Rapid Entry Point Localization for Percutaneous Interventions

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Introduction:

Recent open and wide bore scanners, combined with the advantages inherent to MR imaging, have led to an increased interest in using MR for guidance of minimally invasive percutaneous interventions like aspiration, biopsy, sclerotherapy, targeted drug delivery and thermal ablation [1-6]. All of these procedures require the identification of a skin entry site for needle placement. Even though this sounds straightforward, it is often a time-consuming process as the entry site is usually identified in an iterative fashion under real-time imaging using a fingertip or water-filled syringe [1-4]. In this study, a method is presented to rapidly, accurately, and reproducibly localize the skin entry site without the need for additional imaging or hardware.

Methods:

The first step of any percutaneous needle interventions is to plan the needle trajectory. Thus, a planning application was developed that allows trajectory definition using a highly resolved 3D dataset (Fig. 3A). The 3D coordinates of the prescribed entry point (e_x,e_y,e_z) can be used for precise physical localization of the entry site on the patient's skin by utilizing the built-in landmark-laser (Fig. 1) and image processing methods.

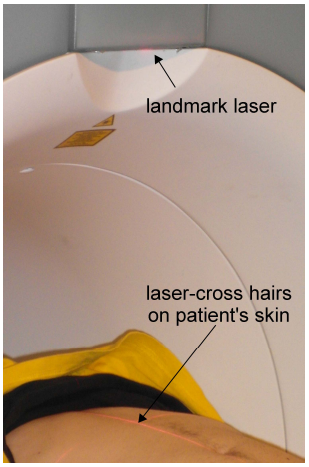

Fig. 1. *Use of built-in landmark laser for physical entry point localization.*

<u>*Superior-inferior localization*</u> is performed by translating the MR scanner table so that the landmark laser delineates the axial slice location corresponding to the entry point. The required table movement t_{move} is calculated by

$$t_{move} = d_{iso,laser} + t_{curr\ pos} + \begin{cases} e_z \\ -e_z \end{cases} \quad patient \quad registered \quad \begin{cases} head \\ feet \end{cases} \quad first$$

where $d_{iso,laser}$ is the distance between the laser light of the MR scanner and the isocenter of the magnet, $t_{curr\ pos}$ is the current table position and e_z the z-coordinate of the planned entry point. Two cases need to be distinguished as the spatial information encoded in the DICOM image header is based on the patient-centered coordinate system. Thus, the coordinate system changes with respect to patient registration.

<u>*Lateral localization:*</u> Having moved the table by t_{move}, the landmark laser light is switched on and the remaining step is to measure the L-R offset from the laser cross-hairs (Fig. 1) using an MR-compatible measuring tape. The L-R offset is calculated using two image processing steps. First, the object in the axial MPR of the planning dataset corresponding to the entry point is segmented using the minimum error thresholding technique [7] (Fig. 2A). Second, a curved line is generated along the edge of the thresholded object from the entry point to the zero x coordinate which corresponds to the lateral position of the laser light cross hairs (Fig. 2B). The length of this curve defines the L-R offset.

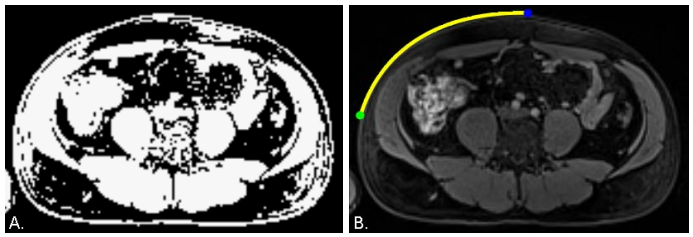

Fig 2. *Axial slice corresponding to the skin entry site. (A) Threshold image used to identify the patient's skin. (B) Calculated curve (yellow) from the planned entry point (green) to the zero x coordinate (blue) defining the L-R offset.*

<u>*Validation:*</u> For validation of the proposed entry point localization method, a volunteer study was performed on 1.5T MR scanner (Siemens MAGNETOM Avanto). 20 entry sites were planned using a high resolution 3D dataset acquired under breath-hold conditions (VIBE: TR/ TE 4.74/2.38 ms, flip-angle 10°, field-of-view 261 x 380mm, matrix 110 x 160, slice thickness 2mm). Each entry point was localized on the volunteer's skin with the proposed approach and a fish-oil capsule was placed on the identified site. For verification of correct entry point localization, two imaging planes were prescribed along the planned trajectory orthogonal to each other using an automatic slice alignment approach. The fish-oil capsule was correctly placed if it could be seen in both slices (see Fig. 3B).

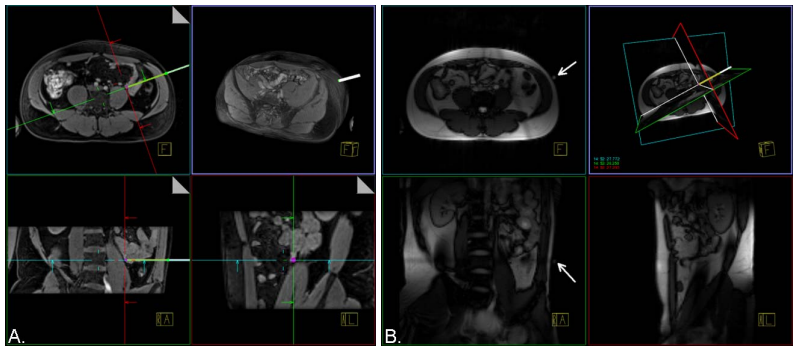

Fig 3. *(A) Planning application used to define the trajectory by setting entry and target points in MPR planes. (B) Verification imaging slices aligned along the planned trajectory confirm correct positioning of fish-oil capsule (arrows) at the prescribed entry point.*

Results: The capsule was successfully placed at the planned entry point in 18 out of 20 cases. In the two unsuccessful cases, the capsule could be identified slightly off the planned path in the verification images. A possible explanation for the misplacement might be that the capsule moved between placement and imaging due to poor fixation.

Conclusion: Rapid, accurate and reproducible skin entry site localization is possible using only the scanner's landmark laser and image processing methods. This technique eliminates the need for additional entry point localization imaging and promises to reduce the overall procedure time. It can be performed on any clinical scanner.

References: [1] Stattaus et al. JMRI, 2008. [2] Fischbach et al. Cardiovasc Intervent Radiol, 2011. [3] Fritz et al. Am J Roentgenol 2009. [4] Weiss et al. JMRI, 2008. [5] Ricke et al. Eur Radiol, 2010. [6] Morrison et al. JMRI, 2008. [7] Kittler et al. Pattern Recognition, 1986.