Image Analysis Technology Offers Quantification of Cardiac MRI Data

In the past, healthcare professionals relied extensively on conventional diagnostic imaging methods, including thorax x-ray, echocardiography, single photon emission tomography (SPECT), and x-ray coronary angiography. Many of these diagnostic tools have been established as a gold standard in the daily clinical routine, and have been the subject of continuous technical improvements over the past decades. Nevertheless, both the rate and the magnitude of progress that has most recently been made in the field of cardiovascular magnetic resonance imaging (MRI) are unparalleled.

Today, cardiac MR imaging enables physicians to perform real-time evaluation of a patient's cardiac system, so they can screen, diagnose and monitor heart disease more accurately. By using multiple imaging sequences, as well as advanced post processing software, they can gain a comprehensive picture of a heart's global function, regional function and tissue characterization.

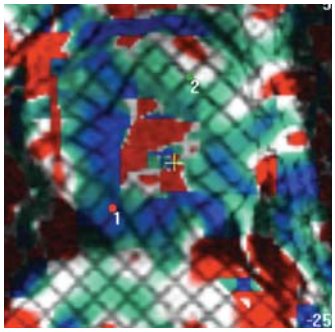
As a continuously growing number of clinicians rely on MRI on a daily basis, leading experts in the field agree that it will revolutionize the diagnosis of heart disease and the great vessels. A non-invasive and cost-effective technique, it operates without harmful ionizing radiation, providing the most accurate visualization of the morphology of the heart and blood vessels. It simultaneously enables quantitative assessment of myocardial function, contractility, viability and blood perfusion, and flow in an unparalleled fashion. Most recent advances in MRI research have further shown that this portfolio of diagnostic and quantitative MRI tools is soon to be expanded with the ability to detect asymptomatic coronary atherosclerosis and other diseases of the heart in their earliest stages. Therefore, MRI will have a most significant impact on the management of cardiovascular disease, the leading cause of morbidity and mortality in the western world.

In summary, Cardiac MRI, along with advanced post processing software, can be used to diagnose and evaluate a number of diseases and conditions, including:

- Coronary heart disease, also called coronary artery disease
- Damage caused by a heart attack
- Heart failure
- Heart valve problems
- Congenital heart defects
- Pericarditis
- Cardiac tumors
- Cardiomyopathies

HARP® Technology

HARP is an image analysis technology that works hand-in-hand with tagged magnetic resonance (MR) data. Tagged MR images are enhanced with regular patterns that encode the motion of the underlying tissue, making it easier to visualize and quantitatively analyze the motion. Tagging is especially good for imaging repetitive muscle motion, as in the muscles that give rise to the contraction of the heart. Prior to the invention of HARP in the late 1990's, tagged MR images were either visually observed, or perhaps analyzed by hand, in order to better understand the mechanics of cardiac motion — in other words, the function of the heart. However these were very time consuming and hindered a wider use of tagging.



Although great strides were made in medical science related to cardiac mechanics, long processing times made clinical use of tagged MR data impossible prior to HARP. The key discovery in HARP is that motion can be automatically and robustly decoded using the *harmonic phases* of the tagged images. By carrying out key

processing steps in the Fourier transform domain — also called k-space within the magnetic resonance physics community – weak signals, tag fading, and even motion artifacts are largely irrelevant to the analysis. The harmonic phases can be decoded to recover the motion of any point within the heart muscle, which allows the program to automatically track the contraction of the heart and recover the mechanical strain taking place at each point in the heart. This, in turn, allows the program to characterize the regional function of the heart.

Computation of the motion of several short-axis sections including the left ventricle of the heart is sufficient for the program to compute several standard measures of heart performance; for example ejection fraction. Computation of the strain within several short-axis sections is sufficient to identify regions of the heart muscle that are not performing well. Since MR tagging data create image sequences—that is, they are movies—this characterization can reveal both spatial as well as temporal anomalies. This makes HARP useful for finding ischemic or infarcted tissues, as well as for dyssynchronous behavior that is indicative of electrical problems within the heart. Besides strain, the rotation and twisting of the left ventricle is also measured using HARP.

HARP is known to characterize only the two-dimensional motion and strain of the heart muscle—the so-called in-plane motion. Typically, HARP is most useful when coupled with short-axis images of the left ventricle; in this case the in-plane motions measured can be identified as either radial (toward or away from the long axis of the left ventricle) or circumferential (around the ventricle) measures. If long-axis images are acquired, HARP can yield both radial and longitudinal—from apex to base—measures. This restriction to two dimensions is not a limitation of HARP but of the conventional implementation of MR tagging on commercial MR scanners. With relatively simple modifications to conventional tagging pulse sequences, out-of-plane tags can be generated and through-plane motion and strain can be studied.

SENC Technology

Strain encoded imaging (SENC) is a very simple and robust approach to the problem of imaging regional function in the heart.

SENC is built on the concept of tagged magnetic imaging, but requires a dramatic change of perspective when thinking about its geometry. Whereas HARP relies on tagged MR images that encode both "horizontal" and "vertical" in-plane motions, SENC encodes the through-plane direction — the direction that is perpendicular to both the horizontal and vertical directions. Because the encoding direction is exactly perpendicular to the imaging plane, it is not possible to visually assess either the motion, nor the mechanical strain, from SENC images. Computer processing is required to yield the through-plane strain. Acquiring both tagged MR images and SENC images in order to obtain regional information about cardiac function in all three directions is also a straightforward process. The information is complementary, not equivalent. In fact, there are other differences in the data. Because of the nature and relationships of the harmonic peaks in Fourier space, SENC strain images are inherently of higher spatial resolution than HARP strain images. Therefore, SENC is better for the visual and quantitative analysis of the right ventricle, which has much thinner wall than the left ventricle. On the other hand, SENC is not capable of tracking the motion (it measures strain without actually measuring the motion), so it cannot be directly used for computing quantities such as rotation and twisting.

Diagnosoft®, Inc. is the sole source for patented and patent-pending HARP and SENC technologies. Diagnosoft's products can rapidly, reliably, and accurately analyze tagged MR images using HARP and SENC images to obtain all motion and motion-related quantities. Resulting information is organized in conventional bull's eye plots and temporal plots over the cardiac cycle, to study and quantify regional cardiac function. These results can be visualized together with other acquired data such as perfusion, delayed enhancement, and cine, to fully characterize cardiac performance and the overall condition of the heart.

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