Susceptibility matched endoluminal coil for the acquisition of high SNR spectra for the observation of the rectal wall

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Introduction

Examination of the rectal wall is critical in the staging and follow-up of the rectal cancer. A recent study showed the relevance of MRS for the diagnosis of cancer in different organs (1) but it remains difficult to obtain a suitable spectrum of the rectal wall, even with recent 32-channels array coils. A previously designed endoluminal coil showed a much higher local SNR than external array coils (Peak SNR about 30 times higher (2)) and could therefore be relevant for this purpose. We aimed at assessing its performances for MRS (SNR and FWHM). Besides, the endoluminal coil suffers from a magnetic susceptibility effect due to the gradient between the inside of the coil (air) and the surrounding tissues, whose susceptibility is approximately equal to water's magnetic susceptibility . This effect is altering the static magnetic field and could result in line broadening and frequency shift. In this work, the ability of ultem used as a susceptibility matching material was assessed. With $\chi_{\text{ultem}} = -8.92$ ppm (SI Units), Ultem presents a 2nd kind magnetic compatibility with water (regarding Shenck classification (3))

Material and Method

The first step was to ascertain the extent of the susceptibility effect. We conducted a simulation of the B0 magnetic field considering our endoluminal coil (at the magnetic susceptibility of air) plunged into an environment (at the magnetic susceptibility of water). The susceptibility effect depends on the difference of susceptibility between the two media and on the shape and orientation of the magnetic susceptibility interface with respect to the direction of the B0 magnetic field. Two extreme cases for a cylindrical shape were simulated (MATLAB, MathWorks): orthogonal and parallel to the direction of the B0 field. For the simulation needs, both the endoluminal coil and the surrounding medium were considered to be infinite cylinders (which is a rather reasonable hypothesis). After these first results, the simulation was conducted again using an ultem filled endoluminal coil (cf fig 1). We focused on the maximum deviation from the reference B0 field (3T) obtained in both cases.

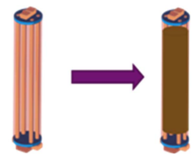

Fig 1: Endoluminal Coil with/without ultem

Assessment of ultem as a susceptibility matching material: Before inserting ultem directly inside the endoluminal coil, which requires disassembling the coil, we conducted experiments to assess the ability of ultem material to limit the susceptibility effect with a different geometrical configuration (cf fig 2). The endoluminal coil was inserted into an ultem cylinder. Experiments were performed on a GE DVMR750 3T and 5mm diameter tubes containing metabolites at 50 mmoL/L concentration were placed on a radius of 1cm away from the endoluminal coil (cf fig 2). We assessed the time and volume normalized SNR (defined as SNR/($\sqrt{T} \times V$)) and the FWHM. The peak positions were noted down and compared to literature (4) in order to assess the shift generated by the gradient of susceptibility. The spectrum were acquired with a monovoxel PRESS sequence centered on the tubes (6x6x8 mm^3 voxel, 5 kHz Spectral Bandwidth, NEX 128, TE/TR = 35/2000 ms, Acquisition Time: 4min56s)

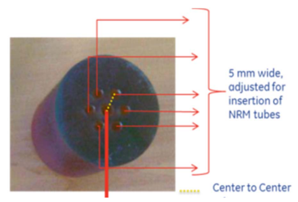

Fig 2: Photograph of the ultem phantom; the endoluminal coil is inserted at the center of the phantom

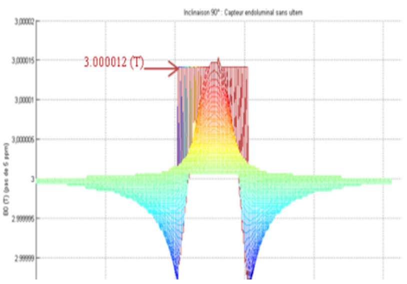

Fig 3: B0 field map with a 90° angle between the original endoluminal coil and the z axis

Results

We modelized the endoluminal coil and its environment by two concentric cylinders. The angle between the z axis and the central axis of the cylinders was set to 90° (an extreme case). With an air/ water interface, the B0 inhomogeneity reached 12 ppm a maximum (cf fig 3) and with an ultem/water interface the maximum B0 inhomogeneity was at 0.3 ppm. It has to be compared to the observation window of spectroscopic exams which is usually 4.7 ppm wide.

	SNR/($\sqrt{T} \times V$)($mL^{-1}.s^{-1/2}$)	FWHM (Hz)	Frequency deviation (ppm)
Endo Creatine	1.2×10^{-3}	8.2	0.11
Endo Choline	2.3×10^{-3}	3.8	0.15
12-channels head coil	7.5×10^{-5}	3.9	

Table 1: Performances of the endoluminal coil for the observation of 2 metabolites (Creatine and Choline), comparison with a 12-channels head coil

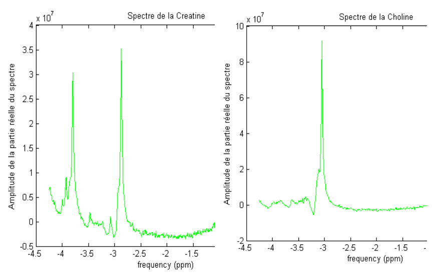

Fig 4: Creatine spectrum (left) and Choline spectrum(right)

Discussion:

- The spectra acquired (cf Fig 4) with the endoluminal coil are promising, when compared with a clinical 12-channels head coil it showed similar FWHM and the time and volume normalized SNR is at least 16 times higher (cf Table1). Still, it is important to be aware of the limitations of this preliminary study: it is conducted on phantom with metabolites at high concentration level and the FWHM depends strongly on the manual shimming of the operator.
- On the use of ultem as a susceptibility matching material: the spectra obtained with ultem present a slight shift of frequency (< 0.2 ppm cf Table 1) which could either come from the susceptibility effect or from the degradation of metabolites.

Conclusion: The simulations conducted have proven the interest of a susceptibility matching material such as ultem. In practice there is still a slight deviation we might further reduce when ultem will be inserted inside the endoluminal coil. As for the performances of endoluminal coil for MRS, we have been able to compare the SNR by normalizing with time and volume and it clearly showed superior performances than a 12-channels clinical head coil.

References

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