Real-Time Non-Subtraction Thermal Ablation Monitoring In-Vivo Using RE-TOSSI

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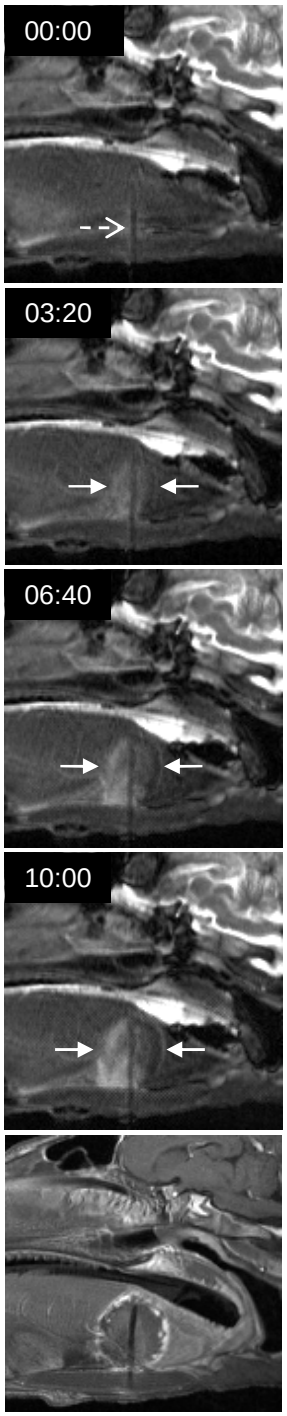
Introduction: Compared to CT and ultrasound, real-time MRI provides improved thermotherapy monitoring capability (1). However, many techniques (e.g. PRF thermometry) may employ some form of image subtraction, involving a baseline pre-therapy image. Subject motion and tissue deformation due to coagulation can severely distort these techniques (2). Self-referenced methods require a large area of tissue around the ablation for polynomial fitting and can't be used when tissue cooling is applied to sensitive structures. RE-TOSSI (3), a new SSFP based pulse sequence, is shown to directly visualize thermal ablation evolution in vivo in real time and eliminate the need for baseline subtraction in thermal therapy monitoring.

Methods: 26 laser ablations were performed in the paraspinal muscle of 6 and tongue base (4) of 5 asymptomatic anesthetized pigs in a short and wide bore 1.5 T scanner (Magnetom Espree, Siemens, Erlangen). Chilled water was circulated over the tongue to protect the mucosa. A water cooled Nd:YAG laser fiber with a 2-cm diffuser tip was guided to the target using a tri-orthogonal plane TrueFISP guidance sequence (5). Ablations were performed at 19 W for 400 s. Monitoring was performed for 600 s with RE-TOSSI (FOV = 240x240 mm^2, matrix 256x256, THK = 5 mm, PF = 6/8, TR = 6.3 ms, TEeff = 456 ms, FA = 50°, BW = 300 Hz/Px, T2 optimization factor = 90 msec, 15 readouts per antiparallel block, λ = 0.35, Tacq = 1.2 s followed by 3.8 s pause for magnetization relaxation) as well as other standard sequences given in table 1. 10 cc of Optimark (Mallinckrodt, St. Louis, USA) was injected and post contrast T1-weighted SE images were acquired (TE/TR = 12 ms/539 ms).

Results: Figure 1 shows several RE-TOSSI monitoring images as well as a post-ablation, post-contrast image for lesion verification. Figure 2 shows the results of manually segmented ablation lesion area from RE-TOSSI monitoring images. The ablated zone to adjacent muscle contrast-to-noise ratio (CNR) was calculated at mid and end ablation as well as end monitoring; the resulting average CNR values are presented in table 1.

Discussion: RE-TOSSI is a completely novel method for near-real-time IMRI thermal therapy monitoring that can clearly and accurately identify ablated muscle tissue in-vivo without baseline subtraction. The method eliminates T1 dependence of the SSFP signal evolution and provides resolution enhancement by shaping the signal evolution. The features of the ablation lesion time course are similar to previous imaging and modeling results (6) yet at higher temporo-spatial resolution and increased SNR. RE-TOSSI provides high lesion conspicuity as measured by CNR compared to the other standard sequences. Although HASTE provided a higher CNR, the spatial resolution was significantly degraded (blurring). Possible explanations for the higher CNR in the tongue base compared to the paraspinal muscle ablations include increased sensitivity using the head matrix coil as opposed to spine and body matrix coils as well as differences in tissue perfusion. Past research has demonstrated the relationship between the hyperintense rim around the zone of ablation and tissue destruction in T2 weighted IMRI studies (1) in the tongue, bone, kidney, liver, and brain. Therefore, we believe that intra-procedural monitoring of the zone of ablation should be performed with the new RE-TOSSI acquisition, unless thermal dose mapping proves more useful than direct visualization in the future.



Left: Fig. 1. Four (of 120) sagittal RE-TOSSI monitoring frames of laser tongue base ablation in-vivo. Times of acquisition at top left (min:s) correspond to: treatment onset, midway through ablation, end of laser treatment, and end of monitoring. Dashed arrow demarcates laser fiber, regular arrows demarcate ablation boundaries. **Bottom:** Post ablation contrast enhanced T1w SE image (22 min post ablation).

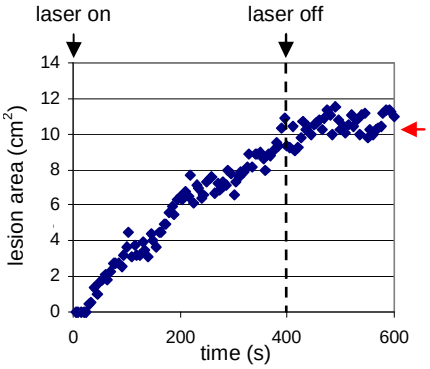


Fig. 2. Estimate of ablated lesion evolution from manually segmented RE-TOSSI monitoring images (fig 1). Red arrow denotes final ablation lesion area (10.1 cm^2) from post contrast T1w SE image (fig 1, bottom).

Table 1. In-vivo lesion to muscle contrast-to-noise ratio (CNR) comparison. TE/TR in ms/ms.

Sequence	CNR	n	TE/TR
tongue			
RE-TOSSI	16.1 ± 4.3	2	3.15/6.3
TrueFISP	2.3 ± 9.1	3	5.4/10.8
paraspinal			
HASTE	8.4 ± 2.7	2	70/3000
RE-TOSSI	4.1 ± 1.5	4	3.15/6.3
T2w TSE	1.9 ± 1.1	2	111/2000
TrueFISP	0.7 ± 0.6	1	3.15/6.3
TrueFISP	0.4 ± 0.4	3	2.2/4.4
FLASH	– 0.5 ± 0.7	5	4.1/8.3
FLASH	– 0.6 ± 1.0	3	10/20
T1w SE	– 1.6 ± 0.8	1	12/300

Acknowledgements: This work was supported in part by Siemens Medical Solutions as well as NIH F30HL094002.

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