Enhancement of RF field by high dielectric constant pad at 3T: Cervical Spine Imaging

Q. X. Yang[1,2], Z. G. Herse[1], M. Ketterman[3], J. Wang[1], C. Sica[1], C. Collins[1,2], J. Wang[4], and M. Lanagan[3]
[1]Radiology, The Pennsylvania State University College of Medicine, Hershey, Pennsylvania, United States, [2]Bioengineering, The Pennsylvania State University College of Medicine, Hershey, Pennsylvania, United States, [3]Materials Research Institute, The Pennsylvania State University, University Park, Pennsylvania, United States, [4]Diagnostic Radiology, Yale School of Medicine

Introduction: Previous work at 7T demonstrated that dielectric material can be used to effectively manipulate RF field distribution (1-2). A recent report at 3T has shown that placement of a high dielectric constant pad (HDC) inside a Trans/Receive head coil improved image signal-to-noise ratio (SNR) while lowering SAR in the human cortex (3). Here experimental results demonstrate that the image SNR can be improved by 40-67% throughout the cervical spine, while RF power input was reduced by 60% using HDC pads around the human neck within a phase-array receive coil. Thus, HDC pads offer a simple and inexpensive method for significantly improving image quality and safety of MRI in a variety of clinical applications at 3T.

Methods: The HDC pad (10x7x.25 in) was filled with Barium titanate ceramic spheres and distilled water with mixing volume fraction of 1/4 (Vh_2o/Vspheres) which yields a dielectric constant 300 at 125 MHz. Human cervical spine images were acquired on a 3T Siemens Magnetom Trio 3T system using a 4-element neck matrix receive coil. RF transmission utilized the Tim Trio body coil. Three human subjects underwent standard clinical T1-, T2-weighted imaging (TE 99 ms, TR 3000 ms) and B_1+ mapping protocols (4,5) with and without dielectric pads around the neck. RF power for 180^o flip angle was adjusted through the automated routine. Image SNR was measured using the magnitude images acquired under the above two conditions in representative ROIs in the neck shown in Figure 1.

Results: Figure. 1 shows cervical spine sagittal and axial images from the same subject with (top) and without (bottom) the HDC pads around the neck. Addition of HDC pads surrounding the neck resulted in a reduction of reference voltage for the 180° pulse by the transmission (body) coil by approximately 40%. As indicated in Table 1, the local SNR was improved by 44 to 54% in the spinal cord across all 7 cervical vertebrate levels with the pad while the image contrast between CSF and spinal cord remained the same. The signal intensity appeared to be higher in the region near the pad. However, deeper into the neck, the SNR in the vertebral body were increased by 34%. As seen in Fig. 2, the transmission RF field (B_1+) was enhanced in the focal areas in the spinal region while reduced in areas of head, face and throat. Reduction of the RF field in the throat area is particularly beneficial because it makes the image less susceptible to ghost artifact due to swallowing.

Discussion: For imaging of the human spine and extremities, specialized local receive coils have been widely used to improve the image quality. During such scans, a significant amount of RF power is transmitted into the body but only a small part of it is for imaging. As demonstrated, by strategic placement of the HDC pads next to or around organs of interests such as spine, knee or other extremities of interest, RF transmission power can be significantly reduced by as much as 60%. With SNR enhancement and SAR reduction, more rapid imaging can be performed with improved image quality. B_1+ field in Fig. 2 appeared to be asymmetric in left to right direction. With further development, use of HDC pads may provide a simple, effective and low-cost method for improving quality and safety of MRI in a variety of applications. As seen in the axial image, strong signal from the HDC pad was observed. Such signal can be removed by replacing water with D_2O in HDC pad preparation or adding compounds that reduce the T2 of water. This is most likely related to the asymmetry of circularly polarization of B_1+. Although it is unclear at this time how much of the gain in SNR may be due to different flip angles versus effects on the receive distribution in the ROI, in this study the procedure followed allowed for automated system self-calibration, and thus should be useful in clinical practice on a similar system.

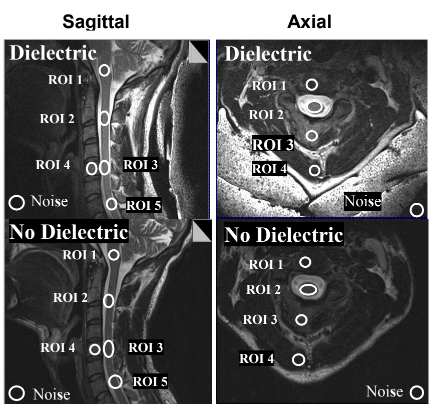

Table 1

Sagittal

ROI	Location	Dielectric SNR	No Dielectric SNR	Δ SNR %
1	Medulla	21.53	17.8	17.32%
2	C2/C3	34.48	18.36	46.75%
3	C5	38.76	17.79	54.10%
4	Vertebral Body	25.23	16.54	34.44%
5	C7	31.87	17.86	43.96%

Axial

ROI	Location	Dielectric SNR	No Dielectric SNR	Δ SNR %
1	Vertebral Body	17.7	10.34	41.58%
2	Spinal Cord	39.63	15.95	59.75%
3	Vertebrae	33.48	13.12	60.81%
4	Trapezius	15.17	4.96	67.30%

Fig. 1. T2 (TSE) images with and without dielectric pad around the neck and SNR in the selected ROIs.

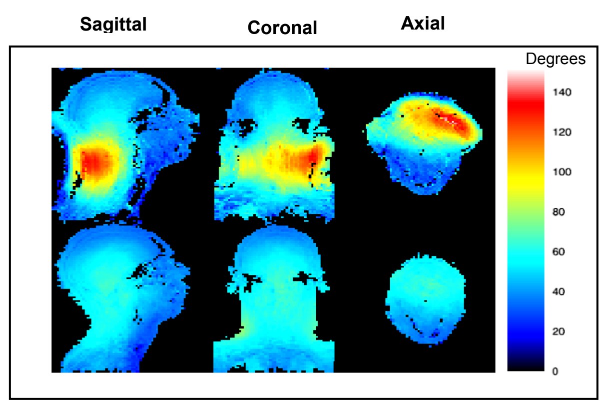

Fig. 2. Measured B_1^+ maps color-coded in degree of flip angle at 128 MHz in three orthogonal planes with (top row) and without the dielectric pad (bottom row).

Reference:

1. Yang QX et al., J Magn Reson Imaging. 2006; 24(1):197-202.
2. Haines K et al., J Magn Reson. 2010; 203(2):323-7.
3. Webb A.G. et al. J Magn Reson 2010; 203; 323-327.
4. Yarnykh VL. Magn Reson Med 2007; **57**:192–200.
5. Nehrke K. Magn Reson Med 2009; **61**:84–92.

Acknowledgments: Funding has been provided in part through NIH R01 EB000454, R01 AG02771 and the Pennsylvania Department of Health.