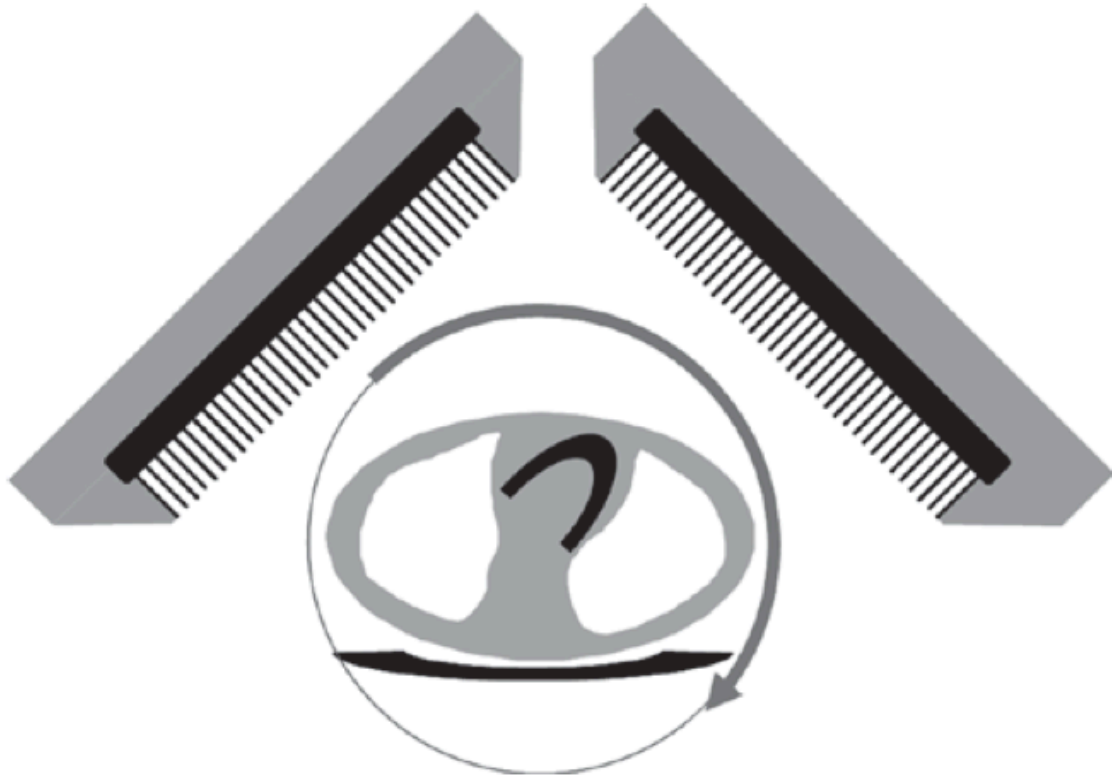
Fig. 3.1 Configuration of a single photon emission computed tomography (SPECT) system. Two gamma camera detector heads, equipped with collimators, rotate in a semi-circular fashion around the chest and create images in multiple positions ("step-and-shoot")

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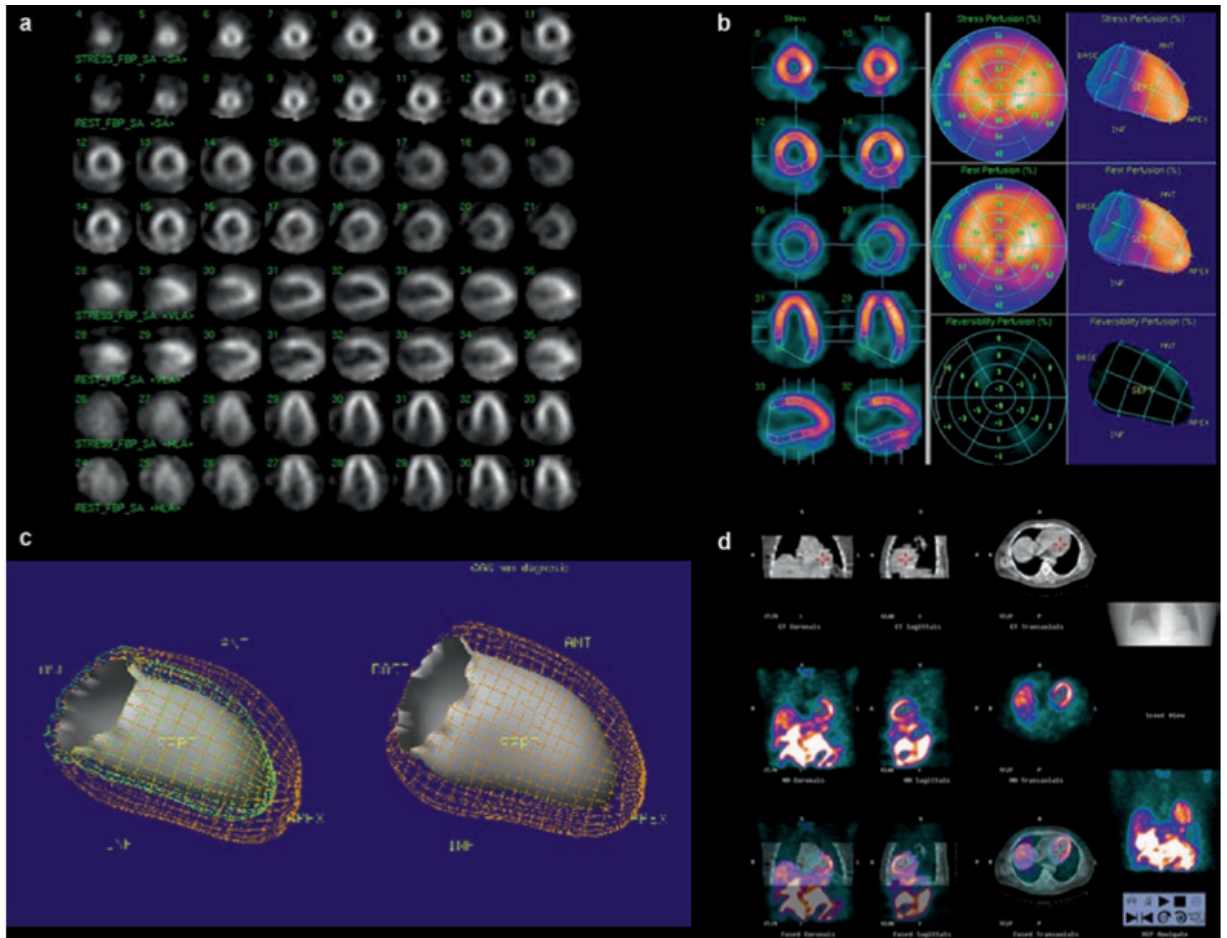
Fig. 3.2 State-of-the-art myocardial SPECT imaging. **(a)** Display of matched stress (*rows 1, 3, 5, 7*) and rest (*rows 2, 4, 6, 8*) tomographic images, reangulated along the short and long axes of the *left* ventricle for visual analysis. **(b)** Creation