Simulations of stent artifacts in MRI

Y. Guo[1], J. Chen[1], and X. Jiang[1]
[1]Department of Electrical Engineering, Tsinghua University, Beijing, China, People's Republic of

Introduction Metallic stents cause artifacts in MR images due to magnetic susceptibility and RF field shielding [1-3]. Local difference in susceptibility between the stent and its surroundings perturbs the spatial uniformity of the static magnetic field (B0).[1] The RF field (B1) shielding impacts both the exciting field and the receiving sensitivity.[2-3] This work proposes an approach to simulate the stent artifacts in MRI based on electromagnetic field analysis. Both static and RF field distributions with a sample stent in a uniform imaging sample are calculated using the commercial FEM software JMAG 10.0 (JRI Solution, Limited, Japan). The images with stent artifacts are simulated by an MRI simulator based on the calculated field distributions.

Method The geometries of the sample stent and the region of interest (ROI) in the imaging sample are shown in Fig. 1. Two kinds of stent materials, 316L stainless steel (σ = 1.35×10^6 S/m, χ= 9×10^{-3}) and NiTi alloy (σ = 1.22×10^6 S/m, χ= 3.1×10^{-4}), are used in this work. The sample (σ = 0.8 S/m, χ= -9.1×10^{-6}) is a cylinder of 40mm diameter and 30mm length. The simulations of the static and RF field distributions are carried out using the three-dimension static magnetic analysis module and the frequency response analysis module of JMAG respectively. The inhomogeneity in ROI is calculated as:

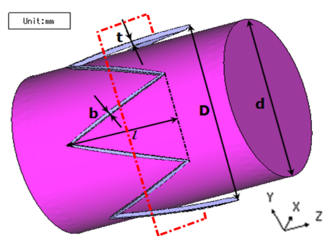

Fig. 1 Geometry of the sample stent (gray region) and ROI (red region), t=0.2mm, b=0.1mm, *l*=5mm, D=8mm, d=7.2mm.

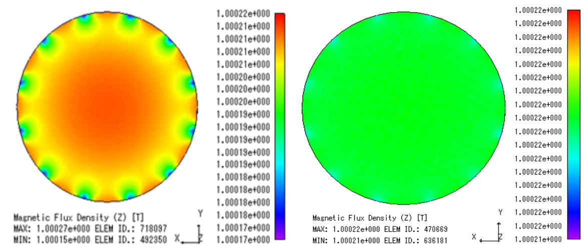

Fig. 2 B0 maps in transversal plane of ROI (left: 316L; right: NiTi).

$$U = 2\times\frac{B_{max} - B_{min}}{B_{max} + B_{min}}$$

where B_{max} and B_{min} are the maximum and minimum magnetic field in ROI respectively.

The MRI simulator consists of three parts: virtual object generation, MRI sequence simulation and reconstruction. The static field distribution is taken as one parameter of the virtual object. During RF pulses the block equation is solved using the Cayley-Klein parameters to simulate the shielding effect on the exciting field [4]. The RF field distribution is taken as the receiving sensitivities in the sample.

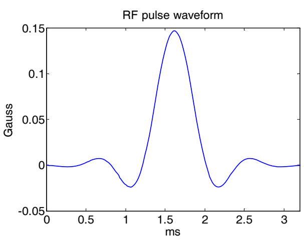

Fig. 4 RF pulse waveform.

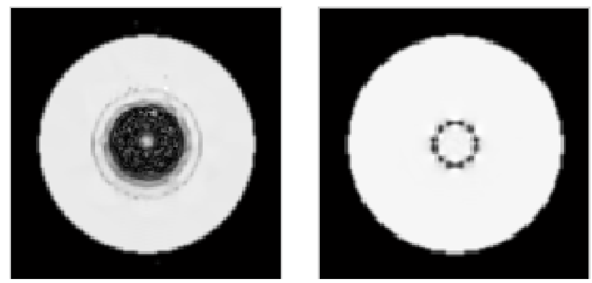

Fig. 3 Simulated images of GRE sequence (left: 316L; right: NiTi).

