Dedicated endoluminal coil for anal sphincter MR imaging

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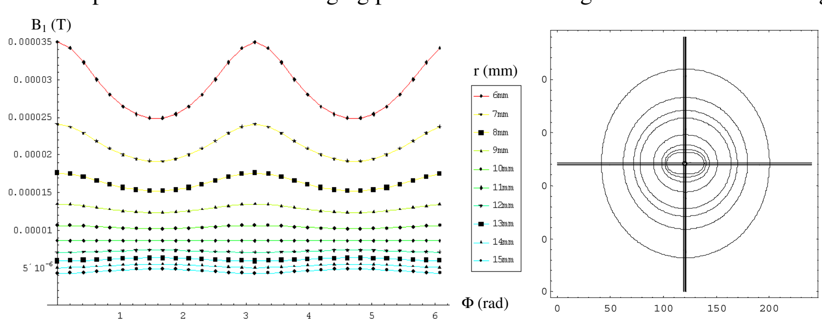
Introduction

The imaging of the anal apparatus is becoming more and more important in the management of patients suffering from anorectal disease. The exact differentiation of the sphincter muscles is a major requirement for the detection of disorders of the anal canal. Despite the enhancement of image spatial resolution and quality both with the increase of main magnetic field and array coil with large number of Radiofrequency (RF) channels, the use of endoluminal RF coil located in the region of interest still dramatically improve SNR [1] and could potentially allow a good evaluation of anal tissues compared to endosonography [2], especially for the external layer of the sphincter. The purpose of this work was to design, to build and to evaluate a dedicated endoluminal coil allowing detailed MR imaging of the anal sphincter.

Material and Methods

Based on previous work [3], a double loop coil prototype (60 mm length, 6 mm width) was designed using Biot-Savart computations implemented under Mathematica software (Wolfram Research, Inc., Champaign, IL). The angle between both loops was optimized to improve radial uniformity of the RF B1 field compared to a single loop (Fig. 1). Double loop coil prototypes were built using four 1mm diameter copper conductor (Fig. 2a). Each side of the loop was closed with double side printed circuit board hosting conventional tuning, matching and active decoupling components (Temex DH 80106 PIN diodes and non-magnetic case A series 100 and 710 ATC capacitors). The coil was tuned to a frequency of 63.7 MHz and matched at 50 Ω for this frequency. The coil was housed in removable biocompatible tubing with an outer diameter of 10 mm. MRI experiments were performed on a 1.5 T MR Symphony system (Siemens Medical Solutions, Erlangen, Germany). Coil performances (SNR, signal uniformity) and decoupling efficiency were assessed by inserting it into a plastic container filled with a 0.45 % NaCl solution. Feasibility study was established *in vivo* on a domestic swine (25 kg weight). The coil was introduced through the anal sphincter up to the colon and maintained by inflating a balloon with 5 ml of air placed at the tip of the coil. The experiments were leaded in accordance with the rules and regulations of the University Ethic Committee on animal experimentations. The imaging protocol combined high-resolution 2D T1-weigted SE, True-Fisp and T2-weigted TSE.



a b

Fig. 1: (a) Simulations of B_1 intensity variations for increasing distance from coil center (r) with the angle and (b) spatial distribution of the magnetic field B_1 represented through iso-contour lines (ranging 2 to 81.10^{-6} T) for a single loop coil.

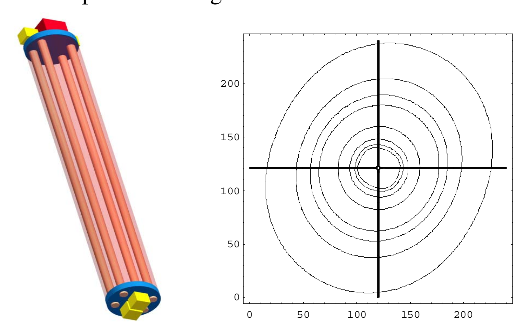


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Fig. 2: (a) 3D representation of the double loop coil with integrated components. (b) Spatial distribution of the magnetic field B_1 represented through iso-contour lines (2 - 81.10^{-6} T) for a double loop with 50 degrees angulation between loops.

Results

Minimum radial variation of signal intensity was found for an angle between 50 and 70°, depending on the radius. The quality factor Q of the "50° coil" embedded in salty water mimicking loading conditions was 124. SNR measured at the close vicinity of the coil (about 5 mm from the center) compared with SNR measured with the regular four-element phased array body coil used for abdominal clinical exams was 30 times higher. The sensitivity pattern falls off rapidly with distance from the coil. The sensitivity of the double loop coil was rather uniform to a fixed radius and improved compared to a signal loop coil. Moreover, it provides a better SNR than the four-element phased-array body coil up to about a radius of 30 mm from the coil centre. The anal sphincter complex was visualized with detail (Fig. 3). The high spatial resolution and excellent tissue contrast in images allowed excellent visualization of anal mucosa/submucosa complex, internal sphincter, and the external sphincter.

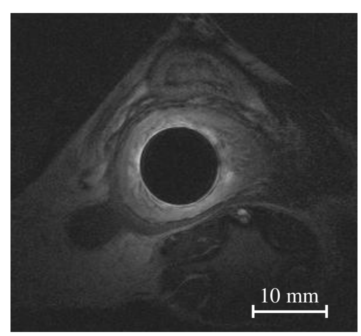

Fig. 3 : Axial T2-weigted TSE images (TR/TE : 3000/82 ms; FOV = 80 mm; 2.5 mm slice thickness; 156 x 195 μm^2 pixel size; 5 min 40 s scan time) showing the internal and external sphincters.

Conclusion

An endoluminal loop RF coil has been developed for the anal apparatus. The internal coil provides a dramatic increase in SNR local to the coil, compared to usual external coils. High-resolution magnetic resonance imaging acquired in the swine provides excellent visualizations of the normal anal sphincter complex anatomy. The results are promising and suggest useful applications in the management of anorectal diseases with minimally invasive procedure.

References

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Acknowledgements

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