of two- (*middle column*) and three-dimensional (3D) polar maps (*right column*) using software-assisted detection of myocardial contours (*left column*), for semi-quantitative analysis of perfusion defects. **(c)** Three-dimensional display of endocardial contours throughout the cardiac cylce from gated SPECT acuisition, for visual and quantitative analysis of left ventricular (LV) function. **(d)** Creation of density maps from transmission images, for attenuation correction of SPECT data
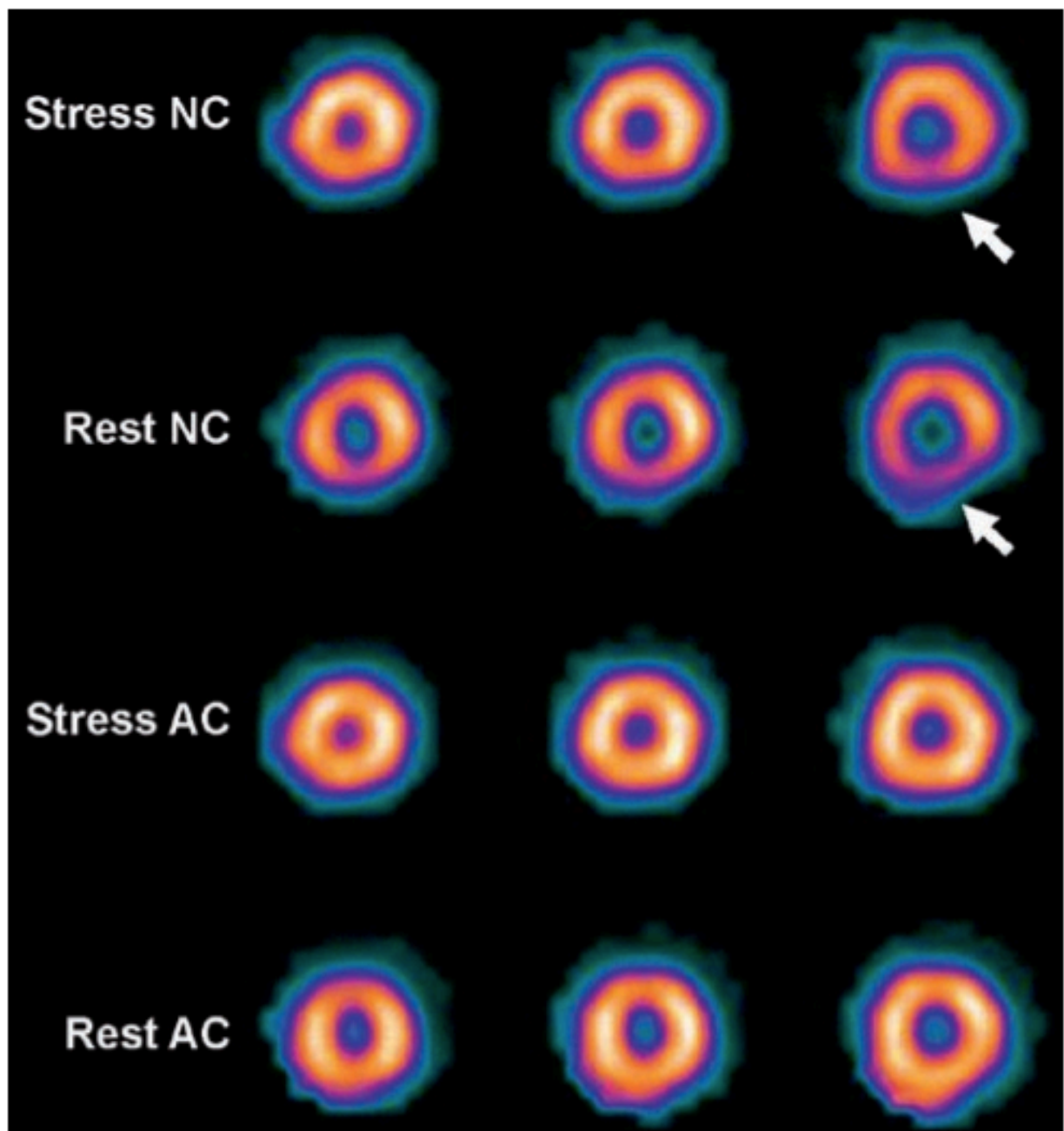
Fig. 3.8 Non-corrected (NC) and attenuation corrected (AC) mid-ventricular short axis myocardial perfusion SPECT images using ^{99m}Tc-sestamibi in an individual with suspected coronary artery disease (CAD). Note the inferior wall defect in NC images (*arrows*) which resolves after AC, indicating the presence of artefact rather than disease

Cardiac CT

The most important components of a CT system are the X-ray tube and the system of detectors

The improvement in spatial resolution regards numerous features of non-invasive coronary imaging:
- It increases the ability to visualize small-diameter vessels (e.g. the distal coronary branches).3
- It increases the ability to quantify calcium in that it reduces blooming artifacts.
