Tracing biological functions with ultra-high-field MR

More and more research institutes and hospitals are investing in ultra-high-field magnetic resonance imaging (MRI) around the world. They are looking to gain new insights into the brain’s function and metabolic processes, as well as to obtain detailed images of the inside of the body. At this point in time, Siemens Healthcare is one of very few manufacturers offering a 7T MRI scanner that includes an actively shielded 7 Tesla (T) magnet. \(^1\) 7T is truly at the cutting edge of research, especially in the field of neuroimaging.

With a magnet field strength 140,000 times stronger than that of the earth’s magnetic field, 7T systems are among the most powerful magnetic resonance imaging systems in the world, allowing ultra-deep insights never seen before. With such information, neurologists, psychologists, and neurosurgeons are able to observe exactly what is going on inside the human body and particularly in the brain.

**7T high-field magnetic resonance imaging – benefits and applications**

The signal to noise ratio (SNR) in an MRI image increases proportionally to the magnetic field strength. Subsequently, the increased SNR translates into more higher and more precise image quality, which allows deeper insights into the brain’s anatomy, function, and metabolic processes. This is essential for improving medicine’s ability to diagnose neurological diseases such as Alzheimer’s, epilepsy, schizophrenia, and multiple sclerosis.

The higher field strength of 7T enables imaging at higher spatial resolution both in anatomical and functional imaging. This plays an important role in displaying fine connections within the human brain and makes possible to examine brain activity at

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\(^1\) The concepts and information presented in this paper are based on research and are not commercially available.
spatial resolutions of submillimeter scale. Researchers can observe activation patterns within the cortical regions at subcortical level and provide a more detailed functional topography of the human brain.

7 Tesla high-field magnetic resonance imaging is particularly valuable when investigating disturbances in the brain’s metabolic processes through spectroscopy, for example, in tumor cases. The strong magnetic field makes it possible to distinguish among a greater variety of chemical substances and perhaps, to even someday observe the effects of medications “live” or in real time. Other applications at 7T are to obtain higher spatial resolution in the musculoskeletal system.

**Magnetic resonance imaging – the modality**
Ubiquitous hydrogen atoms (or rather, protons) found in body fluids and fat tissue, for example, are essential to MRI. When exposed to the MRI system’s magnetic field, these protons’ magnetic properties (spins) cause them to align within the magnetic field. If additional energy is applied to the protons (in the form of a “radio frequency pulse”), some spins flip into a higher-energy state and then return to their initial position, releasing the energy they previously absorbed. The generated signal depends on the proton’s chemical environment (such as fat, muscle, cerebral spinal fluid, blood) and can be converted to images using mathematical process (such as FFT, Fast Fourier Transform). Through additional processes such as filtering MR signals as well as the use of various magnetic field and RF wave techniques, different tissue types can be visualized in extreme detail, and any changes – such as changes caused by tumors or changes in the heart – can be accurately diagnosed.

For over two decades it has been possible to record and visualize the activity of nerve cells in the brain using a similar method. Functional magnetic resonance imaging (fMRI) is based on the measurement of changes in the blood oxygen level, which are directly related to nerve cell activity. It allows the pattern of activity in the human brain to be studied with an accuracy of a few millimeters.

Siemens Healthcare is the leading supplier in the field of 7T high-field magnetic resonance imaging. More than 65 percent of the currently installed systems worldwide are from Siemens.
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