Project title: Full potential imaging with parallel-transmit 7 Tesla MRI using digital twin patient-specific safety models

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Aim of the Project

The potential of parallel transmit (pTx) ultra-high field (UHF) MRI is limited by the high safety margins calculated from a few available computational human models. These high safety limits pose a challenge for image parameters, and hampers the full potential of ultra-high field MR image quality. We propose a solution: to create digital twin patient safety models that allow patient-specific safety margins to be applied on the scanner. Our technique builds on electromagnetic simulations performed using ~200 segmented patients' models with pTx coil arrays and creating the digital twins of probabilistic safety margins using seven characteristics based on the patient body composition, gender, age and coil position. The goal is to use this approach to determine patient-specific safety margins using the localiser images on the scanner associated with the probabilistic safety database. The outcome of this project will advance the field of pTx UHF MRI.

Project Description

Ultra-high field MRI systems (7 tesla and above) provide increased signal-to-noise and contrast-to-noise ratio that allow higher spatial resolution and better detection of anatomical and pathological features. The high spatial resolution at 7 tesla has been a game changer for neuroimaging applications not only in MS but also in epilepsy, brain tumours, dementia and neurodegenerative disorders. Although 7T MRI is the state-of-the-art clinical MRI scanner for brain imaging, it is not yet for torso imaging. Imaging of prostate, kidney, liver, pancreas, heart or hip will potentially benefit from non-invasive high-resolution imaging with 7T. However, large field-of-view imaging is challenging due to increased tissue heating deposition and reduced radiofrequency (RF) homogeneity, which leads to RF safety problems and signal voids. The latter issue finds its origin in the fact that the RF wavelength becomes smaller than the subject dimensions such as the pelvis. Parallel-transmit technology addresses the increased spatial variations in the radiofrequency (RF) field distribution by optimizing the transmit signal magnitude and phase. Using a transmit coil array can provide an efficient and homogeneous signal in the imaging tissue region by focusing the field using parallel-transmit excitation. However, currently it has failed to reach widespread clinical adoption for body imaging. The main factors include the intersubject variability in local specific absorption rate (SAR), which leads to large safety margins to ensure compliance to regulatory limits [1,2]. The large safety margins hamper the use of 7 Tesla for body imaging as high-resolution anatomical T2 weighted images are limited to a few slices only, and does not allow full coverage of the anatomical tissue.

In this project, we propose a digital twin solution to establish patient-specific safety limits to ensure safe and efficient scanning with 7T. The digital twin of the patient will allow us real-time implementation of safety margins with high probabilistic occurrence.

Suggested reading:

[1] Ipek O, Raaijmakers AJ, Lagendijk JJ, Luijten PR, van den Berg CAT. Intersubject local SAR variation for 7T prostate MR imaging with an eight-channel single-side adapted dipole array. Magn Reson Med 2014, p1559-1567.

[2] Ajanovic A, Hajnal J, Malik S. Positional Sensitivity of Specific Absorption Rate in Head at 7T. ISMRM 202, p.4251.

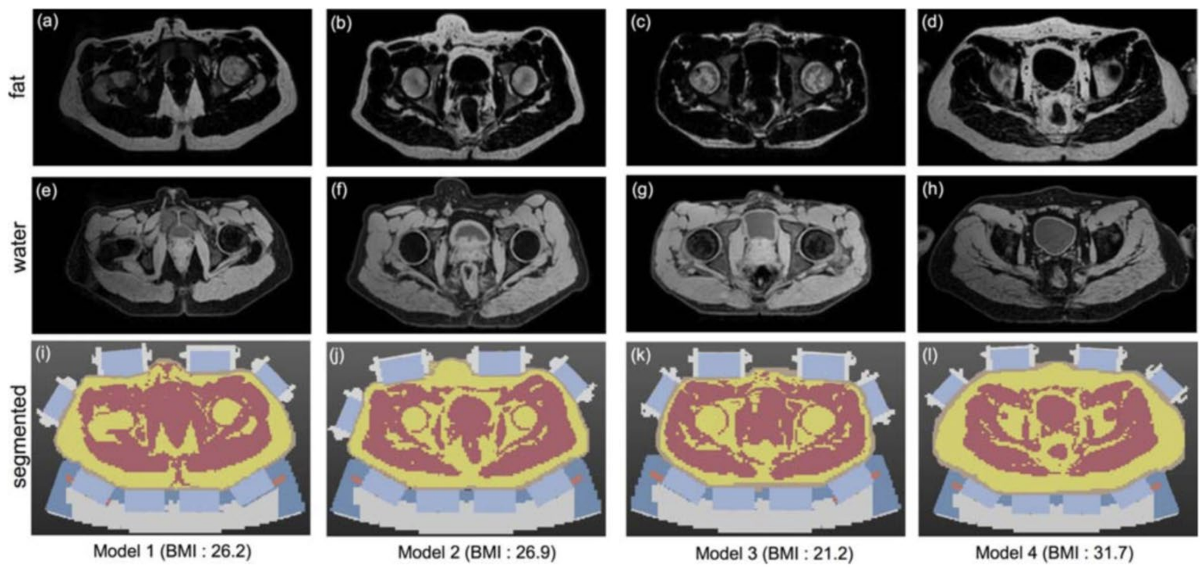

Figure 1. Transverse Dixon fat)a-d) and water separated (e-h) images for four volunteers with various BMIs and their segmented images (i-l) (yellow: fat, red: muscle, brown: skin)