Endometrial Imaging at High Magnetic Fields: Feasibility of In-Vivo Studies at 7 T

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Introduction: The potential for increased SNR from a 7 T body imaging system may be able to offer advantages over clinically available field strengths. This study establishes the framework for performing clinically relevant measurements at 7 T to assess the possible advantages of ultra-high magnetic fields in imaging of the endometrium for the staging of endometrial carcinoma and the diagnosis of adenomyosis. Body imaging at high fields remained elusive until recently because of multiple experimental obstacles including susceptibility artifacts due to magnetic field B_0 inhomogeneities and RF pulse field imperfections. However, with the recent development in our laboratory of a comprehensive B_1-shimming procedure for the correction of phase (1), body imaging became more feasible at high fields, providing possibilities for the study of small lesions with greater temporal and spatial resolution at 7 T. Preoperative staging of endometrial carcinoma is an important clinical application of MRI for determining the depth of tumor invasion into the myometrium, which is correlated with outcome (2). The use of gadolinium-based contrast agents aids in assessment of the tumor volume and vascularization with dynamic contrast enhancement (DCE) (3). Another potential application for high-field endometrial imaging would be the diagnosis of adenomyosis, especially in distinguishing it from endometriosis, which presents with very similar symptoms.

Methods: Studies were conducted on a 7 T whole-body magnet (Magnex Scientific, Oxfordshire, UK) with a Sonata gradient system and TIMS console (Siemens Medical Systems, Erlangen, Germany). An 8-channel TEM/stripline flexible body transceiver array was used for imaging (4). An algorithm for B_1 shimming was employed for the removal of destructive interference from the area of interest, significantly improving the utility of ultra-high field imaging of the uterus (1). Both GRE and T_2-weighted turbo-spin echo (TSE) images were collected (Figure 1). Sagittal images were collected as well as transverse images perpendicular to the long axis of the uterus, a view important for determination of invasion and later histological comparison following hysterectomy. The gradient recalled echo (GRE) images were collected with TR/TE = 50/4.08 ms, 3.0 mm slice thickness, matrix = 512x512. The sagittal TSE imaging was performed with TR/TE = 5000/143, 2.0mm slice thickness, and matrix = 512x512, while transverse images were collected with TR/TE = 10000/143 ms. A GRE variable flip angle (GRE-vfl) sequence was also used to collect images along the long and short axes of the uterus (Figure 2).

Results: T_2-weighted MRI provides the greatest anatomical differentiation at lower field strengths. However, the GRE images remain important for their role in fast DCE applications. To demonstrate that this clinically important test can be transferred to 7 T from the lower field strength magnets, images were collected with a time resolution of 22 s per slice with high in-plane resolution, 3.0 mm slice thickness, and TR/TE = 40/4.08 ms. Utilization of the conventional GRE and TSE pulse sequences at 7 T with no B_1-shimming algorithm was found inadequate because of the phase artifacts, which were successfully removed using the B_1-shimming procedure (Figure 1). GRE-vfl imaging provided better visualization of the myometrial layers as compared to GRE and TSE sequences.

Discussion: High-field magnetic resonance imaging provides high spatial and temporal resolution images with tissue differentiation in the uterus. Through developments in coil design and B_1 shimming, 7 T has become a promising platform for the study of endometrial carcinoma and adenomyosis. The potential increase in SNR could improve tissue differentiation and possibly alleviate the need for an endovaginal or endorectal coil avoiding the associated discomfort for the women.

References: 1) Van de Moortele P-F, et al., MRM 2005; 2) Frei KA, Kinkel K, JMRI 2001; 3) Saez F, et al., JMRI 2000; 4) Vaughan JT, et al., MRM 2004

