# A Polymer-absorbed Gd-DTPA Complex Marker for the Passive Catheter Tracking

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**Introduction** In MR guided catheter tracking, catheter visualization and automated scan plane positioning are required. For passive catheter tracking, the susceptibility artifact from the catheter or the metal marker rings was used. The disadvantage of the tracking using susceptibility artifact was that the shape and size of the artifacts were changed by the direction of the magnetic field. Therefore we had developed the Gd-DTPA polymer ink that performed as the passive marker and could be coated on the catheter. This marker appeared as a white pattern with high intensity on MR images. Even if it was dipped into water or saline, it did not rub off easily. In this study, we had optimized content ratio of the Gd-DTPA complex to the saline absorbed polymer and coating thickness of the Gd-DTPA polymer on the catheter for optimizing visibility of the marker. Further, we had calculated T1 value of the Gd-DTPA polymer using the inversion-recovery method. And the effectiveness of our visualization technique was derived by the experiment of catheter tracking with vessel model.

**Materials and Methods** The Gd-DTPA polymer ink that we developed was synthesized in following steps. In the first step, copolymer from methacrylic acid and the DTPA/HEMA monomer complex coordinated with gadolinium ion. And, DTPA/HEMA monomer was esterified compound from DTPA anhydrate and HEMA. We surveyed that the gadolinium remained in the polymer ten hours after the polymer-absorbed gadolinium complex dipped into pure water by the fluorescence X-ray analyzer.

We optimized the contents ratio of gadolinium complex to the polymer. The developed polymer which absorbed the gadolinium complex was embrocated on a grass preparation. The polymer was covered with another polymer with the hydrophilic property for protecting from out flowing of the gadolinium and rubbing off of the polymer. The content ratios of gadolinium complex to the polymer were 0.1, 0.5, 1.0, 2.0, 3.0, 5.0, 9.0 and 12.0%. The coating thicknesses of the polymer were 5, 40-60, 100-150 micrometers. For comparison, the samples with covering and without covering by hydrophilic polymer were prepared. Ten or twelve hours after the samples were dipped into saline, the markers became visible in the image. The images were acquired with a spoiled gradient echo (SPGR) sequence (TR/TE 40/10 ms, FA 60degrees, BW 10.42 kHz, slice thickness 10mm, FOV 24 x 24 $cm^2$, spatial matrix 256x128 and accumulation 1). Scanning was performed on a 0.5T Open MRI GE Yokogawa Medical Systems Inc. Signa SP/i system with the head coil.

We also calculated T1 value of the Gd-DTPA polymer using inversion-recovery method. The Gd-DTPA polymer ink was painted on the catheter (5Fr, MK50BH0.06, Medikit Co. Ltd., Tokyo, Japan) as show in figure 1. The images of the catheter coated by Gd-DTPA polymer ink (the content ratios of the Gd-DTPA complex were 1.0, 2.0, 3.0%) were acquired with inversion recovery sequence (TR/TE 5000/20ms, FA 90 degrees, BW 10.42kHz, slice thickness 5mm, FOV 20x20$cm^2$, spatial matrix 256x128). The signal at TI was given as $S(TI)=M_0(1-2\exp(-TI/T1))$…(1) . Then T1 value could be obtained by fitting the mean MR signal intensity of a selected region of Gd-DTPA. T1 could be calculated from a two parameters fit given $M_0$ and $TI_0$ when $S(TI)$ became zero. Then $TI_0 = -\ln(1/2)T1=0.69315\ T1$…(2).

The experiment of catheter tracking was performed using the stereoscopic projection method using the vessel model (silicon tube: inner diameter was 10mm and joints made from polycarbonate). Stereoscopic images using our gradient-echo-based pulse sequence in which two thick slice with slightly different oblique angles were acquired each four seconds with a spoiled gradient echo sequence (TR/TE 50/12ms, FA 60degrees, BW 10.42kHz, slice thickness 10mm, FOV 20x20$cm^2$ spatial matrix 256x128, accumulation 1 and oblique angle between two images 20 degrees ). Three dimensional locations of the Gd-DTPA polymer markers were reconstructed from the extracted points on the two slabs so that the projected marker image should lie in the cross point of the projection lines in the two slabs. The image centers of the next images were set to the calculated points of Gd-DTPA polymer marker using the real-time MR control system.

