151 Monitoring Cardiac Contraction: The Pilot Tone

The next generation of heart motion sensors will likely allow automatic capture of the cardiac cycle, replacing the use of electrodes (ECG monitoring). Placement of ECG leads is time-consuming and often difficult. ECG signals are also prone to artifacts caused by the gradients and by blood flow (the magnetohydrodynamic effect), particularly at higher field strengths. The latter leads to an increase in the amplitude of the T wave, hindering detection of the R peak. Receiver coils that contain the necessary electronics to perform Pilot Tone (PT) navigation are already available, with scan sequence development in progress. Full-fledged implementation (hardware and software) is anticipated in the near future.

In the current implementation of this technology, the Pilot Tone transmitter is integrated into a local RF coil. This generates an ultra-low-power RF signal with a fixed frequency (the "Pilot Tone") just outside the MR signal band. This signal is modulated by changes in conductive geometry and specifically heart motion and is then detected by the local RF receiver coils used for imaging. Correctly obtained, the signal is stable and detectable during free breathing. It has been shown to correlate well with the ECG and to allow acquisition of high-quality images of the heart. As previously noted, the RF frequency used is just outside the MR signal band (62.5 MHz in initial work at 1.5 T). The Pilot Tone (PT) design improves the robustness of cardiac scans, specifically eliminating the problems related to the gradients and placement of the ECG leads. It also could allow for flexible trigger time point placement (triggering, e.g., at maximum contraction), potentially another major advance. It is also possible to monitor respiration with this approach, since both cardiac motion and respiration influence the Pilot Tone and can be observed. Prospective cardiac triggering in patients at both 1.5 and 3 T has been demonstrated, during both free breathing and breath-holding, with the acquired cine heart images highly correlated to that acquired using the ECG (Fig. 151.1).

Potential advantages of Pilot Tone navigation include ease of use and the direct measurement of cardiac motion. The latter differs substantially from ECG triggering, in which the electrical activity of the heart is monitored. It should be noted that the objective of cardiac imaging is to achieve images of the heart without motion, for which the ECG is of secondary interest and the position of the heart muscle itself primary. Furthermore, Pilot Tone navigation can be performed with any scan sequence. It also does not require modification of a scan sequence, for example, the addition of radiofrequency pulses, as with the use of navigator echoes.

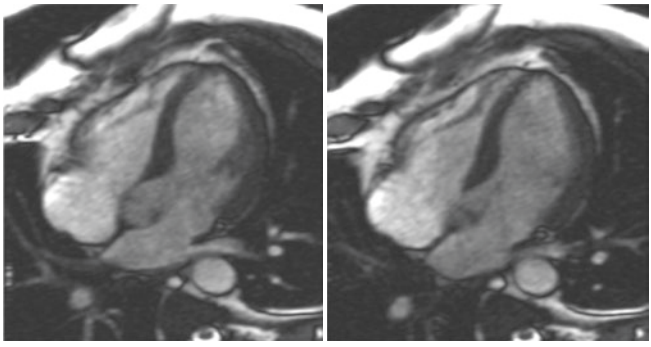

Fig. 151.1 Early-diastolic images from a segmented cardiac cine scan triggered by PT (left) and ECG (right). Courtesy of Mario Bacher (Siemens Healthcare).