Repair of Vascular Defects Using MR Radio Frequency Coagulation

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PURPOSE: Current treatment methods for vascular defects, such as aneurysms, include surgical clipping or endovascular embolization with coils, particles or a coagulable material such as Onyx (Micro Therapeutics Inc.). These methods entail either highly invasive surgery or the introduction of foreign bodies into the patient and the risk of an immune reaction. Previous research has successfully demonstrated ablation of tissue using RF energy harvested from the MR scanner [1]. In this work we present a proof-of-concept for the embolization of aneurysms through scanner-induced coagulation of an albumin protein solution, whose human equivalent is naturally present in blood thus eliminating the possibility of an immune reaction.

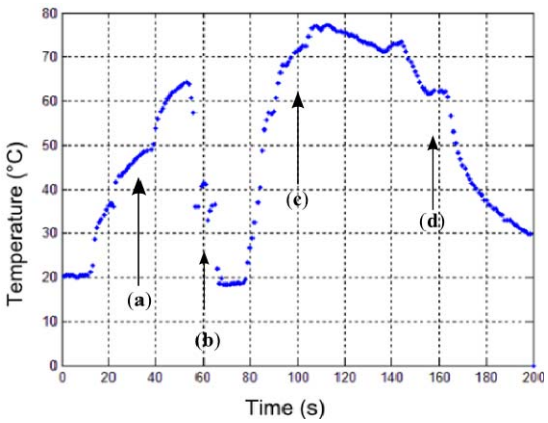

Figure 1: The four stages of the coagulation procedure are shown in this temperature profile. Saline preheating (**a**) was followed by albumin injection (**b**). After coagulation (**c**) the saline was allowed to return to room temperature (**d**). Note the rapid rise of temperature when the injection stops.

METHODS: To demonstrate the feasibility of coagulating albumin via the MR scanner, a phantom was constructed from a 10 mL syringe filled with 0.9% saline. An antenna consisting of a 26 AWG Teflon insulated silver-plated copper wire with a 1.5 cm exposed tip was inserted into the syringe along with a catheter and a fiber-optic thermometer (Neoptix Inc.). A variable RF duty cycle pulse sequence controlled the power deposition and the temperature at the wire tip was sampled every second.

Experiments were performed on a Magnex 15T 130 mm horizontal bore magnet interfaced to a Siemens clinical MR console. The RF "body" coil was a 45 mm ID transmit/receive birdcage. The wire length chosen, 13 cm, was experimentally optimized to yield maximal heating at the tip. In this study we use egg white, containing ~10% ovalbumin, as a cheap alternative to Human Serum Albumin in light of their similar thermal coagulation properties.

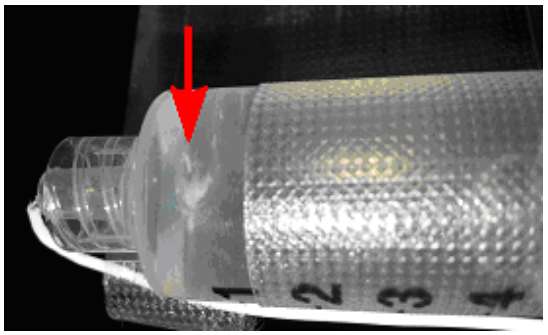

Figure 2: Syringe phantom with coagulated albumin (arrow). The white wire is the RF antenna. The fiber optic temperature sensor is inside the phantom.

RESULTS: To demonstrate RF coagulation, the pulse sequence was started and the wire tip temperature was allowed to reach 60 °C (Figure 1a), at which point albumin solution was injected into the saline syringe via the catheter. The inrush of cool solution resulted in a momentary drop in temperature at the antenna tip, followed by resumed temperature increase (Figure 1b) when the injection is stopped (Figure 1c). The heating was continued for an additional 2 minutes, following which the sequence was stopped and the coagulum allowed to cool (Figure 1c). The phantom was then removed and examined. The small volume of nonadherent coagulated protein, formed at the antenna tip, is shown in Figure 2 (arrow).

DISCUSSION and CONCLUSION: A novel method for treatment of aneurysms by coagulation of a protein solution is described and a simple demonstration carried out successfully. Analytical computation of the resonant length of the antenna is difficult due to the various media (dielectric constants and conductivities) it passes through and must hence be found experimentally. Numerical FEM simulations and additional experiments under flow conditions with a controlled background temperature are currently being carried out.

REFERENCES: [1] Hue et al., ISMRM 2010