

Haptic Guidance Platform for MR-guided Cardiac Electrophysiology Therapy

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Target Audience: Scientists and clinicians interested in MR-guided EP and haptic applications in medical surgery.

Purpose: MR-guided cardiac electrophysiological (EP) therapy is a rapidly growing field for treatment of heart rhythm disorders thanks to the advances of cardiac MRI for high-resolution vasculature visualization [1]. T2-weighted and delayed myocardial enhancement MR imaging can serve as luminal, edema, and scar maps for radiofrequency ablation (RFA). Despite improved cardiovascular visualization, navigation and manipulation of a flexible EP catheter can be challenging to cardiac electrophysiologists due to the lack of tactile and force feedback at the catheter tip. Perforation of thin vessel walls (e.g the atrium) by excessive force or vaporization of tissue is uncommon, but devastating complication during EP procedures [2]. We hypothesized that a catheter control device with simulating haptic (force and tactile) feeling of the interaction between the cardiovascular structure and catheter tip, could enhance the RFA safety and reliability.

Methods: An MR-conditional haptic software and hardware interface was designed to integrate with the clinically-used catheters and kits in MR-guided EP. **Fig.1a** shows 3D reconstructed MR model of the left atrium (LA). Based on the catheter tip proximity to the margin of target lesion deduced from MR images, two feedbacks – intermittent vibration and resistance force was generated to the operator during the catheter advancement. The haptic feedbacks were rendered from a resistive catheter brake and a shaker with their design shown in **Fig.1.b-d**. Detailed validation was conducted to evaluate the effect of such vibration and force feedback on improved catheter manipulation and lesion RFA. A 7-French EP electroanatomical mapping (EAM) catheter (St Jude Medical, Ltd) was channeled smoothly along the brake unit when the brake was not actuated. When the catheter tip advanced to the margin of the LA model, the catheter brake unit gently resisted to the operator from pushing the catheter forward (**Fig.1b**), until the catheter was completely locked by the brake to prevent perforation.

The shaker unit consists of an unbalanced-weighted rotor (**Fig. 1c**), whose rotation speed was pneumatically controlled to generate various levels of vibration, which signaled to the operator when the catheter tip was close to the pre-defined RFA targets. MR-conditional piezoelectric valves (Hoerbiger, Ltd) were used to regulate the pressure supplied to both the brake and vibration units. Driving electronics were placed in an aluminum box for radiofrequency (RF) shielding.

Results and Discussions: EP RFA task was simulated to investigate the clinical potential of our proposed interface. Volunteer catheter operators ($N=12$) were invited to complete a set of RFA tasks with and without haptic feedback provided. Given 5-min time, each subject was required to manipulate the catheter tip in contact with the pre-defined RFA targets at pulmonary vein (**Fig. 1a**). Six performances indexes were introduced to demonstrate the safety, accuracy, and the sufficiency of lesions formed by RFA. **Fig. 2** depicts the quantitative results in detail which shows the significant improvement (at least >30%) among the indices. Wilcoxon rank sum test was also performed due to the limited number of subjects involved. It results in significantly small p -values of two indices relevant to RFA safety.

Conclusion: The proposed haptic interface shows improvement in safety, accuracy and RFA sufficiency during EP catheter manipulation.
References: [1] CE Saikus, JACC Img.'09; [2] Dipen Shah, ESC'10

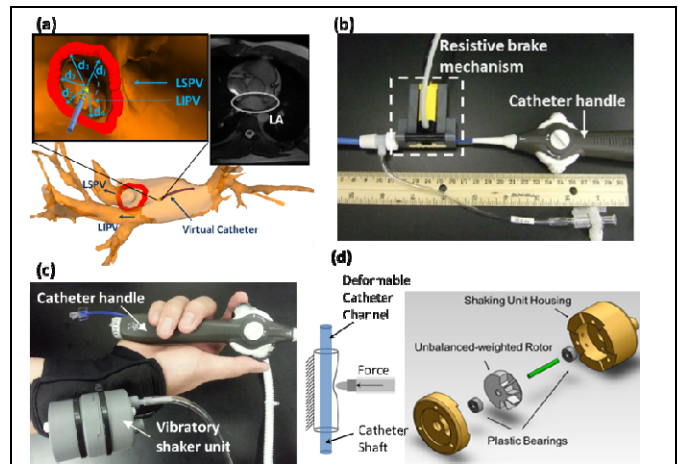


Fig. 1 (a) Cardiac real time MR image. Red circle is the predefined RFA targets for distance calculation (LSPV: left superior pulmonary vein; LIPV: left inferior pulmonary vein; LA: left atrium); (b-c) haptic interface actuator working mechanism; (d) Working mechanism of the haptic actuators

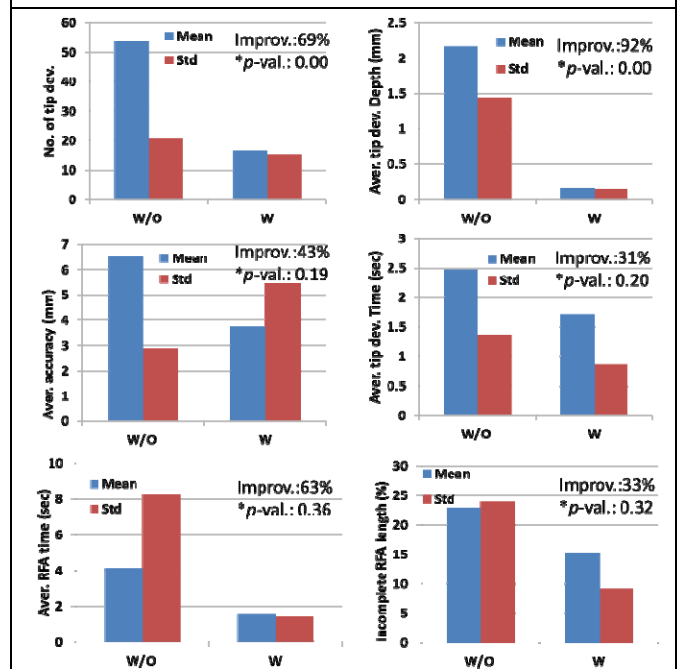


Fig. 2 RFA catheterization performances without and with haptic interface