Results

A. An external B0 of unit tesla along z axis (symmetric axis of ROI) is applied. The stents made of 316L and NiTi are simulated respectively. The B0 distributions in the transversal center planes (illustrated by the dashed line in Fig.1) of ROI are shown in Fig. 2. The field inhomogeneity in ROI is 120ppm for 316L and 10ppm for NiTi, while the inhomogeneity in the transversal plane is 7.87ppm for 316L and 0.34ppm for NiTi. With a B0 of 0.3T, the simulated images of the transversal plane are acquired, as shown in Fig. 3, with a perfectly homogenous RF field of 12.77MHz, using a gradient-recalled echo (GRE) sequence with flip angle = 90^o, TE = 30 ms, FOV = 5 cm × 5 cm, 128×128 imaging matrix, slice thickness = 1 mm. The diameter of the cylinder imaging sample is 40mm, and the RF pulse waveform with a flip angle of 90^o is shown in Fig. 4. It can be seen that the stent made of NiTi causes smaller artifacts compared with those by 316L, which has larger magnetic susceptibility.

B. An external B1 of unit tesla (rms) rotating at a frequency of 12.77MHz is applied. The NiTi stent is simulated with B1 rotating surrounding z and x axis respectively. The B1 distributions in the transversal plane of ROI are shown in Fig. 5. The simulated images, shown in Fig. 5, are acquired with a perfectly homogenous B0 field of 0.3T, using a spin echo (SE) sequence with TE = 30 ms, FOV = 5 cm × 5 cm, 128×128 imaging matrix, slice thickness = 1 mm. More serious B1 field inhomogeneity is caused when B1 is rotating surrounding x axis, resulting in larger coupling between B1 and the conductive loop of the stent. However, no significant difference between two images can be observed.

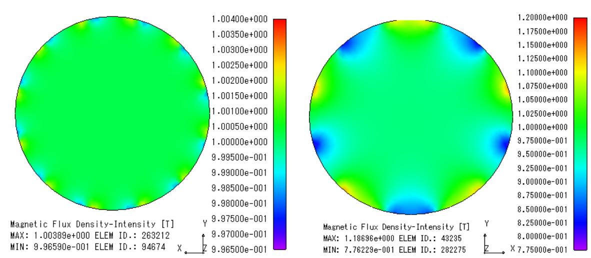

Fig. 5 B1 maps in transversal plane of ROI (left: B1 rotating surrounding z axis; right: B1 rotating surrounding x axis).

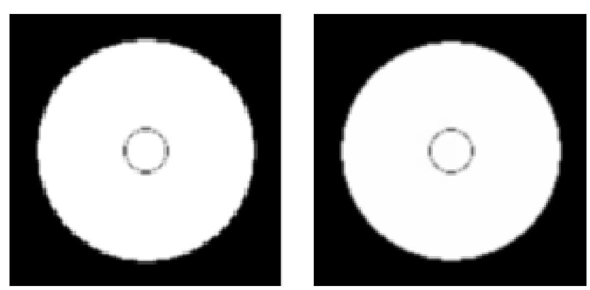

Fig. 6 Simulated images of SE sequence (left: B1 rotating surrounding z axis; right: B1 rotating surrounding x axis).

Conclusion A method of simulation of stent artifacts in MRI is developed based on electromagnetic field analysis. By an MRI simulator the simulated images with the stent artifacts are acquired. The results indicate that the stent made of NiTi with a small magnetic susceptibility is promising for obtaining the inside information without significant distortion while the stent of 316L seems difficult to look inside in MRI.

References 1) Klemm T. *Journal of Magnetic Resonance Imaging* 2000, 12:606-615; 2) Bartels LW. *Magnetic Resonance in Medicine* 2002, 47:171-180; 3) Yi Wang. *Magnetic Resonance in Medicine* 2003, 49:972-976; 4) Johe Pauly. *Journal of Magnetic Resonance*, 1989, 82:571-587