- It enables the reduction of blooming artifacts in stents and therefore enables the visualization of the stent lumen.
- It improves the definition of the presence of coronary plaques and better quantifies their characteristics (volume, attenuation, etc.).
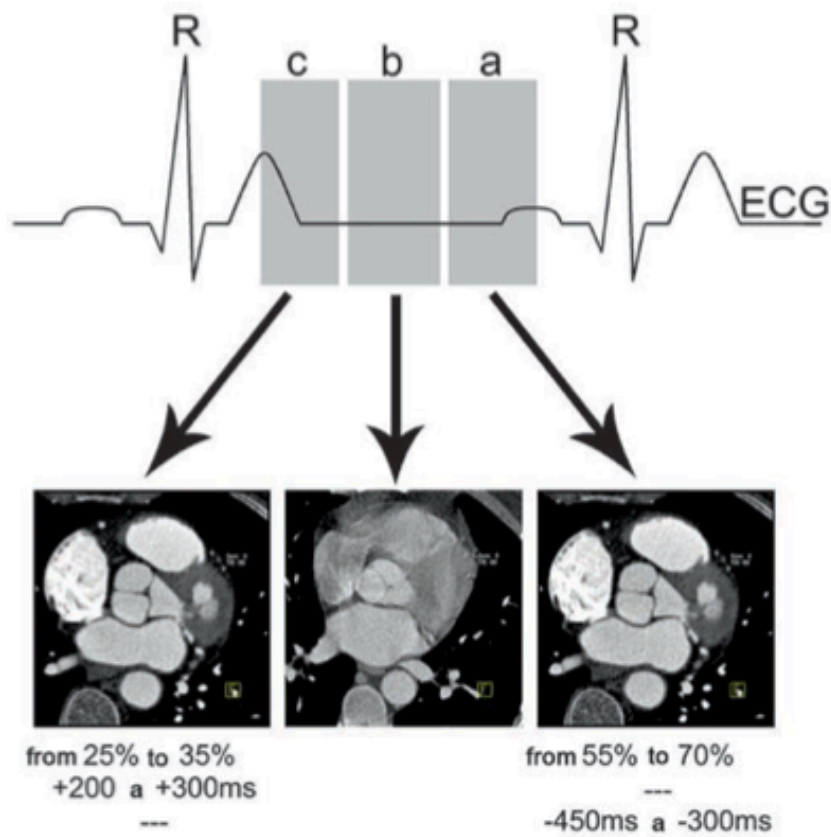
Fig. 5.5 Positioning the reconstruction time window. Several principles need to be borne in mind regarding the positioning of the time window when performing image reconstruction in MDCT coronary angiography. The operator should concentrate on three main areas of the ECG trace. The first (a) is the end-diastolic phase. In this phase, the ventricle has completed filling, just prior to atrial systole and motion is at a minimum. The second phase (b) is the early-mid diastolic phase. In this phase, the heart is filling and there is generally residual motion, which does not allow adequate coronary artery imaging. The third phase (c) is end-systole. In this phase, the heart is in isovolumetric contraction and motion is at a minimum. The images obtained in this phase can be just as valid as those obtained at end-diastole and in a number of cases, even better

CMR: Basic Principles

- Cardiac magnetic resonance imaging (CMR) is one of the newer non-invasive cardiac diagnostic imaging modalities.
- Recent advances have enabled CMR to come close to the goal of a complete examination of the cardiovascular system by a single modality.
- It can provide relevant information on most aspects of the heart–structure, global and regional ventricular function, valve function, flow patterns, myocardial perfusion, coronary anatomy, and myocardial viability, all obtained non-invasively in a single study in 30–60 min.
