A radiofrequency coil configuration for imaging the human vertebral column at 7 Tesla

M. E. Vossen[1], W. M. Teeuwisse[1], M. Reijnierse[1], N. B. Smith[1], C. M. Collins[2], and A. G. Webb[1]
[1]Radiology, Leiden University Medical Center, Leiden, Netherlands, [2]Radiology, Hershey Medical College

Introduction. Imaging of the human vertebral column at high field is one of MSK's most challenging applications [1-3]. The location of the human spine close to the centre of the body makes high demands on RF coil design, and can lead to very low SNR in the anterior part of the spine. In order to image the entire spinal cord in two or three positions of the patient table, a large FOV must be acquired while maintaining high spatial resolution. We describe the design and testing of a quadrature transmit, eight-channel receive array RF coil configuration for the acquisition of images of the entire human spinal column at 7 Tesla. Large field of view (FOV) scanning enabled sagittal imaging of the spine in two or three stations, depending upon the height of the volunteer, with a total scan time of between 10 and 15 minutes.

Methods. All imaging protocols were performed on a whole body 7T system (Philips Achieva) with subjects positioned head first and in a supine position. Electromagnetic simulations (xFDTD, Remcom) were performed using a model of the human body with appropriate conductivity and dielectric properties and a mesh size of 5 x 5 x 5 mm. The transmit coil is a quadrature double-loop design, with each loop being 20 cm in diameter with an overlap of ~3 cm., segmented into eight sections with 3.9 pF capacitors and one 1-30 pF variable capacitor for fine tuning. The receive coil is an eight element array, with each element being octagonal in shape (13.5 x 18.5 cm) and split by five 3.9 pF capacitors and one 1-30 pF variable capacitor. Balanced impedance matching, an LC lattice balun, diodes for decoupling, and small "figure-8 cable traps" were placed in front of each element of the array. A multiple 2D sagittal gradient echo sequence was used: TR/TE 15/2 ms (partial echo acquisition), field-of-view 450 x 240 mm, data matrix 600 x 320, in-plane resolution 0.75 x 0.75 mm, 3 mm slice thickness, 0.3 mm interslice gap, 4 signal averages, fourteen slices, total data acquisition time ~6 minutes.

Results. Figure 1 shows results from the electromagnetic simulations of the rotating B_1^+ component of the transmit field and the voxel-wise SAR. Compared to transmission from the back, the B_1^+ to SAR ratio is increased substantially using the former approach.

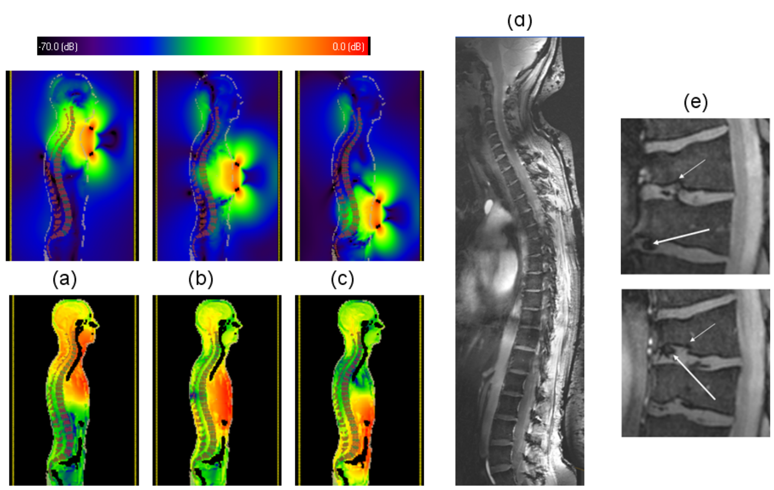

Figure 1. (a)-(c) Simulated B_1^+ maps (top) and SAR maps (bottom) with a quadrature transmit surface coil placed at the front of the subject in three positions. (d) Composite three-station image of the spinal cord of a healthy volunteer. (e) Zoomed images of two collapsed vertebrae from a second volunteer. Cortical irregularity of the endplates can be seen (thin arrows), consistent with osteochondrosis. The intervertebral discs show inhomogeneities (thick arrows) which corresponds to degeneration.

Discussion. An RF coil arrangement is presented which enables imaging of the entire vertebral column at 7 Tesla. Imaging parameters such as the spatial resolution have been matched to standard clinical scans enabling an imaging time of a few minutes. Based upon previous observations of the relative efficiency of RF transmission through the posterior and anterior sides of the body [1], and our own EM simulations, we used a coil placed on the anterior side of the patient to transmit through tissues with relatively low density (lungs, bowels). This approach produces scans with high signal uniformity, and does not suffer from signal dropout at the anterior edge of the vertebral column unlike some previous designs.

References. [1] J.T. Vaughan et al. Magn Reson Med 61 (2009) 244-248. [2] B. Wu et al. IEEE Trans Biomed Eng 57 (2010) 397-403. [3] O. Kraff et al. Invest Radiol. 44 (2009) 734-740.