2.1 Morphological Study of Heart Chambers

a. Left ventricle (LV)

The morphological assessment of the LV can be performed by either spin-echo (SE) T1-weighted (“black-blood”) or gradient-echo (GRE) (“white-blood”) sequences, both obtained during breath-hold. The first ones provide statical high-resolution images with excellent contrast between the myocardium and the intracavitary flow without the need for contrast agents \(^1\) (Figure 2.1). The GRE sequences, used for the obtention of cine images, had shown a relatively low level of contrast, even when using fast imaging sequences (Figure 2.2). However, the introduction of new improved modalities of acquisition, as the segmented Steady-State Free Precession (SSFP) sequences, has greatly improved the image quality \(^2\) (Figure 2.3), being the “white-blood” sequences widely used at present for the assessment of the LV, including the measurement of dimensions and wall thickness, and the calculation of functional parameters.

Whatever technique is used, and in order to get standardized and reproducible measurements, it is important to follow an acquisition strategy \(^3\) allowing the obtention of slices on either longitudinal or transverse true anatomical planes of the LV. Since the longventricular axis is not generally aligned within any of the natural planes of the body (Figure 2.4), it will be necessary to perform a series of angulations, the whole process including optimally 5 steps: (1) first, one of the scout axial planes is selected where an estimate of the position of the base and the apex of the LV can be taken (Figure 2.5); by using these two reference points (line on Figure 2.5) we will prescribe on this plane a single slice, that will give (2) an oblique sagittal image oriented on a vertical longitudinal plane (VLP) of the LV (2-chamber view), including the anterior wall, the ventricular apex and the inferior wall (Figure 2.6); then, a natural complementary orientation would be an horizontal plane, orthogonal to the vertical one, but for an optimal orientation a previous intermediate step is recommended: it consists of (3) a transverse plane of the ventricles (Figure 2.7) taken on the VLP (vertical line on Figure 2.6); now, by using the two views
described in steps 2 and 3, a plane is prescribed with a double angulation: orthogonal to the VLP (horizontal line on Figure 2.6), on one side, and then aligned with the maximal diameter of the right ventricle on the transverse plane (line on Figure 2.7), this giving (4) a true horizontal longitudinal plane (HLP) of the LV (4-chamber view of the heart), including the septal wall, the ventricular apex and the lateral free wall (Figure 2.8); a final step is the obtention of (5) multiple transverse planes of the ventricles (Figure 2.9) with an orientation parallel to the atrio-ventricular plane (lines on Figure 2.8).

The obtention of this series of sequences can be performed at present, by using, for instance, SSFP cine sequences with breath-hold acquisition, in less than 10 minutes. A strict routine following this protocol is highly recommended as a part of most CMR studies, as it provides a complete dataset containing accurate and reliable information on the LV, both morphological and functional.

Basic measurements of the LV can be performed on these standard anatomically-oriented views, as the maximal transverse dimension of the LV, with a mean normal value in adult men of 50 mm (upper 95% limit: 59 mm); and, in adult women, 46 mm (upper 95% limit: 51 mm); or the diastolic septal and wall thickness, with normal means of 10 mm (upper 95% limit: 12 mm) in men, and 9 mm (upper 95% limit: 10 mm) in women. Moreover, in a good deal of heart diseases, a complete morphological study of the LV must include a determination of the left ventricular mass (LVM). It can be obtained by means of an appropriate software allowing the computation of the diastolic endocardial and epicardial contours of the ventricle (Figure 2.10) on the series of transverse planes covering the whole extension of the chamber, from base to apex. A standard planning of the sequences, with slice thickness between 8–10 mm, interslice gap of up to 5 mm and in-plane resolution (pixel size) up to 3 mm, allow a reliable calculation of LVM in practice. The method has shown a high degree of accuracy in animal experimental studies and is considered at present as a reference against which other methods can be compared: when echocardiography, the most widely-used technique for the estimation of LVM in practice, has been tested, a significant variation in LVM estimates from the direct measurement of CMR has been observed, which is not surprising, provided the diverse geometric assumptions involved in the calculation by ultrasound. The excellent reproducibility of LVM measurement by MRI should be noted, which has important practical applications in those cases in which a series of determinations of this parameter are required, particularly when the objective is to estimate evolutionary changes of ventricular hypertrophy. Values for LVM estimated by CMR on normal populations have been published, that can be used as a reference to detect abnormal left ventricular hypertrophy in practice (Table 2.1).

b. Right ventricle (RV)
Due to the complex morphology of the RV, it is necessary to consider in its evaluation two anatomical regions: the inflow and outflow chambers. In axial slices the limit between both is determined by the change in configuration of the chamber, from triangular at the inflow chamber (Figure 2.1) to circular shaped in the outflow chamber (Figure 2.11), situated above. The outflow portion of the ventricle is also easily imaged in its longitudinal plane by means of sagittal views (Figure 2.12). Based on these images it is possible to determine the right ventricular wall thickness, which in normal individuals is 3 mm (upper 95% limit: 5 mm) in diastolic images, as well as the maximum diameters of the chamber, the normal values being 32 mm (upper 95% limit: 42 mm) in the inflow chamber, and 26 mm (upper 95% limit: 34 mm) in the outflow portion.

It is also possible to determine the right ventricular mass (RVM) by applying the method of summation of transverse planes in a similar way to the calculation of LVM (Figure 2.10), and on the same set of images, tracing in this case the endocardial and epicardial contours of the RV (Figure 2.13). The method has been shown highly accurate in animal experimental studies. Normal values of RVM have been published, absolute mean values ranging between 50 g (upper 95% limit: 70 g) for adult men to 40 g (upper 95% limit: 55 g) for women. As expected due to the particularly complex morphology of the right ventricular cavity, this method is less reproducible than in the case of the LVM, which may have consequences on sample size of