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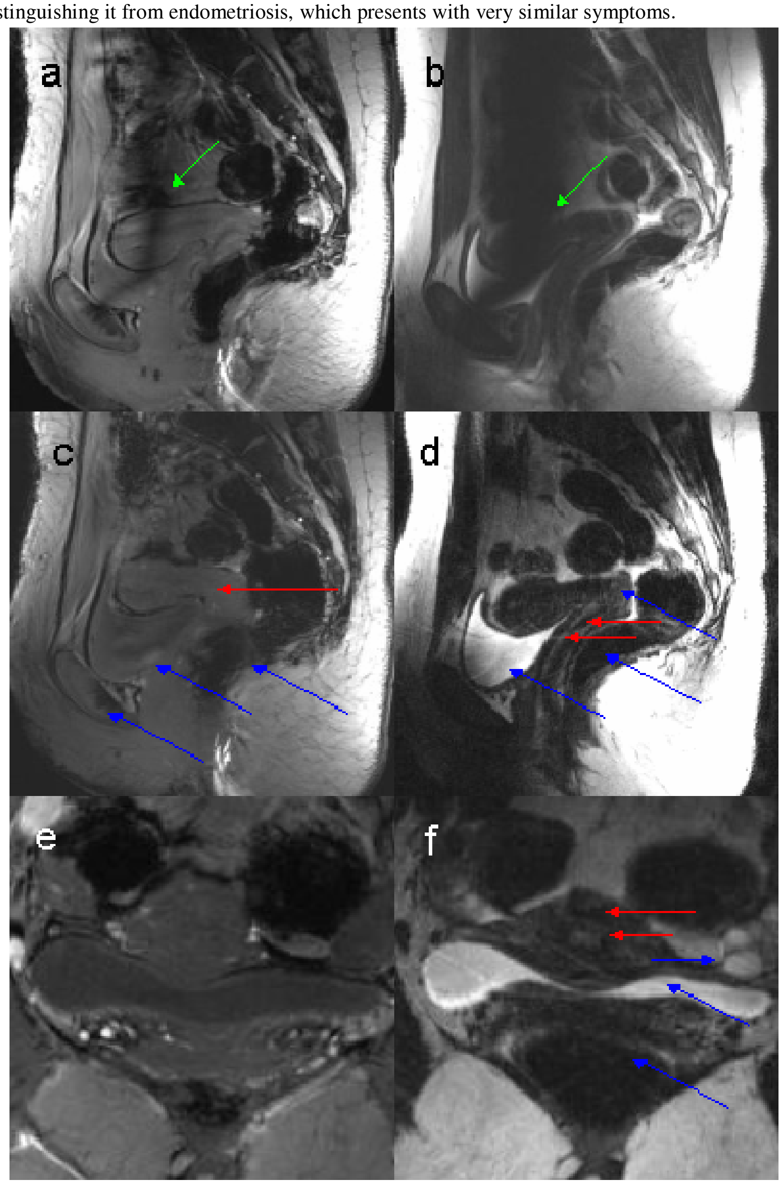

Figure 1 – Sagittal images before (a,b) and after (c,d) B_1 shimming and transverse (e,f) images using a GRE sequence (a,c,e) (TR/TE = 50/4.08 ms, 3.0 mm slice thickness) and using a T_2-weighted TSE sequence (b,d,f) (sagittal images, TR/TE = 5000/143 ms; transverse image TR/TE = 10000/143 ms; all TSE, 2.0 cm slice thickness). In images a) and b), the arrows indicate the area of interference which is no longer visible in the corresponding images, c) and d), as a result of B_1 shimming. In image c) the arrows show, from top to bottom, the uterus, rectum, bladder, and pubic symphysis. On image d), from top to bottom, the arrows show the cervix, vaginal wall, vaginal epithelium, rectum, and bladder. In image f), from top to bottom, the arrows indicate the myometrium, endometrium, ovarian follicles, bladder, and rectum.

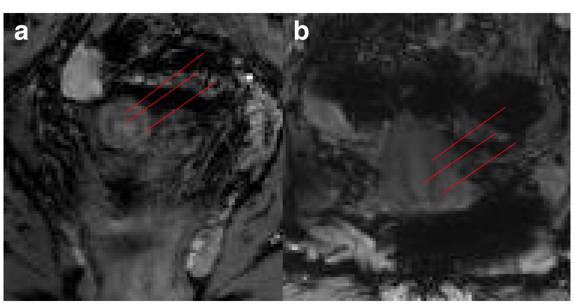

Figure 2 GRE variable flip angle imaging along the short (a) and long (b) axes of the uterus. Here the endometrium (center line) can be seen as well as the inner (top line) and outer (bottom line) layers of the myometrium.