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Real-time Magnetic Particle Sensing for Brain Perfusion – a simulation study

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Introduction: Stroke is a major global health burden, affecting 15 million people annually, with 5 million deaths and 5 million cases of permanent disability [1]. As incidence rises with aging and lifestyle factors, better diagnosis and treatment are essential especially in the first hours – because **time is brain**. Recent advances in Magnetic Particle Imaging (MPI) [2] and Magnetic Particle Spectroscopy (MPS) [3] offer new opportunities for rapid stroke diagnostics [4] using magnetic nanoparticles (MNPs) to enable real-time, highly sensitive measurement of cerebral blood flow. Here, we introduce the concept of **StrokeCap**, a lightweight setup for early stroke detection.

Methods: The basic idea behind rapid stroke detection is the measurement of blood perfusion in different areas of the brain. For that, MNPs are intravenously injected in the blood flow and measured using MPS [5]: the presence of MNPs near an MPS sensor causes an unambiguous signal in form of higher harmonics due to the nonlinear magnetization response to a sinusoidal magnetic field (amplitude: ~5mT@15kHz) (**fig.1a**). Using a single-sided tx/rx system (**fig.1b**), the amount of MNPs can be tracked over time within the sensitivity area of each corresponding rx-coil. Arranging an array of MPS sensors around the head allows spatio-temporal detection of perfusion on the brain's surface (**fig.1c**). The time-dependent perfusion signals (**fig.1d**) can be visualized in different ways, e.g., as time-to-peak visualization (TTP) (**fig1.e**).

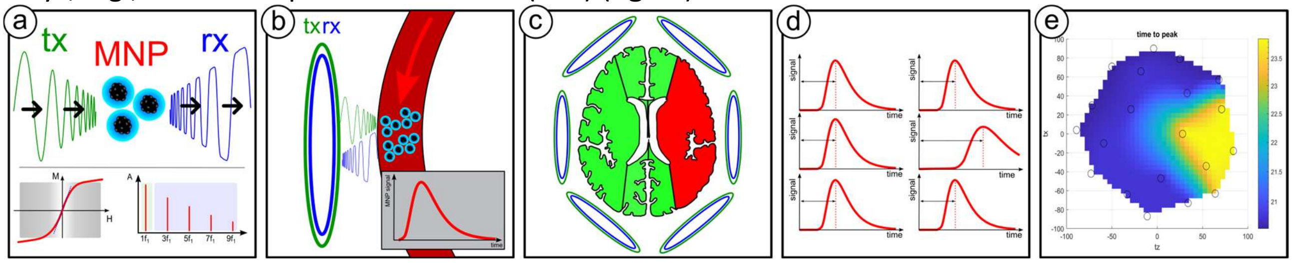

Fig. 1: (a) MPS basics: nonlinear magnetization response of MNPs to sinusoidal magnetic fields. **(b)** Single-sided MPS sensors provide spatio-temporal detection of MNPs using an array of MPS sensors **(c)**. The MPS signals of each MPS sensor **(d)** can be visualized in different ways, e.g., as time-to-peak representation **(e)**.

Results: For initial simulation studies, real CT perfusion data from stroke patients have been processed to provide 3D time-dependent perfusion information of the injected tracer. Using a home-built software [6], different tx/rx coil setups have been implemented and compared for their performance.

Discussion and Conclusion: The use of real perfusion data from CT within a home-built simulation framework requires several steps and is limited due to CT's temporal resolution, which restrains the optimization process of tx-rx systems for the StrokeCap.
However, initial simulation results allowed to design a lightweight concept for rapid and flexible deployment in emergency medical settings.

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References [1] Feigin V.L. et al., The Lancet Neurology. 20(10):795-820 (2019). [2] M. Graeser et al., Nat Commun. 10:1936 (2019). [3] P. Vogel et al., Nat Commun. 13:7230 (2022). [4] J. Guenther et al., IJMPI. 8(1):2203064 (2022). [5] S. Biederer et al., J Phys D: Appl Phys. 42:25007 (2009). [6] P. Vogel et al., IJMPI. 9(1):2303081 (2022).