Developments in Endovascular Multi-Mode Coil Design: In Vivo Swine Study

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Introduction: The multi-mode coil [1], constructed on an endovascular catheter, enables three functionalities in a single device that is connected to the MR scanner through a single coaxial cable. These are 1) accurate tracking of the position of the distal tip of the catheter, 2) detection of the catheter orientation by visualizing a small length of the catheter and 3) high sensitivity, limited field of view endovascular imaging. While the first two functionalities enable accurate MR guidance of the catheter to the target region, the third functionality may be used in conjunction with external imaging coils to provide high resolution insets of the target region in the context of a roadmap image or to enhance the SNR of the target region in the combined image. Our previous work has detailed the principle of operation of the multi-mode coil and demonstrated its use in *ex vivo* studies. In this *in vivo* swine study, we add a unipolar RF ablation tip to the distal end of the catheter and demonstrate real time MR guidance of the multi-mode coil into the left ventricle of the swine heart, where ablation is performed.

Methods: All imaging experiments were performed on a 1.5T MRI scanner (Signa, GE Healthcare, Waukesha, WI). A commercial 4 channel cardiac coil was used to obtain roadmap images. A multi-mode coil (figure 1a) constructed at the distal end of a modified 6F double lumen balloon catheter using 36 gauge wire was used to guide the catheter through the vasculature to the target region and also obtain limited FOV endovascular images. A machined brass ablation electrode was placed at the distal tip of the catheter and connected to a commercial RF generator via a 22 AWG magnet wire that was routed through the balloon lumen of the catheter. All coils were interfaced to the scanner via a modified 8-channel connector. A swine model was used for imaging experiments, for which all necessary approvals were obtained. First, the multi-mode catheter was introduced into the femoral artery. Using a real time imaging environment (rtHawk, Heartvista, CA) [2] and the unique signal profile of the multi-mode coil, the catheter was placed near the aortic arch and its progress through the descending aorta was tracked using the Vurtigo (Sunnybrook, Canada) visualization platform. An image (2D FIESTA, 256x256, FOV=18cm, TR/TE=6.9/1.3ms, NEX=4, FA=45^{o}) of the aortic wall was obtained using the multi-mode coil. Next, the multi-mode catheter was introduced into the carotid artery and guided into the left ventricle via the ascending aorta using rtHawk and Vurtigo as above. The catheter was advanced inside the left ventricle until the ablation tip was in firm contact with the ventricular wall. 60 watts of ablative power at 450 kHz was delivered to the tissue via the ablation tip. The animal was then sacrificed as per the approved protocol and the heart, harvested. The ablation region was then visually inspected by dissecting the left ventricle.

Results and Discussion: Figure 1b shows the spatial signal profile of the multi-mode coil. The narrow, dominant peak is due to the tracking solenoid and the broad signal profile is due to the imaging loop. Figure 2 is a series of images that shows the progress of the multi-mode catheter along the descending aorta, towards the aortic arch. The multi-mode coil signal is superimposed onto the dynamically updated roadmap image obtained with the external coil and enables visualization of a small length (4 cm) of the distal end of the catheter, displaying its orientation. In figure 3a, a high resolution image of the aortic wall obtained with the multimode coil is shown as a magnified inset of a low resolution image of the same slice. Alternatively, the multi-mode coil image may be used to enhance the SNR of a ROI in a combined image obtained using both, the external and multi-mode coils. Figure 4a shows MR guidance of the multi-mode catheter into the swine left ventricle where tissue is ablated. The wireless marker mode of operation of the multi-mode coil is shown in figure 4b, which is an image obtained with the external coil alone. A picture of the ablated tissue after dissection of the excised heart is shown in figure 5. Charring indicates the use of excessive ablative power.

Conclusions: We have demonstrated the operation of the multi-mode coil and all its functionalities *in vivo*, viz. 1) tip tracking, 2) high resolution imaging, 3) wireless marker tracking and 4) RF ablation capability.

References: [1] Kurpad KN *et al*, JMRI v33(4), p995, [2] Unal *et al*, ISMRM 2012 (submitted)

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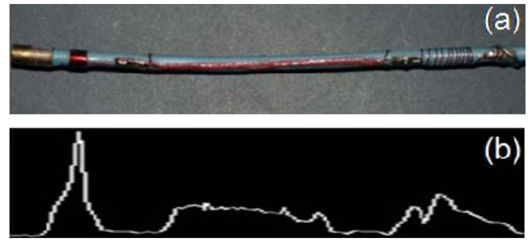

FIG. 1 Picture of the multi-mode coil with the ablation tip (a) and its signal profile (b).

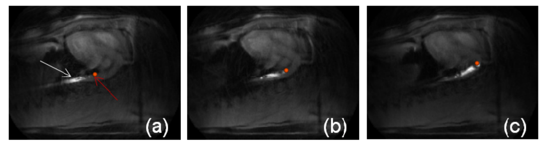

FIG. 2 Series of images showing the progress of the multi-mode catheter through the descending aorta (a-c). The red arrow in (a) indicates the software dot that is placed on the tracking peak. The white arrow indicates the multi-mode coil signal superimposed on the dynamically obtained roadmap images.

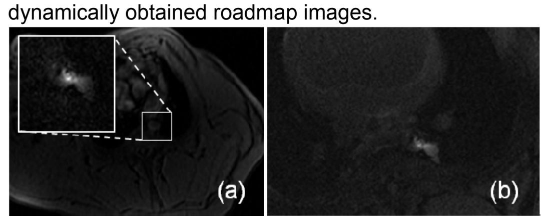

FIG. 3 A magnified high resolution (0.7mm) image of the target region (inset) obtained using the multi-mode coil (a). The multi-mode coil may also be used to enhance SNR of a target region.

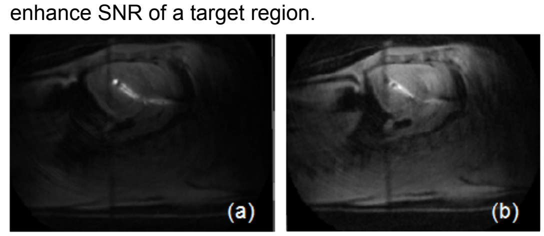

FIG. 4 The multi-mode coil image superimposed on the roadmap showing position of the distal end of the catheter inside the left ventricle (a). Multi-mode coil as a wireless marker in an image obtained with the external coil alone.

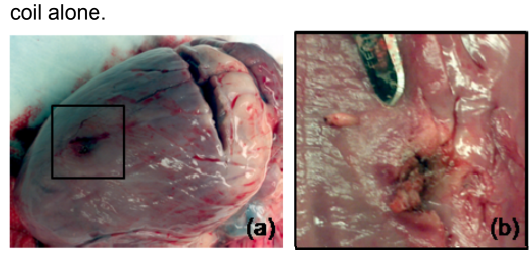

FIG. 5 Picture of the ablated tissue enclosed in the black box (a) and a picture of the same from the dissected left ventricle (b).