Optimizing signal-to-noise for portable low field MRI systems

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Introduction: The recent growing interest in portable point-of-care (POC) MRI (1-4) has been driven by the concept of increasing the accessibility of a traditionally extremely expensive imaging modality. POC low-field systems increase access to MRI by enabling it to be used in situations in which it has not previously been possible: examples include the intensive care unit and emergency room in the developed world, and sites in lower and middle income countries (LMICs) which lack the finance and/or infrastructure for conventional MRI systems (5-9). The two major technical challenges of POC MRI are much lower signal-to-noise ratio (SNR) and much higher magnet field (B0) inhomogeneity compared to conventional clinical systems. This talk will consider the intrinsic SNR, and how RF coil and MR sequence design can be used to optimize image quality

RF Coil design.

Unlike the situation at conventional clinical field strengths, coil loss dominates for portable low field systems. This means that low-loss coil design is critical for obtaining the highest SNR. Litz wire can be used to obtain Q values >500. However, high Q also comes with challenges. The coil bandwidth may be less than the imaging bandwidth and the ring-down time can cause quite severe pulse shape distortions. In addition, construction of receive array coils becomes extremely challenging due to the very high inter-coil coupling in the absence of body loading.

MR sequence design.

The field dependence of dipole-dipole interactions means that the T_1 values of tissue are substantially shorter than at clinical field strengths, with the T_2 values remaining very similar. This has the advantage of allowing more rapid pulsing, but the disadvantage that tissue contrast between, for example, white matter and gray matter is reduced. Since it is essentially liquid, the cerebrospinal fluid has very long T_1 and T_2 values, making sequences such as fluid attenuated inversion recovery (FLAIR) very time consuming. The specific absorption ratio (SAR) is not a concern for portable systems, and so long train turbo spin echo (TSE) sequences can be run, with the echo train length (ETL) only limited by the available gradient strength. Given all of these considerations, sequence design is a multi-factorial process, which continues to evolve: Figure 1 shows current results from our 46 mT system with different clinically-relevant contrasts.

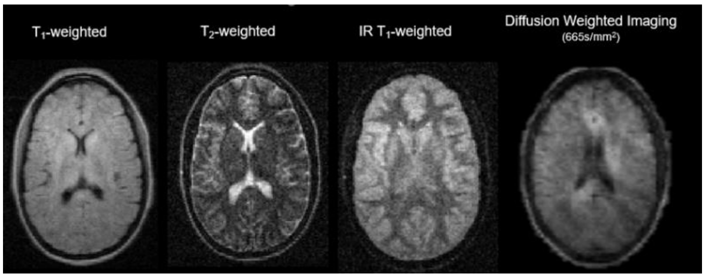

Figure 1. Images acquired on a healthy volunteer on a portable 46 mT scanner. Spatial resolution 1.5 x 1.5 x 5 mm, diffusion 2.5 x 2.5 x 6 mm. Imaging times: 4 mins, 10 mins, 10 mons and 16 mins, respectively.

References: [1] Liu YL et al.. Nat Commun 2021;12(1).[2] Yang L et al. IEEE T Bio-Med Eng 2022;69(11):3415-3426. [3] O'Reilly T et al. Magn Reson Med 2021;85(1):495-505.[4] Cooley CZ et al.Nat Biomed Eng 2021;5(3):229-239.[5] Salameh N et al. MAGMA 2023;36(3):329-333. [6] Arnold TC et al. J Magn Reson Imaging 2023;57(1):25-44.[7] Samardzija A et al. Annu Rev Biomed Eng 2024;26(1):67-91.[8] Kimberly WT et al. Nat Rev Bioeng 2023;1(9):617-630. [9] Wald LL et al. Magn Reson Imaging 2019.