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Flash 2 – Real-Time Magnetic Resonance Imaging (MRI)

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Background

Magnetic resonance imaging (MRI) is nowadays a leading modality for diagnostic imaging with about 100 million examinations per year worldwide. However, when invented by Paul Christian Lauterbur in 1973, MRI was too slow to allow for routine medical applications. A breakthrough was achieved in 1985 by the FLASH (Fast Low Angle Shot) technique developed by Jens Frahm and his team at the Max-Planck-Institute for Biophysical Chemistry in Göttingen, Germany. With FLASH the measuring time for a cross-sectional image was reduced to about one second, continuous measurements became possible, and for the first time high-resolution three-dimensional imaging was realized in a few minutes. Altogether, FLASH sets the ground for state-of-the-art MRI and many modern applications.

However, monitoring dynamic processes in real time remained impossible. This limitation was caused by the long acquisition times of datasets with many different spatial encodings that were required for the reconstruction of images with high spatial resolution and adequate signal-to-noise ratio. FLASH 2 solves this problem.

Technology

By developing suitable non-Cartesian encoding strategies as well as novel mathematical approaches for image reconstruction of highly undersampled datasets, Frahm's team was able to reduce the measuring times of serial images to only about 10 to 40 milliseconds corresponding to MRI movies at 25 to 100 frames per second. The technology allows for the acquisition, reconstruction, and display of magnetic resonance images in real time, i.e. without detectable delay. Real-time imaging using FLASH 2 is expected to alter the future of MRI by offering many hitherto impossible applications in medicine and science. Selected examples include:

- Live cardiovascular imaging without the need for synchronization with the electrocardiogram and during free breathing (see Fig. 1),
- Online assessments of quantitative blood flow,
- Real-time studies of cerebrospinal fluid (CSF) dynamics,
- Access to human articulatory processes, e.g. during speech production (stuttering) or brass playing (embouchure dystonia), or with the use of visual feedback,
- Dynamic assessment of joint movements, e.g. of the temporomandibular joint,
- Unique access to swallowing processes, e.g. in dysphagia, gastrointestinal reflux disorder, disturbances of stomach motility,
- Immediate visualization of physiological responses, e.g. of myocardial function and aortic blood flow to stress or physical exercise, or of tissue perfusion after administration of an MRI contrast agent,
- Real-time monitoring of minimally invasive interventions.

Other variants of FLASH 2 enable high-speed volume coverage and simultaneous real-time MRI of multiple sections, while extensions of the basic technology lead to much improved solutions for quantitative MRI such as single-shot T1 mapping and phase-contrast flow MRI using model-based reconstructions.

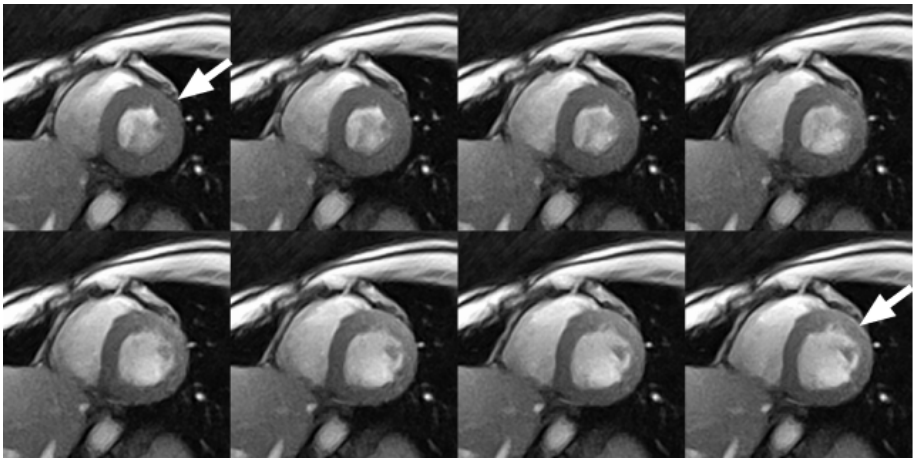

Fig. 1: Real-time MRI of the heart (short-axis view) at a resolution of 33 ms (i.e., 30 frames per second). The images cover the period from (top left) systolic thickening and contraction of the myocardial wall to (bottom right) diastolic expansion. The bright signal in the heart chambers is the blood.

FLASH 2 is already used for research purposes by a growing number of leading research institutes and clinics worldwide, for example:

- University Medical Center, University of Göttingen, Germany,
- Radcliffe Hospital, University of Oxford, UK,
- John Hopkins University, Baltimore, USA.

Currently, FLASH 2 is commercially available for MRI equipment produced by SIEMENS. Implementation and use require software for established measuring protocols as well as a bypass computer with multiple graphical processing units (GPU) and implementation of the FLASH 2 reconstruction software.

FLASH 2 can also be implemented on MRI systems of other vendors by adapting acquisition protocols as well as data and image transfer to the GPU computer.

Example videos of real-time MRI can be found at
www.biomednmr.mpg.de/index.php?option=com_content&task=view&id=132&Itemid=39

Advantages of the proposed real-time MRI technology

- Unsurpassed temporal resolution
- High image quality
- Robust to motion
- Insensitive to susceptibility artifacts
- Flexible spatial and temporal resolution, variable contrasts
- Access to arbitrary physiological processes and body functions
- Ease of implementation

Patent Information

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