7T Imaging of the head and neck region: B0 and B1+ challenges

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Introduction

Images of the brain at 7T show high quality results [1]. The goal of this work is to obtain results of comparable quality in the head and neck region to improve tumor delineation in radiotherapy. The regions of interest are the nasopharynx, oropharynx, hypopharynx and larynx. For delineation T1W, T2W, SWI, BOLD and angio sequences are of use. Due to air cavities in the head and neck region, large susceptibility effects are present, leading to pronounced B_0 distortions. Figure 1b shows the B_0 distribution without shimming for a transverse slice (coinciding with the line in figure 1a), indicating off-resonances in the range of -5 µT to beyond 11 µT (-200 Hz to beyond 500 Hz). There are no dedicated 7T transmit coils for the head and neck region while a high peak B_1^+ field is needed to minimize the effects of the B_0 distortions during excitation. In this work the transmit performances of two setups in the head and neck region are compared: (1) a volume T/R coil and (2) a traveling wave setup [2].

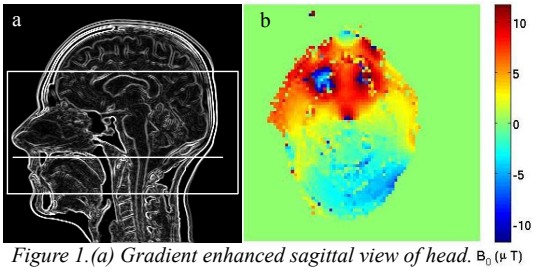

Figure 1.(a) Gradient enhanced sagittal view of head. B_0 (µT) (b) Transverse B_0 distribution at the line in (a).

Materials and methods

All experiments were performed on a 7T MR scanner (Philips Healthcare, Cleveland, OH, USA). The volume T/R coil (Nova Medical, Wilmington, MA, USA) was used for both transmit and receive without the 16-channel receive coil to permit placement of the coil near the neck (figure 2 a and c). For the traveling wave setup [2], a patch antenna (diameter 35 cm, matched to 50 Ohms) was placed 1 m from the body. It was used for transmit and receive. To minimize RF attenuation 32 dielectric insets (PVC tubes, diameter = 4 cm, length = 125 cm, filled with distilled water, mounted in a 57-cm-diameter ring) were placed in the bore [3] (figure 2 b and d). Both setups were driven in quadrature mode with one 4 kW amplifier. To investigate the SAR distribution, electromagnetic simulations were performed using SEMCAD (SPEAG, Zurich, Switzerland), with the adult male model from the virtual family [4].

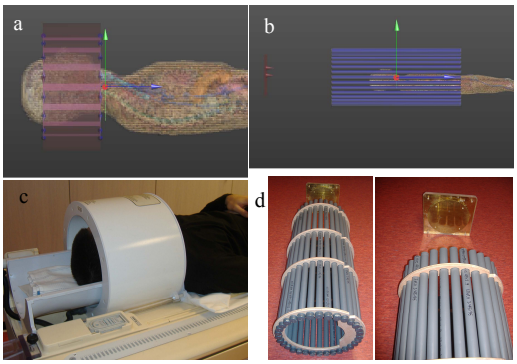

Figure 2: Simulation models (top) and setups (bottom) outside the bore. (a),(c) Shifted volume T/R coil. (b),(d) Patch antenna and dielectric insets of traveling wave setup.

