Marking Technique for "Bamboo" Tracking Catheter in MR Guided Intervention

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Introduction Real-time MR guided intervention requires catheters visualization and automated scan plane positioning. In this study, we have developed a novel catheter visualization technique called "bamboo catheter" which utilizes a periodical dark-bright pattern suitable for filtering out from the tissue signal in k-space. We examined various marking techniques for the bamboo catheter. Those were (1) a polymer-absorbed Gadolinium complex marker and (2) An electrical marking technique with a very small aperture RF receiver coil or DC current coil. And we demonstrated the effectiveness the proposed bamboo catheter by tracking procedure using stereoscopic projection method [1] to derive the catheter tip.

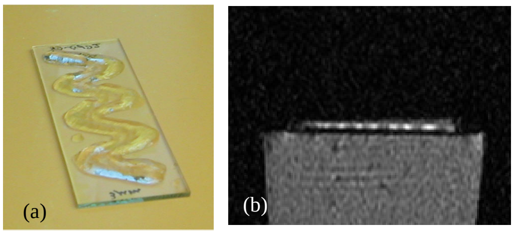

Figure 1: (a)The swelling polymer embrocated on the grass preparation. (b)MR image of the Gadolinium polymer embrocated on the grass preparation in the saline bath on agar. The contrast effect of catheter to saline was 219%

Method The developed polymer which absorbed the Gadolinium complex was embrocated on a grass preparation as shown in Figure 1(a). The content ratio of Gadolinium complex to the polymer was 9 %. There was no MR signal when the polymer was dry. When the catheter was dipped into saline, the polymer absorbed saline and Gadolinium complex enhanced signal from proton. The polymer-absorbed Gadolinium complex was dipped into saline and the image was collected after five minutes (shown in Figure 1(b)). The image was of a Spoiled Gradient Echo (SPGR) sequence (27 ms TR, 10 ms TE 60^o flip angle, 10.4 kHz bandwidth, 10mm slice thickness, 24 cm FOV, 256x128 image matrix and 1 NEX).

Figure 2 shows a prototype catheter made with of fluorine resin heat shrinkage tube (1.3mm diameter, shrinkaged). The components of the coil were 10 elements. Each element on the catheter was made with 2 turns of 0.1mm cooper wire. The elements were spaced with 7 mm interval. The lead track was twisted cooper wire and tuning/matching circuits were 40 cm far from coils. In Figure 3, (a) shows an image acquired with the catheter coil and (b) shows superimpose image with a grass phantom that the catheter was inserted. The images were of a SPGR sequence (50 ms TR, 20 ms TE, 10 degree flip angle, 6.94kHz bandwidth, 10mm slice thickness, 24 cm FOV, 256x128 image matrix and 1 NEX).

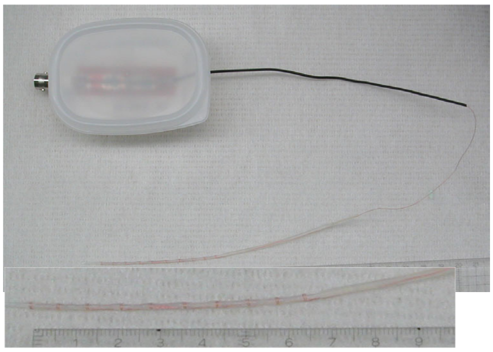

Figure 2: Tracking coil. Tuning/matching circuits are in the seal box.

A periodical dark-bright pattern was shown in the each image. Bright objects seemed like bamboo joints. The intensity of pixels at bamboo joints was higher than the intensity of surrounding pixels. In order to extract the bright objects of bamboo joints, a threshold was applied to all pixels of the image. However, the extracted bright objects might include not only the polymer-absorbed Gadolinium complex but also noise or other objects. The bamboo joints made of coils or the polymer-absorbed Gadolinium complex had same interval so that the bamboo joints were extracted by searching the object sequence that had same interval. An endmost object of the sequence was expected the tip of the catheter. The sophisticated method was applied when bamboo joint and surrounding organs overlapped each other so that bamboo joints could not be extracted that simple method. Band-path filter (frequency was of bamboo joints) was applied to the tissue signal k-space image so that bamboo joints in the Fourier transferred image were enhanced [2]. After that the simple extracting method with threshold was applied on the filtered image.

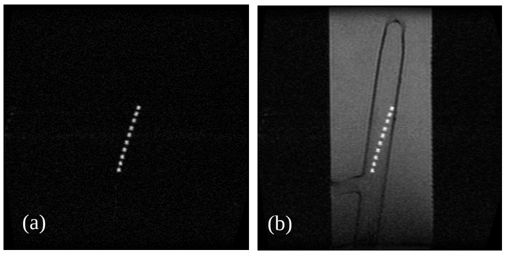

Figure3: MR images of the tracking coil. (a) The MR image acquired using tracking coil. (b) Superimpose image with a grass phantom.

Three-dimensional information of the catheter tip was acquired by stereoscopic projection method [1]. The stereoscopic images were acquired using our gradient-echo-based pulse sequence in which two thick slices with slightly different oblique angles were obtained. The tracking software had not only image processing part such as extracting a catheter tip, but also real time control capability to update necessary imaging parameters such as image center during the interventional procedures to prevent missing of catheter within the field of view and to maintain high image fidelity. If the three-dimensional catheter tip location would deviate from the slices, imaging center of each image was automatically updated to the coordinate of the catheter tip.

Results The experiments were in opened MRI with 0.5T field (Signa 5.7, GE Medical Systems, Inc., Milwaukee, WI, USA).The tracing software examined for prototype catheter which had tracking coil in grass phantom. Figure 4 shows the window layout of the tracking software. In the top window, acquired images were displayed in real-time. Tracking images which acquired with slightly different oblique angle were picked up in the bottom left window and a catheter tip was searched by stereoscopic projection method. The FOV center of the next image was changed to the coordinate of the catheter tip by real-time control imaging workstation part (bottom right window).

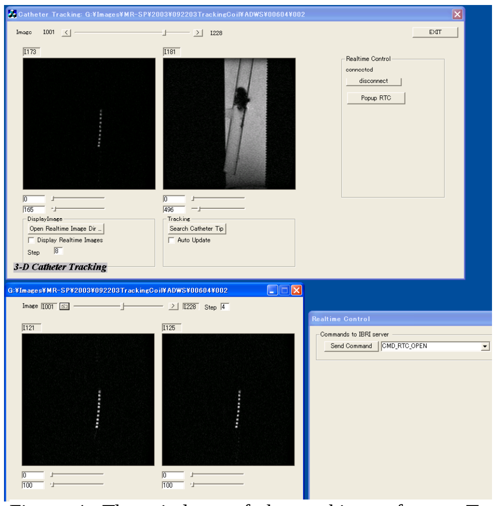

Figure 4: The windows of the tracking software. Top window shows acquired image in real-time. Bottom left is the working window of stereo matching. Bottom right window is the real-time control of imaging workstation.

Discussion Periodical dark-bright patterns were visualized clearly on the MR images as shown in Figure 1(b) and Figure 3. A dark-bright pattern with an electrical marking technique with a very small aperture RF receiver coil was very clearly projected on the MR image. The catheter tip was precisely extracted and reconstructed into three-dimensional coordinate. Therefore the prototype catheter with a RF receiver coil was seemed to be useful for catheter tracking in MR intervention. The polymer-absorbed Gadolinium complex was also projected very clearly on the MR image. The "bamboo catheter" technique was expected for clinical feasibility if the marking technique would be implemented to catheters in clinical use.

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References

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