Proton and sodium MR imaging of in vivo human prostate using dual-tuned body and endorectal coils at 7T

K. T. Bae[1], J-H. Kim[1], A. Furlan[1], C. Moon[1], B. Park[1], and T. Zhao[2]
[1]University of Pittsburgh, Pittsburgh, PA, United States, [2]MR Research Support, Siemens Healthcare, Pittsburgh, PA, United States

[Introduction] Prostate cancer is the most frequently diagnosed male malignancy and the second most common cause of cancer death among men in the United States [1]. Prostate cancer typically appears as a low intensity mass against the bright peripheral zone on T2-weighted MR images. Despite its high sensitivity, T2-weighted MR imaging lacks adequate specificity for prostate cancer detection. In order to improve diagnostic accuracy, a combination of endorectal MR imaging and MR spectroscopy (MRS) has been advocated. MRS, however, is not widely used in daily clinical practice because of the challenges related to images acquisition and interpretation. Sodium (^{23}Na) MRI also provides useful information that reflects the physiological and biochemical characteristics of normal and cancerous tissues [2]. Prostate cancer from excised specimen was found to have low ^{23}Na concentrations [3, 4]. Although ^{23}Na MRI may improve the detection and characterization of prostate cancer, the image quality is poor compared to proton imaging because of its intrinsic low concentration in tissues. Therefore, it is highly desirable to image both ^{1}H and ^{23}Na MRI using a dual-tuned coil without changing coils. The dual-tuned imaging will maximize the benefits of acquiring both morphologic (^{1}H) and functional information (^{23}Na) for accurate diagnosis of prostate cancer in a clinical setting. To achieve this objective, we have recently developed a dual-tuned body coil with a sodium-only endorectal receiver. Thus, the purpose of this study was to assess the feasibility and performance of a dual-tuned RF coil for in-vivo ^{1}H and ^{23}Na MR imaging of human prostate at 7T.

[Materials and Methods] All images were acquired using a 7T MR scanner (Siemens Medical, Erlangen, Germany) with an in-house dual (^{1}H/^{23}Na)-tuned RF coil. A four-channel ^{1}H Tx/Rx coil was tuned and matched at 297.2 Mhz (S11, -15 – -20 dB); 8 channels ^{23}Na Tx/Rx coil was tuned at 78.61 Mhz (S11, -20 dB). One proton and two sodium loops were located at each plane (Figs. 1A, B). A ^{23}Na receiver-only endorectal coil was constructed using the mechanical housing and conductors of a commercial 3T balloon-type endorectal probe (Medrad, USA) and matched to 50 Ω at 78.6 MHz (Figs. 1C, D). The design is similar to those used for proton imaging as being safe for in vivo imaging at 7T [5, 6]. The performance of the coils was tested and confirmed on a phantom made of a plastic container filled with 60 mM [^{23}Na] solution.

Imaging was performed using both coils on 2 healthy male volunteers. Calibration markers (4 tubes with 80 mM [^{23}Na] solution) were placed on pelvis and low back of the subjects. Proton anatomical imaging of the pelvis was obtained using gradient-echo (TR/TE = 300/5 ms, in-plane resolution = 1.4×1.3 mm^2, slice thickness = 2 mm) and Turbo spin echo T2-weighted sequences (TR/TE 7000/63 ms, in-plane resolution= 2.0×1.6 mm^2, slice thickness = 5 mm). Sodium imaging of the pelvis was performed using 3D spiral trajectory sequence (TR/TE = 80 – 100/0.3 – 0.5 ms, isotropic resolution = 6.3 – 4.0 mm^3 and total acquisition time = ~20 min) with using both the endorectal and body coils as a receiver or with the endorectal coil alone as a receiver. Sodium signal intensity was measured on the peripheral and central zone of the prostate, as well as the surrounding areas.

