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Historical Perspective

FLASH MR imaging: A success story since 25 years

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Interview with the author(s).

A video interview with the author(s) associated with this Historical Perspective and the original article can be found in the online version, at doi:10.1016/j.jmr.2011.08.007.

In 1985, 15 years after the invention of NMR imaging, there was no longer any doubt that this imaging modality opened a new era of non-invasive medical diagnosis.

At this time it was already known that many diseases, could be detected by NMR, such as tumors, infarcts, and inflammation. No other imaging modality showed a better soft tissue contrast. This image contrast was based on tissue specific differences in NMR relaxation times (T1, T2, and $T2^*$), diffusion constants, chemical shifts, etc.

Nevertheless, the main obstacle for a major breakthrough of NMR imaging in medical applications was the long detection time of several minutes to create a single image or the long investigation time of up to one hour or more for a single patient examination.

Faster imaging sequences were urgently needed. A rapid NMR imaging method was already known since 1977 due to the pioneering work of Peter Mansfield on echo planar imaging (EPI) [1]. This technique needed special NMR hardware and had its intrinsic problems in image quality.

Fast Low Angle Shot (FLASH) NMR imaging was another method, which we invented in 1985 and published it in the Journal of Magnetic Resonance in 1986 [2]. During our experiments at the Max-Planck-Institute for Biophysical Chemistry in Göttingen (Germany), we had a clear objective to develop quantitative imaging methods of NMR parameters, such as T1, T2 or diffusion constants. For that purpose, faster and more efficient NMR pulse sequences had to be applied. We decided to move from spin echo sequences used in these days to stimulated echoes and gradient echoes. This step was quite successful, since we could develop within a short time more than 70 new imaging pulse sequences, serving different purposes and including rapid imaging as well.

One of these pulse sequences was FLASH, which could immediately be applied by many researchers and in numerous clinical studies.

The advantage of FLASH was clear from the beginning: no special hardware was needed. But there were disadvantages as well: the image contrast was difficult to interpret and the magnetic field inhomogeneity resulted in a signal loss.

FLASH is based on the acquisition of a gradient echo after the NMR excitation with a low flip angle pulse. The repetition time during our first experiments in 1985 was of the order of 20 ms. This fact was because of the slow ramp times of the magnetic field gradient pulses for imaging and software limitations. The whole measuring time needed – depending on the spatial resolution – only a few seconds, sometimes only a few hundred milliseconds. During the next five years, especially the gradient systems could be improved. Already in 1988, we were able to use repetition times of less than 3 ms, which further opened up new possibilities for quantitative fast imaging [3].

FLASH had immediately consequences for almost all clinical applications. There were less motional image artifacts and a more efficient use of the highly expensive imaging system became possible. The detection of the first NMR movies of the beating human heart, moving joint and breathing motions were possible. With application of an NMR contrast agent bolus, it was possible to detect the function of internal organs, like fMRI of brain activities.

In addition, when a 2D-image needed a measuring time of a few seconds, a complete 3D-acquisition could be finished in a few minutes.

The understanding of parameters like NMR relaxation times, diffusion constants and perfusion, flow velocities in biological tissues is of great importance. Using FLASH NMR imaging it was for the first time possible to quantitatively measure these parameters in acceptable times. Quantitative values are now the basis of many clinical and biological applications of NMR imaging.

During the last almost 30 years the hardware of NMR scanners could be dramatically improved: more speed, more stability, more reproducibility, more homogeneity was achieved.

These technical developments further improved FLASH sequences and the overall image quality, but also dramatically advanced EPI techniques. Today, more than 25 years after FLASH imaging was first described, both techniques can be used in clinical NMR scanners. Many "hybrid imaging sequences" combining FLASH and EPI modalities are now in use and have their basic advantages while avoiding their intrinsic disadvantages.

This is not the final step. Once more, a combination of advanced hardware and NMR methods is useful: parallel imaging with new phased-array NMR coils and using FLASH, EPI or any other imaging modality can further reduce the measuring time.

Fast imaging is of prime importance for modern NMR applications in biology and medicine. In scientific studies more informa-

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tion can be acquired in shorter time intervals. In clinical investigations the whole workflow for imaging diagnosis is optimized.

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