Local Refinement for Automatic Probe Detection in 3T MRI

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Purpose: The purpose of this study is to develop an accurate and robust approach for automatic detection of multiple 3D probes in 3T abdominal HASTE images obtained during MRI-guided cryoablation. The detected probes can be used to guide automatic iceball segmentation[1,2] during the freeze cycles of the procedure.

Methods: This work represents a significant improvement of our previous 3D probe localization method[2,3]. The proposed approach has two phases. In the first phase, an initial 2D line strip segment is localized in one slice (*S*) of a 3D slicewise acquisition to represent an approximate location of the 3D probes. We introduce a new template to model the probe artifact, as shown in Fig.1, where *L* is the probe length. Let $\Omega_1=\{R_1 \cup R_3 \cup R_5\}$ and $\Omega_2=\{R_2 \cup R_4 \cup R_6\}$, and R_1, e.g., represents region 1 in Fig.1. We search throughout *S* to locate a place, as shown in Fig.2a, where the *p*-value of a one-tailed *t*-test between intensities in Ω_1 and Ω_2 is minimum, since we assume the mean intensity in Ω_1 is less than that in Ω_2. The initial 2D line is then refined locally through either a "push-in" or a "pull-out" step to better align the end of the initial 2D line with the skin entry site in the image. Similar as in the previous step, the process iteratively updated the *p*-value with $\Omega_1=\{R_3 \text{ (or } R_5)\}$ and $\Omega_2=\{R_4 \text{ (or } R_6)\}$, while moving the initial 2D line toward the correct direction with small step size, until a certain threshold of *p*-value is met. Fig.2b shows initial 2D line after pull-out. Finally in this phase, a circular sector-shaped region of interest (ROI) is created automatically according to the initial 2D line, as illustrated in Fig.3c. In the second phase, multiple 3D probes are detected within the ROI using the 3D Hough Transform[4].

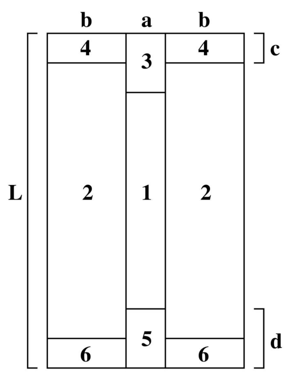

Fig.1 Search template

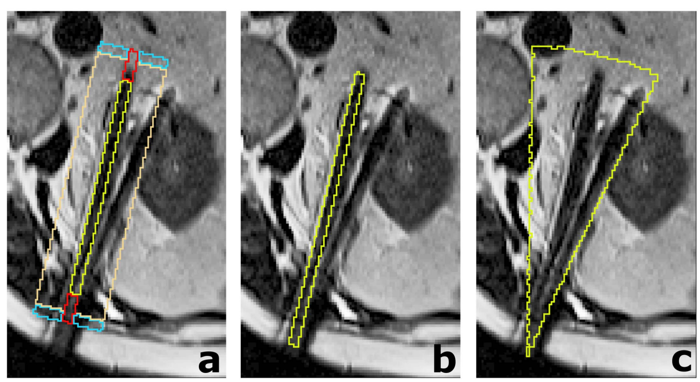

Fig.2 Local refinement and ROI creation

We tested our automatic probe detection method retrospectively based on images acquired from 13 MRI-guided kidney tumor cryoablation procedures, which were performed using a 3Tesla wide-bore MRI scanner (Siemens Verio; Erlangen, Germany) and axial T2-weighted breath-hold half-Fourier acquisition single shot turbo spin echo (HASTE) sequence. The automatically detected 3D probes were compared to manually labeled 3D probes in the baseline scans (the scans obtained just before freezing), using three metrics: Euclidean distance between probe tips, differences in elevation angle θ, and azimuth angle φ. Angles θ and φ uniquely determine the direction of probe axis in 3D space.

Results: Our automatic probe detection method succeeds in detection of an accurate initial 2D line in 12 of the 13 cases. Of the 39 probes of the 12 successful cases (each case may use 2-5 probes), the mean distance between probe tips is 5.3±3.9 mm (average tumor diameter 35 mm; average probe length 115 mm); the mean differences in θ and φ are 2.9±2.8° and 1.8±1.3°, respectively. Our approach reduces the mean error distance between probe tips by more than 40%, compared to the previous approach[2]. The average computational time is 90 s, whereas the execution time of manual labeling is 2-5 min. It also shows high accuracy and robustness in the automatic iceball segmentation[1,2] , if guided by the detected probes using the proposed approach.

Conclusion: Our automated probe detection method with local refinement is promising to replace manual labeling of probes during the procedure. It can be immediately applied to practical use to guide the 3D iceball segmentation in real-time during the freeze cycles of the cryoablation therapy.

References: **1**. Liu X, Tuncali K, Wells WM III, Morrison P, Zientara GP. Fully automatic 3D segmentation of iceball for image-guided cryoablation. Proc. IEEE Conf Engrg Med Bio 2012; 2327-30. **2.** Liu X, Tuncali K, Wells WM III, Zientara GP. Automatic 3D probe localization and iceball segmentation for MRI-guided kidney cryoablation. Proc. 21st Ann Mtg ISMRM 2013, 1821.
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