A Clinical Comparison of Rigid and Inflatable Endorectal Coil Probes for MRI and 3D MRSI of the Prostate

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Introduction Endorectal coils can provide improved signal to noise (S/N) and spatial resolution for MR imaging the prostate (1,2). This is particularly important for functional imaging studies such as spectroscopic, dynamic contrast-enhanced and diffusion imaging. Commonly, a coil placed on an air-inflatated balloon is used. An alternative design uses a coil placed in a rigid frame. The air-inflated probe is known to cause more tissue distortion than the rigid probe (3). The performance of four endorectal probe setups, a GE Medical Systems rigid coil designed for MR guided biopsies, a prototype USA Instruments rigid coil, a MedRad balloon inflatable coil, filled with air and a MedRad balloon inflatable coil, filled with FC-77 FLUORINERT, a perflourcarbon (PFC) compound (3M, St. Paul) (4), as first demonstrated by Guclu et al. (5), are compared.

Methods The theoretical reception profiles of the coils were modeled via computer simulation based upon their specific geometries. For each probe, images and spectra were acquired on phantoms and on 5 patients, for a total of 20 patients. Scans were performed using the given endorectal probe and a pelvic phased array on a GE 1.5T Signa Imager. MR imaging included axial Tl and fast spin-echo T2 images. The 16x8x8 3DMRSI used PRESS to acquire 7x7x7 mm^3 voxels (0.3cc) with TR/TE = 1000/130.

On axial images, typical distances from the coil to the rectal wall, from the rectal wall to the start and end of the peripheral zone, and to the most anterior part of the central gland were measured. A circular ROI was drawn in phantoms at the typical distance of the peripheral zone from the given coil. S/N measurements were made for these sensitive regions of the coils versus a background noise measurement, which were then normalized to the maximum of the inflatable endorectal probe. These relative S/N measurements were applied to the theoretical coil reception profiles.

The time required for properly positioning the endorectal coils was recorded. For this study, the USA coil was placed without coil positioning devices more recently developed to aid positioning and reduce motion. An experienced spectroscopist evaluated the T2 weighted images of patient studies for motion artifact using a 1-5 scaling system, with 1 having the least and 5 having the greatest artifact. Additionally, data sets were scored for spectral quality on a 1-5 scale (1-excellent and 5-poor) based on S/N, spectral resolution, and water and lipid suppression. The motion artifact and spectral quality scores were compared among the four endorectal coil setups. The time required for shimming and the value of the x, y and z gradient shims were recorded after auto-shimming and after subsequent manual shimming. Linewidths of water were also measured.

Results Line profiles for the center of the coils are shown in Figure 1. S/N was significantly higher for the rigid probe datasets for most of the peripheral zone regions. In the center of the coil, at the distance of the peripheral zone, phantom studies showed the rigid probe to have 260% and the biopsy probe to have 240% of the inflatable probe S/N. On the lateral sides, the smaller rigid probes demonstrated lower signal to noise than the inflatable probe. Also, the signal to noise of the biopsy probe dropped dramatically by the apex. The rigid probes were not only smaller in size, but were positioned closer to the peripheral zone, as the inflated balloon distanced that coil from the rectal wall. However, the inflated balloon also acted to compress the rectal wall, decreasing the distance to the peripheral zone. Overall, the inflated coil probe remained further from the peripheral zone.

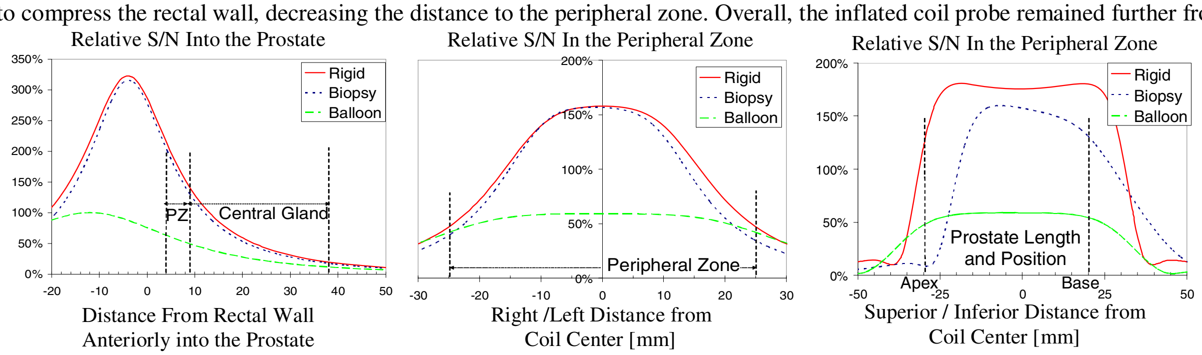

Figure 1

Line profiles in three planes through the theoretical reception profiles of the coils. PZ=peripheral zone

The time required for placement was longer for the rigid probes (10 ± 2 min) versus the inflatable probes (7 ± 2 min). This was due to the fact that the inflatable coil seats itself on the prostate when inflated and does not move as the patient is transferred from his side to his back. The time to inflate the balloon coil with PFC versus air was insignificantly increased (< 1 min), although removal of the PFC took slightly longer than air. The time required for manual shimming was less for rigid probes (5 ± 3 and 4 ± 3 min.) versus the air inflated probe (7 ± 4 min.), but least for the PFC inflated probe (1.6 ± 0.5 min). Also, the autoshim values were farthest from the subsequent manual touch-up shim values for the air-inflated probe. The mean motion score for images acquired using both rigid probes (2.4±0.5 and 2.4±0.5) was greater than for the inflatable probe (1.4 ± 0.5 and 1.8 ± 0.7). Although water linewidths were not significantly different for the rigid and the air inflatable probes, the spectral quality score was significantly better for the rigid probes (1.6 ± 0.5 and 1.5 ± 0.6) than for the inflatable probe filled with air (2.5±0.6). The inflatable probe filled with PFC had smaller linewidths and the best spectral score (1.4±0.5).

Discussion The different endorectal probes provide both advantages and disadvantages. The S/N is increased with the smaller, rigid probes, but this increase drops off laterally and towards the apex of the prostate. The biopsy probe demonstrated a decrease in sensitivity towards the apex. This is due to the shape of the probe bending away from the prostate to allow a biopsy needle to pass through the probe into the prostate. This probe is intended to be repositioned along the superior/ inferior direction during imaging to acquire biopsy samples from different locations and so could compensate for this falloff. The inflatable probe took less time to position and stayed in place better than the rigid probes. Additionally, the inflatable probe has less motion artifacts than the rigid probes. Newly designed rigid probe holders may address some of these issues. The air- or PFC- inflated balloon may absorb some of the motion. However the design of the air inflated probe compresses the rectal wall and introduces a pocket of air between the coil and the peripheral zone, increasing magnetic susceptibility artifacts, making shimming more difficult relative to the other probes. This problem was addressed in the PFC-inflated probe setup. For general use, the PFC-inflated probe is recommended, due to its shorter placement time, low motion artifacts, and high quality spectra, but it does cause greater tissue distortions than the rigid probes. Rigid probes may be preferred for higher S/N needs, less tissue distortion (such as for radiation treatment planning), motion insensitive scans, or for MR guided biopsies.

References 1. Hricak, H. Radiology. 193:703-309.1994. 2. Watkins, R. Proc. ISMRM. 412. 2000. 3. Kim Y. Med Phys. 2005 3569-3578. 4. FC-77 MSDS, 3M Company, St. Paul MN55144, www.3M.com. 5. Guclu CC. Proc. ISMRM. 302. 2004.