Results

For the volume T/R coil shifted down to the shoulders and using a net power of 1.04 kW, a coronal B_1^+ map (obtained by the AFI method [5], TR1/TR2 = 50ms/300ms) is shown in figure 3a. In the center the B_1^+ field is above 10 µT, sufficient for a spin echo refocusing pulse. At the edges the field strength decays. From certain regions no signal is obtained, resulting in gaps in the B_1^+ map. This is not because there is no B_1^+ available, but because the range of B_1^+ is too large for the method used here. In figure 3b a T2-weighted image is shown at the location indicated by line 1 in figure 1, left image. The rectangle in figure 1 indicates the area where the head coil in the current position has sufficient signal coverage to obtain TSE images comparable in quality to figure 3b. Figure 5a shows the B_1^+ distribution for the traveling wave setup. Using the same input power as for the head coil, a maximum B_1^+ of only 3 µT is obtained in the neck region in the experiments. Figure 4 shows the coverage of the traveling wave setup, indicating signal coverage over a large volume. Simulation results scaled to the net power available during the measurements show B_1^+ values of similar magnitude to those in the experiment (figure 5b). SAR calculations indicate a maximum SAR_{10g} of 0.128 W/kg per 1 Watt power, limiting the continuous power to 78 W when a maximum SAR_{10g} of 10 W/kg is maintained. The SAR_{10g} values for the current measurement conditions with a duty cycle (= pulse duration / TR) of 5% are displayed in figure 5c. The net peak power can be raised up to 1.6 kW in the traveling wave setup before the SAR_{10g} exceeds 10 W/kg. This will raise the maximum B_1^+ to 3.8 µT, but that is still insufficient for spin echo refocusing pulses.

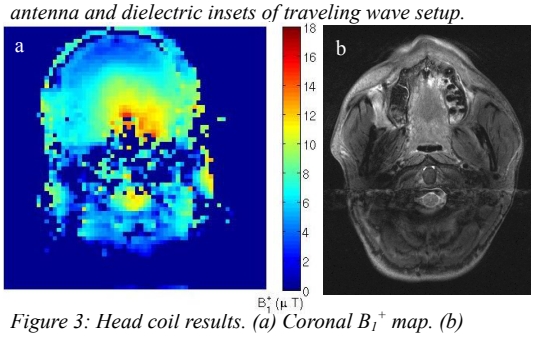

Figure 3: Head coil results. (a) Coronal B_1^+ map. (b) Transverse T_2-weighted TSE in the nasopharynx, turbo factor = 11, TR = 5193 ms, TE = 60 ms, FA = 130°, refocusing angle = 110°, voxel size = 0.5 mm by 0.7 mm, slice thickness = 4 mm.

Conclusion and discussion

Evaluating the results of the volume T/R coil and the traveling wave setup in the head and neck region shows the volume T/R coil has a larger B_1^+, whereas the traveling wave setup covers a larger volume. For imaging the nasopharynx and the oropharynx the head coil can be used for T1W, T2W, SWI, BOLD and angio sequences. Although the traveling wave setup covers a large volume, the B_1^+ field is below 3 µT. It is applicable only for sequences that require a low flip angle such as SWI, BOLD etc. The B_1^+ that is required to confront the B_0-challenge of figure 1b depends on the off-resonances that remain after shimming. The B_1^+ should be several times larger than the off-resonances. The traveling wave setup is unlikely to provide the necessary B_1^+ values.

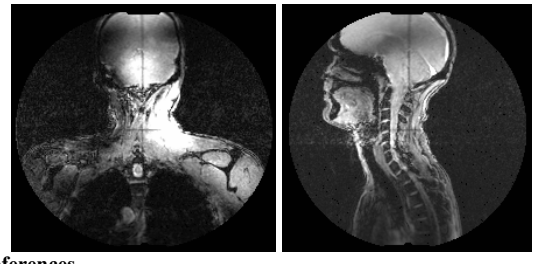

Figure 4: Traveling wave FFE, TR = 100 ms, TE = 2.3 ms, FA = 45°.

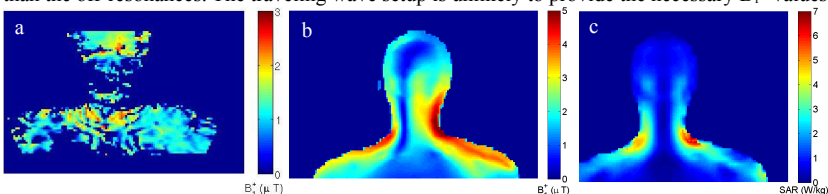

Figure 5: Traveling wave results. (a) B_1^+ map from experiment for 1.04 kW net power. Gaps are a result of applying the AFI method for a large B_1^+ range. (b) B_1^+ from simulations for comparable power. (c) Simulated SAR averaged over 10 g for the same power.

References
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