Simultaneous MR Temperature Mapping and Radiofrequency Ablation

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Synopsis

Magnetic resonance imaging and temperature mapping can be difficult to perform concurrently with radio-frequency (RF) ablation due to interference between the RF generator and the MR imaging system. A commercially available RF generator system has been modified with a filtering and isolation network to allow simultaneous RF treatment and MR proton resonance frequency (PRF) shift temperature mapping at the higher RF powers needed for many types of ablative procedures.

Introduction

Radio-frequency (RF) ablation techniques are widely used for the treatment of malignancies, usually under CT and/or ultrasound guidance. The use of magnetic resonance imaging is desirable for its ability to visualize soft tissue changes and monitor tissue temperature during treatment. However, imaging is often complicated by interference from the RF generator. MR imaging is often only performed prior to and immediately following treatment, or intermittently as treatment is stopped during the procedure. Investigators have previously used filtering [1,2] as a means of suppressing interference, but at low RF power (up to 15W [2]). A custom-built switching device has also been used which multiplexes MR imaging with the RF generator operation [3]. The purpose of this work is to describe a system which allows the use of RF ablation at high RF generator power simultaneously with continuous MR imaging and temperature mapping in an ex vivo liver phantom.

Methods

Magnetic resonance imaging and radio-frequency (RF) ablation tests were performed on a 0.5T interventional MR system (Signa SP, GE Medical Systems, Milwaukee WI), which was fully RF-shielded. A radio-frequency generator (RF3000, Boston Scientific Corporation, San Jose CA) was placed outside the room, and modified to eliminate interference at frequencies near those detected in imaging. The output of the RF source from the generator was passed through a filter network, which can be approximated as a low-pass LC filter with a cutoff frequency at 1.5 MHz (Fig. 1). The signal is then sent to a filter and isolation network in a shielding box firmly attached to the RF shielding pass-through panel of the MRI suite. The band-pass filter in this shielded box has a pass frequency at 460 kHz, which is the frequency of the RF generator. An umbrella-shaped needle electrode (LeVeen, Boston Scientific Corporation, San Jose CA) was attached to the output of the filter/isolation network inside the magnet room, and inserted into an ex vivo bovine liver phantom. Although just one path is shown in the simplified circuit of Figure 1, four paths are actually used with the four return electrodes connected to a conductive plate on the bottom of the tissue sample.

MR imaging was performed with a 2D gradient-echo sequence (TR/TE/BW = 67ms/27ms/±16kHz) with temperature maps calculated by the proton resonance frequency (PRF) method and displayed in real-time on an offline workstation. Imaging was performed with an unmodified RF generator switched on (i.e. without the isolation and filter network); and switched on with the isolation/filter network in place at 75W for 15 min.

Results

Images acquired with the unmodified RF generator were dominated by interference at frequencies within the acquisition bandwidth, and were uninterpretable. Temperature maps acquired during the application of RF generator power with the filtering and isolation network in place are shown in Figure 2 prior to heating, and at 3.5 min., 6.0 min., and 7.5 min. after the beginning of heating. No noticeable interference was observed in any images during the application of RF generator power.

Discussion

A filtering and isolation network was added to a radio-frequency generator used for RF ablative techniques. RF generator interference in the MR images was essentially eliminated with this system, compared with the use of a standard unfiltered RF generator.

References