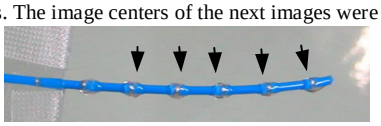

**Figure 1** The catheter coated by Gd-DTPA polymer ink (after swelling)

**Results** Figure 2(a) shows the coronal images of the Gd-DTPA polymer samples and figure 2(b) shows the signal to noise ratio of each samples. As shown in figure 2(b), the optical content ratio of Gd-DTPA complex should be from 1 to 3 percentage of each coating thickness. Figure 3 shows the MR signal intensity of selected regions of Gd-DTPA as a function of TI. According to figure 3 and the formula (2), the T1 values of each contents ratio were calculated as 1307ms (1%), 1084ms (2%) and 1069ms (3%). And figure 4 shows the tracking images acquired using the stereoscopic projection method.

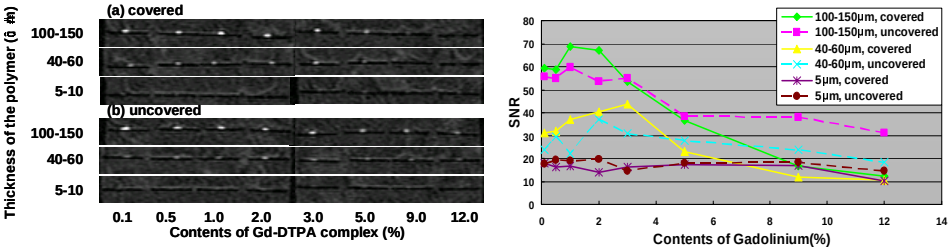


**Figure 2** (a) The coronal images of the polymer-absorbed Gd-DTPA complex dipped into the saline for 21 days. (b) signal to noise ratio of each samples as a function of a contents of Gd-DTPA complex

**Discussions and Conclusions** We had optimized the contents ratio of the Gd-DTPA complex to the polymer and the coating thickness on the catheter. Additionally, we calculated the T1 value of the Gd-DTPA polymer using the inversion-recovery method. According to the experiment of catheter tracking with the stereoscopic projection method, we had shown the developed Gd-DTPA polymer ink seemed to be very useful for visualization of catheter so that periodical dark-bright pattern was very clearly on the MR images. The Gd-DTPA polymer ink could be expected to coat other interventional devices (e.g. endoscope, ablation needle...). However it took long time that the polymer swelled to become visible on the MR images. Once the polymer swelled enough, the visibility of the Gd-DTPA polymer would be covered long periods. The signal to noise ratio of the Gd-DTPA polymer marker became higher as the coating thickness became large. However, in contrast, the thickness should be thinner as far as possible in the view of clinical use. For more sophistication of the marker, we should consider the strength of the covering polymer and sterilization of the covered catheter polymer for clinical use.

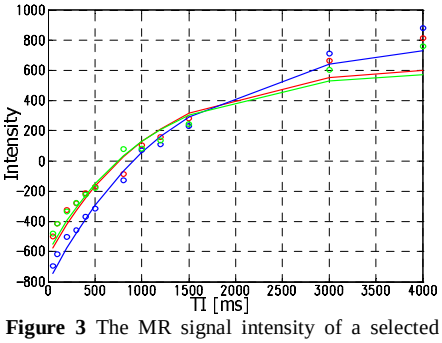


**Figure 3** The MR signal intensity of a selected region of Gd-DTPA of each sample as a function of TI. Circle points are the mean MR signal intensity of a selected region of Gd-DTPA. Solid lines are the function fitted the mean MR signal intensity to formula (2).

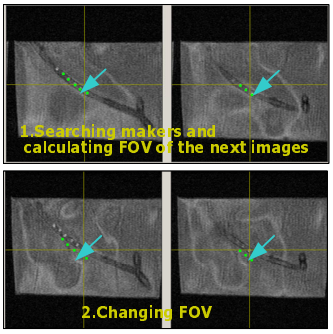


**Figure 4** The example of the catheter tracking. The cross cursor points are the center of the image. Green points are extracted markers. Arrows are the position of the catheter tip.

**Acknowledgement** This work was supported by Medical and Engineering Cooperative Research Project (1999 - 2004) of New Energy and Industrial Technology Development Organization (NEDO), Japan.

**References**

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