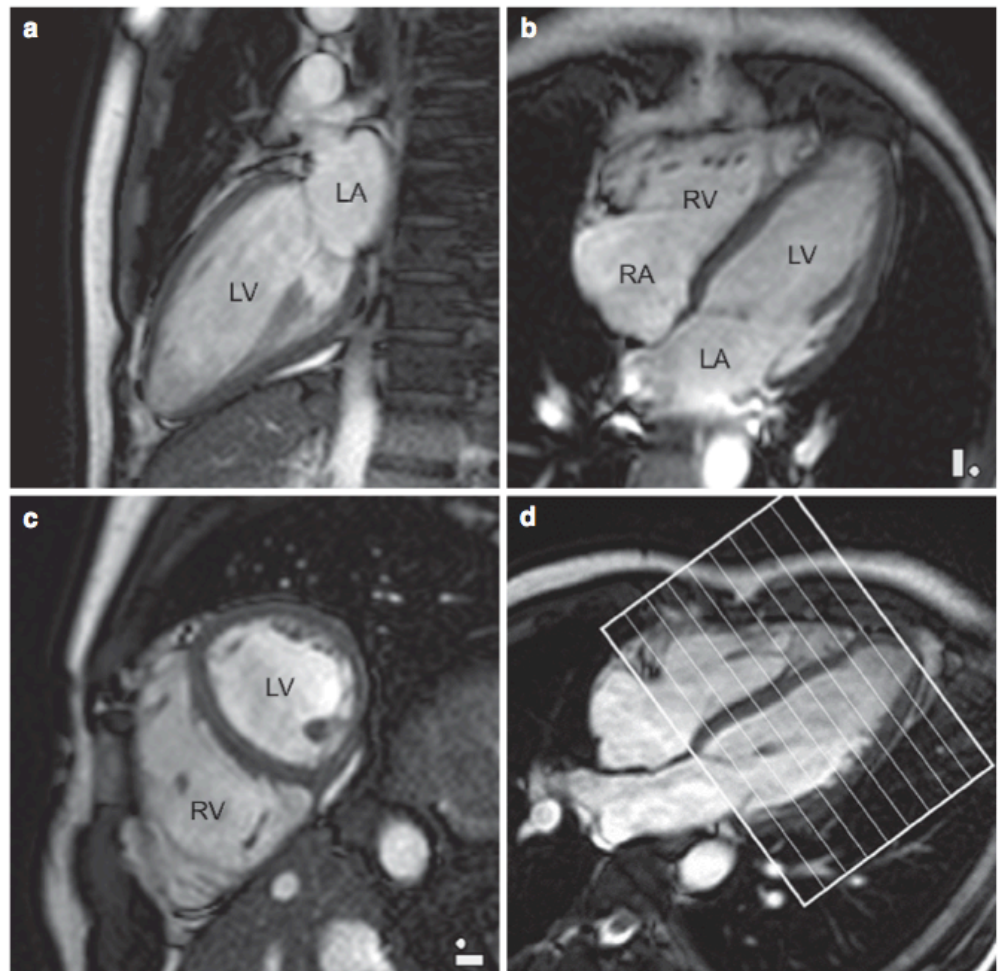
Fig. 6.1 Assessment of cardiac function. A b-SSFP cine sequence is used for functional assessment (only end diastolic frames are shown here). From the localizer scout images, the VLA plane is prescribed (a). A plane perpendicular to the VLA produces the HLA (b). The LV short-axis plane can now be prescribed, perpendicular to both the VLA and HLA (c). The LV is encompassed by a stack of slices in the short-axis plane (d) to enable quantification of ventricular volumes and assessment of global and regional systolic function. *LV* Left ventricle; *LA* Left atrium; *RV* Right ventricle; *RA* Right atrium; *VLA* Vertical long axis; *HLA* Horizontal long axis

Fig. 6.2 Assessment of valve morphology. Valve morphology and function can be qualitatively assessed with b-SSFP cine imaging. Short-axis images of the aortic valve at end diastole (a) and mid-systole (b) demonstrate a tri-leaflet aortic valve with thin leaflets that open normally (*arrow*)