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Magnetic Particle Imaging (MPI) Quick Facts

How does MPI technology work?

Magnetic Particle Imaging (MPI) is a new imaging modality that directly detects iron oxide nanoparticle tracers using time varying magnetic fields. Because the tracer is not normally found in the body, MPI images have exceptional contrast and high sensitivity. The MPI technique is straight forward and can be described classically with three key concepts:

Concept 1: The Field Free Region. Magnetic Particle Imaging uses a unique geometry of magnetics to create a field free region (FFR). This is something you may have experienced when pointing two magnets at each other. That sensitive point controls the direction of a nanoparticle (figure 1).

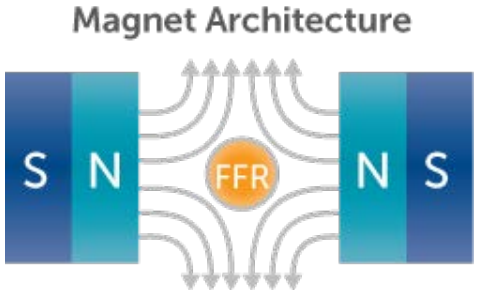


Figure 1: Two permanent magnets create a strong magnetic field gradient and a sensitive point, called the field free region (FFR). Only the SPIOs in the instantaneous location of the FFP create an MPI signal [1].

Concept 2: Producing a signal through rapid movement. Rapidly moving the sensitive point causes a "flip" in the magnetic direction of the superparamagnetic iron oxide (SPIO) nanoparticle which induces a signal in a receive coil (figure 2).

Concept 3: Reconstructing an image. Since we know where the sensitive point is at all times, we can assign the signal to the known position to produce a quantitative MPI image using the x-space reconstruction process [1]. This patented process is the only proven approach that enables high-resolution, linear quantitation of tracers across the animal.

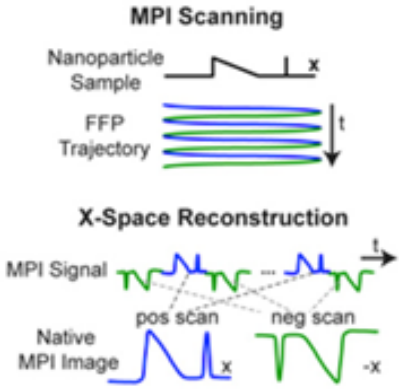


Figure 2: To cover the imaging field-of-view, the FFR is moved rapidly in a trajectory across the imaged volume. Using X-space reconstruction, we grid the MPI signal to the instantaneous position of the FFR to form a native MPI image [1].

MPI: Nuclear Medicine for Nanoparticles

MPI "sees" nanoparticles and does not detect tissue. This leads high-contrast images with little to no background, high signal to noise ratios, and no depth attenuation. Only ionizing and magnetic imaging techniques do not suffer from depth attenuation. By generating a quantifiable, positive contrast signal without tissue attenuation or introducing harmful radioisotopes we can sharply distinguish MPI technology from MRI, PET/SPECT and Optical imaging modalities, while complimenting them at the same time.

MPI Quantitation for cell tracking: The MPI signal is linearly quantitative, making MPI cell tracking effortless for both quantifying cell number and position. SPIO contrast agents used in MPI are human-safe which are commonly used in MRI imaging and variants as a therapeutic. SPIOs readily tag cells, and when used properly, have no short or long term effects on cell viability, proliferation or differentiation. In a typical cell tracking experiment, we develop a standard curve using known quantities of cells to calibrate the number of cells present in each voxel of the image. This straight-forward approach is in contrast to the traditional optical techniques used for cell tracking, which suffer from non-linear attenuation with depth and photon diffusion that lead to non-linear quantitation [2].

Synergy between the nanoparticle properties and the magnetic field gradient: MPI is unique among imaging techniques in how the resolution and sensitivity of the technique rely on the partnership between the SPIO nanoparticle and the magnetic field gradient. With the proper nanoparticle and gradient, MPI reaches detection limits of minutiae quantities of cells in a voxel at sub-millimeter resolutions [3]. The nanoparticle core size of 12 to 30 nm seen in MPI is clinically relevant and is common in research and clinical MRI. Importantly, as an emerging field, MPI has only recently been able to support researchers developing new particles and coatings.

Clinical Translatability: MPI sees deep into tissue with no depth attenuation, enabling scaling of the MPI to full-body clinical imaging. MPI uses benign, low frequency magnetic fields for imaging and iron oxide nanoparticles, both of which have strong precedence in the clinic.

The MOMENTUM Magnetic Particle Imager

Magnetic Insight has introduced the world's highest sensitivity and resolution MPI imager, the MOMENTUM. Our world-leading imager incorporates high-pressure water-cooled electromagnets and an iron core designed using techniques developed from high energy physics to achieve the world's highest resolution and sensitivity magnetic particle imager. The system reaches a field strength of 6.3 T/m with a FFL magnetic field configuration that produces 5-fold better linear resolution and an order of magnitude more signal than Field Free Point (FFP) magnetic field configurations used by competitors.

MOMENTUM workflow: The user experience is designed with the researcher in mind, and the scanner has the work flow of optical. The system can rapidly scan in projection mode for high throughput work with scan times of less than 20 seconds, with the option for high-sensitivity tomographic scans in less than 5 minutes.

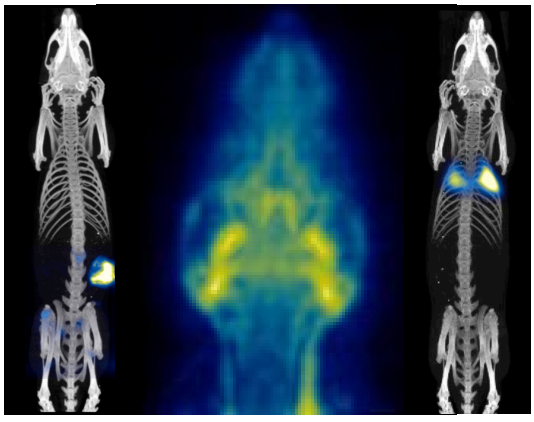
MOMETUM siting: The imager is designed for siting in a core, side-by-side with other imaging units, including CTs, and Optical Imagers. The system is self-shielded with no cryogens.

Conclusion

MPI technology is an emerging imaging modality unique from MRI and all other in vivo modalities. MPI delivers positive contrast images of magnetic tracers that are linearly quantitative, enable absolute quantitation of cell numbers, at sub-millimeter resolutions. The commercially available Momentum provides a highly powerful magnetic gradient while allowing an optical like high throughput imaging protocols.

References

1. J Magn Reson. 2013 Apr;229:116-26. doi: 10.1016
2. Adv Mater. 2012 Jul 24;24(28):3870-7
3. Int J Nanomedicine. 2015 Apr 22;10:3097-114



Left: Tumor detection, Middle: Quantitative neuroperfusion Right: Stem Cell tracking

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