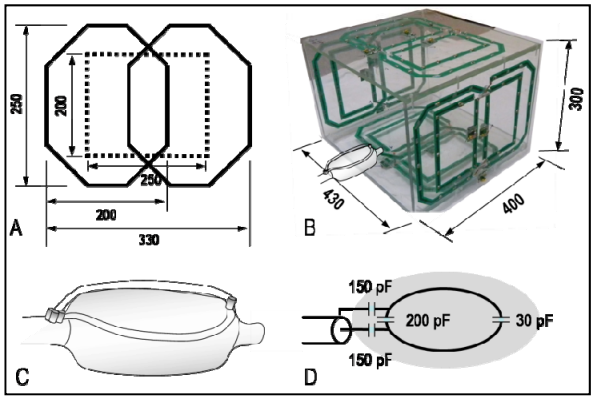

Fig. 1- Body and endorectal coils for prostate MR imaging at 7T. Schematic diagram (**A**) and dual (^{1}H/^{23}Na)-tuned body RF coil (**B**). In **A**, *solid lines* are loops for ^{23}Na and *dotted line* loops for ^{1}H. Drawing (**C**) and schematic diagram (**D**) of endorectal ^{23}Na-receiver only coil.

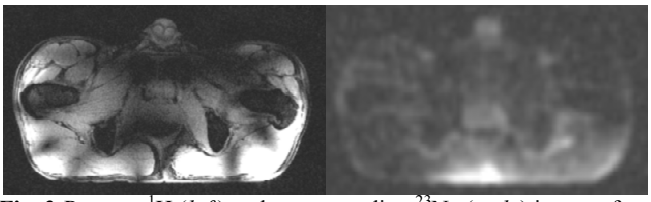

Fig. 2-Prostate ^{1}H (*left*) and corresponding ^{23}Na (*right*) image of subject 1 using dual-tuned (^{1}H/^{23}Na) T/Rx coil.

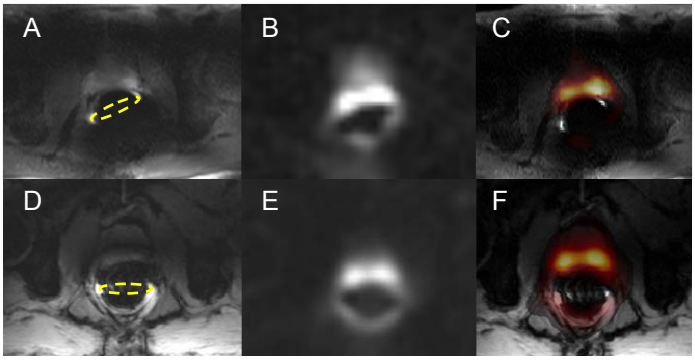

Fig. 3- Prostate ^{1}H (**A**,**D**), ^{23}Na (**B**,**E**), and fusion (**C**,**F**) images of subject 1 (*top panel*) and subject 2 (*bottom panel*) using endorectal coil (*yellow dotted line* in **A** and **D**)

[Results and Discussions] We obtained images of the prostate from both subjects using the body dual tuned coil alone (Fig. 2) and the combination of body and endorectal coil (Fig. 3). On sodium MR images the prostate showed a relatively high signal intensity compared to the surrounding tissues (Figs. 2B, 3B, 3C). The high sodium concentration in the prostate likely corresponds to abundant glandular tissues of high degree secretion. Differentiation between peripheral and central prostate zone could be clearly appreciated on T2-weighted proton MR images (Fig. 3A). On sodium images, the signal intensity from the peripheral zone (mean value = 1734) was higher than that form the central zone (1115) (Figs, 3B,C,E,F). Marker signal intensity was 492. Pelvic anatomical structures showing prominent sodium signal include cerebral spinal fluid (328), urine (928) in the urinary bladder, and pelvic blood vessels (200). Weak sodium signal was observed from the intestine (41) and pelvic wall muscles (52).

In conclusion, we demonstrated the feasibility of ^{1}H and ^{23}Na imaging of in vivo human prostate using a dual-tuned (^{1}H/^{23}Na) Tx/Rx and endorectal Rx only coils at 7T. Our on-going research includes the optimization of the dual-tuned coil to improve SNR and the inclusion of patients with prostate cancer.

[Reference] [1] Jemal et al., *CA Cancer J Clin* 55:10-30, 2005. [2] Jacobs et al. *Techn Cancer Res Treat*, 3:543-550, 2004. [3] Lenkinski et al., *ISMRM* abstract, p5273, 2002. [4] Bae et al., *ISMRM* abstract, p2236, 2008. [5] Klomp et al. *ISMRM* abstract, p1598, 2007. [6] Metzger et al. *ISMRM* abstract, p171, 2008.