

86 T1/T2/T2* Quantitative Parametric Mapping in the Heart

In recent years, quantitative MRI has become increasingly important for assessment of a range of cardiac diseases. Such techniques can reduce the subjectivity encountered in traditional nonquantitative techniques, are largely independent of sequence parameters and surface coil profiles, and can detect both focal and global pathological changes within the heart. This chapter provides a brief overview of various specialized acquisition strategies that have evolved to achieve parametric mapping in the heart given the additional constraints of ECG triggering and patient breath-hold limitations.

Quantification of T1 relaxation, with and without the use of gadolinium-based contrast agents, is of great importance for the characterization of myocardial tissue to assess both ischemic and nonischemic cardiomyopathies. Without the administration of a contrast agent, an elevated value of myocardial T1 is consistent with edema, which may be related to the inflammatory response to myocardial injury. Following the administration of a gadolinium chelate, a shortened T1 (corresponding to increased contrast agent concentration) is associated with fibrotic scar or diffuse fibrosis that has a greater extracellular volume (ECV) than normal. Late gadolinium-enhanced (LGE) MRI allows for an accurate assessment of focal fibrosis, but it is less sensitive to diffuse fibrosis. By incorporating both pre- and post-contrast T1 maps, and a measure of blood hematocrit, quantitative ECV maps can be derived. These ECV maps have shown considerable potential to reliably identify diffuse fibrosis. Cardiac T1 mapping is performed by sampling the T1 recovery curve using ECG triggered single shot acquisitions during diastole, following an inversion or saturation radiofrequency pulse. The magnetization is sampled over multiple heartbeats, and recovery periods are typically inserted to allow for sufficient T1 recovery before the next preparation pulse. Several inversion recovery or saturation recovery acquisitions are performed, with different recovery times, to obtain a sufficient number of images (each with a different contrast) within a single breath-hold for accurate T1 quantification. This series of images may need to be aligned using automatic registration software to compensate for respiratory motion. Finally, a multiparametric pixel-wise curve fitting is used to estimate the T1 recovery. **Fig. 86.1** shows an example of T1 mapping used to assess diffuse fibrosis in a

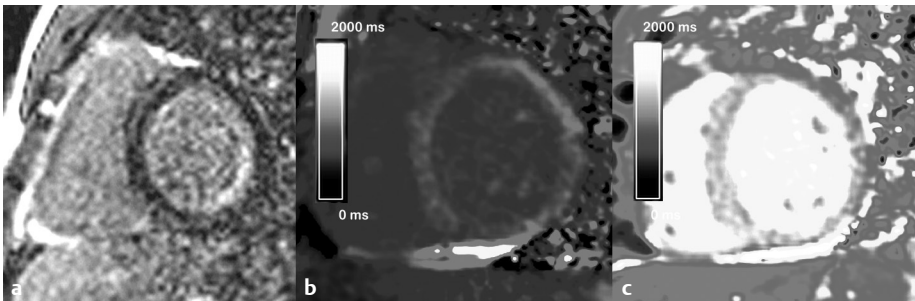


Fig. 86.1

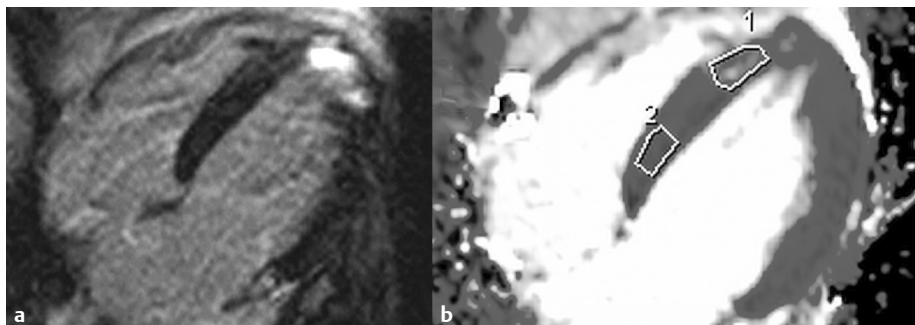


Fig. 86.2

Figures courtesy of Jeremy Collins and James Carr.

patient with cardiac amyloidosis. (a) Post-contrast inversion recovery image showing diffuse subendocardial enhancement. (b) Pre-contrast and (c) post-contrast T1 maps showing patchy variation in T1 (note that very different window and center values have been used for B and C, to highlight the findings in the myocardium). The ECV values for this patient were $\sim 45\%$, which is above the normal range. ECV was estimated using manually defined regions of interest on the T1 maps.

Quantitative T2 mapping has been recently shown to provide diagnostic information in pathologies such as acute myocardial infarction, myocarditis, and heart transplant rejection, which alter the myocardial water content and consequently prolong T2 relaxation times. T2 mapping has been shown to address the limitations of qualitative T2-weighted imaging, thereby increasing the accuracy and reliability of detecting edematous myocardial tissue. Sampling T2 decay may be performed using a segmented multiecho spin echo sequence or using single shot acquisitions with variable T2 preparation RF pulses. Images are acquired during diastole, and at intervals of several heartbeats, to allow for sufficient magnetization recovery in between acquisitions. An optional motion correction step is applied to align the different images, and a pixel-wise T2 fit is done assuming mono-exponential signal decay. **Fig. 86.2** presents an example of a patient with an acute myocardial infarct. (a) The delayed enhancement magnitude inversion recovery image shows apical transmural enhancement. (b) The T2 map shows normal T2 values in the basal septum (48 msec) and elevated T2 (72 msec) in viable myocardium adjacent to the scar.

Similarly, myocardial T2* measurement provides a valuable indicator for noninvasive assessment of iron overload, and is clinically employed for planning and monitoring iron-chelating treatments for transfused thalassemia major patients. T2* mapping uses a segmented multiecho ECG-triggered gradient echo sequence to acquire multiple samples during T2* decay. Black blood preparation is usually performed to reduce artifacts, but susceptibility effects limit the ability for pixel-based T2* mapping, so region-of-interest analyses are more common. Data are acquired over several heartbeats and at the same diastolic phase of the cardiac cycle, and fitting is performed assuming a mono-exponential decay. Fitting techniques can be optimized to reduce the effect of noise in images with longer TEs.