Evaluation of positive contrast around SPIO-loaded polymer threads for surgical mesh delineation by MRI

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Introduction

Surgical textile mesh implants for abdominal hernia repair are hard to delineate in MRI. To improve MR-visualization, superparamagnetic iron oxides (SPIO) were implanted in the mesh polymer base material. SPIO generate magnetic susceptibility gradients. These gradients generate voids in gradient echo images. In abdominal MRI, proton free structures, e.g. intestinal gases, cannot be discriminated from these voids. To discriminate between voids positive contrast susceptibility imaging (PCSI) was developed to generate hyperintense signal from susceptibility gradients (Krämer 2010). In this study, four PCSI techniques are compared on a single SPIO-loaded polymer thread - water suppressed gradient echo imaging (IRON, Stuber 2007), balanced gradient echo imaging with reduced flip angle (FLAPS, Dharmakumar 2006), dephasing of the measurement gradient in a gradient echo image (white-marker imaging, Seppenwoolde 2007) and susceptibility gradient mapping (SGM, Dahnke 2008).

Methods

One SPIO-loaded polymer thread (120 µm diameter) was embedded in a 2 mass% agarose phantom (3 mM CuSO4). The thread was positioned orthogonal to B0. Al images (unless stated otherwise) were acquired as single slice gradient echo images at 1.5 T with excitation pulse = 20°, TE = 4.6 ms, TR = 50 ms, NSA = 1, FOV = 256 x 256 mm^2, acquisition voxel size = 1.0 x 1.0 mm^2, reconstruction voxel size = 0.5 x 0.5 mm^2, slice thickness = 3 mm, fold-over direction = AP, pixel bandwidth (PBW) = 217 Hz and water-fat shift = 1 pixel. Constant level appearance encoding (CLEAR) was used for signal intensity homogenization over the phantom.

A : standard gradient echo image, scan duration = 12.8 sec.
B: gradient echo image as A with 150°Sinc-Gauss water suppression pulse of 5 ms (IRON), TFE factor = single shot, scan duration = 24.6 sec.
C: balanced FFE with excitation pulse = 4°, TE = 3.6 ms, TR = 7.2 ms and offset = 0° (FLAPS), scan duration = 14.1 sec.
D: balanced FFE with excitation pulse = 4° as C and offset = -50° (FLAPS), scan duration = 14.1 sec.
E: balanced FFE with excitation pulse = 4° as C and offset = +50° (FLAPS), scan duration = 14.1 sec.
F: gradient echo image as A with dephased measurement gradient, cumulated over all 4 possible orientations for the frequency and phase encoding direction (white-marker imaging), scan duration = 51.2 sec.
G: Susceptibility gradient map calculated from A with "true resolution" algorithm (SGM-TR), scan duration = 12.8 sec.
H: Susceptibility gradient map calculated from A with "Short term Fourier transform" algorithm (SGM-STFT), scan duration = 12.8 sec.

To quantify the formed positive contrast, the pixels above half the signal intensity between noise and maximum signal level were selected.in a region of interest around the SPIO loaded thread. The length/width ratio was calculated and the number of included pixels was counted.

Results

7 different types of PCSI were obtained (fig. 1). The length/width ratio and the number of pixels varied for the various methods (table 1).
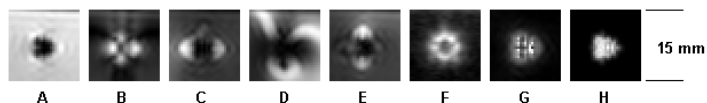

Figure 1, Four methods to generate positive contrast from one SPIO loaded polymer thread used for abdominal hernia meshes are presented: gradient echo image (A), IRON (B), FLAPS (C-E), white-marker imaging (F) and SGM (G, H).

Table 1, Quantitative comparison of positive contrast around a SPIO loaded thread.

Image	Method	Length / Width	Nr pixel	Conclusion
B	IRON	1.25	72	++
C	FLAPS	2.375	59	-
D	FLAPS	?	?	--
E	FLAPS	0.421053	57	-
F	white-marker imaging	1.07692	121	+
G	SGM-TR	0.8	40	-
H	SGM-STFT	1.11111	72	+++

Conclusions

Method D cannot be used because the contrast is not focused around the thread. C, E and G do not give an accurate estimation of the thread location and are therefore not usable. B, F and H give accurate location estimations and have a more or less equal length / width ratio. Method F requires substantially more preparation and measurement time, which makes it less attractive. Method H is calculated from a standard gradient echo image which is otherwise used as anatomic image. From these observations, the acquisition of a gradient echo image with a calculated Short Term Fourier Transform SGM image is to be preferred for positive contrast imaging of SPIO loaded hernia meshes.

References

Krämer NA, Donker HC, Otto J, et al., Invest Radiol 2010;45(8):477-483
Stuber M, Gilson WD, Schär M, et al., Magn Reson Med. 2007;58:1072–1077
Dharmakumar R, Koktzoglou I and Li D, Phys Med Biol 2006;51:4201–4215
Jan-Henry Seppenwoolde JH, Vincken KL, and Bakker CJG, Magn Reson Med. 58:605–609 (2007)
Dahnke H, Liu W, Herzka D, Frank JA, Schaeffter T, Magn Reson Med. 2008 Sep;60(3):595-603
Dahnke H, Liu W, Bowtell R, Frank JA, ISMRM 2008; 1513.