MR Imaging of Thiel Embalmed Human Cadavers

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Abstract: Human cadavers preserved by the Thiel embalming technique [1] retain their natural colours and life-like flexibility, features which are of considerable benefit in teaching of anatomy and related skills, and in research and development of new medical techniques, *e.g.* MR-guided interventions, and devices.

The motivation for the present work is the observed loss of signal and contrast when Thiel-embalmed human cadavers are imaged using clinical MR sequences. Here, we present the results from dual angle B1+ magnitude mapping of Thiel-embalmed human cadavers. Additionally, EM simulations that characterize the radio frequency (RF) penetration in a male human body model (HBM) were carried out for a range of tissue conductivities. The simulations show that RF penetration issues begin to surface for values of electrical conductivity as low as 2.6 S/m. The DC conductivity of the embalming fluids is within the range 5 to 10 S/m and hence is the most likely explanation for the observed loss of signal and contrast. All MR imaging was carried out on a medical GE Signa HDx 1.5T scanner (GE, Milwaukee, WI, USA) using commercially available coils.

Materials and Methods: B1+ mapping: Three Thiel-embalmed human cadavers, one male and two female with an average weight of 70 kg, were imaged in a medical GE Signa HDx 1.5T scanner using GE's 8-channel high definition body array (48 cm S-I coverage). Standard Spoiled Gradient Echo (SPGR) imaging sequence was used to collect a set of images with flip angles α and 2α, respectively while all other sequence parameters were kept the same. The flip angle map, which is an indirect measure of the B1+ field, was calculated as the *arccos* of the ratio of the signal intensities obtained with the above flip angles, as described in [2]. The following imaging parameters were used: TR=8240 ms, TE=3.4 ms, acquisition matrix 256×256; field of view =400 mm, slice thickness=8 mm, bandwidth=122 Hz/pix, flip angles of 30º and 60º. Long TR was used to mitigate undesirable T1-effects in the images.

DC conductivity measurements: DC conductivity measurements of the Thiel embalming fluids were carried out, at room temperature, using a hand-held conductivity meter Eutech 110 (LIA International Ltd. Berkshire RG17 0PP, UK). Calibration of the conductivity probe was carried out using commercially available calibrating fluid with DC conductivity of 11.1 S/m at 20 C. The associated conductivity values for some tissues at 64MHz can be higher than those at DC.

EM modeling: The modeled 16-rung high-pass birdcage (HPBC) RF body coil (dia.= 61.0 cm, length = 62.0 cm) is shielded by a copper shield (dia.= 66.0 cm, length =122.0 cm). The dimensions of the shield and coil are based on typical body coil dimensions. Since our goal is to elucidate the impact of electrical conductivity values on RF penetration of EM fields at 64MHz, the HPBC coils can be excited in the ideal case where appropriate current sources replace all capacitors [3, 4]. The magnitude and phases of the current sources are chosen such that the coils' currents in the imaging mode are recreated. Each current source has the same amplitude (4.0A sinusoid, 64 MHz) and a phase that is dependent on the azimuthal position of the rung it drives, *e.g.*, first and second end-rings have phase values of 0° and 22.5°, respectively. The HBM is positioned such that its heart is located in the middle of the rungs, and its back is 17.5 cm from the furthest rung in the posterior direction.

Results and Discussion: The DC conductivities of two types of fluids, Thiel moist fluid (least concentrated) and Thiel bathing fluid (more concentrated fluid in which the cadavers are submerged while stored) were measured at room temperature and found to be 5.1 and 9.8 S/m, respectively. In Fig 1(a) a flip angle map of a mid-coronal slice through a Thiel-embalmed cadaver (thorax and abdomen) is shown. The calculated flip angles for most of the pixels in the image are well below the intended value of 30º. To test our hypothesis that the high conductivity of the cadavers' tissues is indeed causing the observed loss of signal, the B1+ distributions in a male human model were simulated using xFDTD (Remcom, State College, PA). Figs.1 (b-e) show mid-coronal slices of numerically computed B1+ maps in the visible man model when all water-based tissues are assigned electrical conductivities of 1.0 (close to that of some water-based tissues in a living human at 64MHz), 5.8 (close to that of mild Thiel fluid) and 10.6 S/m (close to that of concentrated Thiel fluid), respectively. The EM simulations demonstrate that increasing the conductivity of the tissues up to the range of the Thiel fluid results in a dramatic loss of transmitted B1+ signal and contrast. There is almost total loss of signal from the thorax for the highest conductivity of 10.6 S/m. The results from the numerical simulations support our hypothesis that the loss of signal and contrast when imaging Thiel cadavers is caused by the high conductivity of the embalming liquids. The effect of signal loss is more pronounced for Spin-Echo (SE) based MR sequences and less pronounced in images obtained using Gradient-Echo (GRE) based sequences. The reason for the worse performance of the SE-based sequences is that they rely on perfect 90 and 180 degree pulses to obtain an image, while GRE-based ones are less sensitive to flip angle imperfections which are inevitably present when imaging highly conductive objects. In addition, SE image intensity is proportional to $\sin^3$(flip angle) while GRE image intensity is proportional to sin(flip angle), which suggests that the diminished flip angles in the core of the cadaver due to RF penetration issues will cause more signal intensity suppression in SE images compared to GRE images.

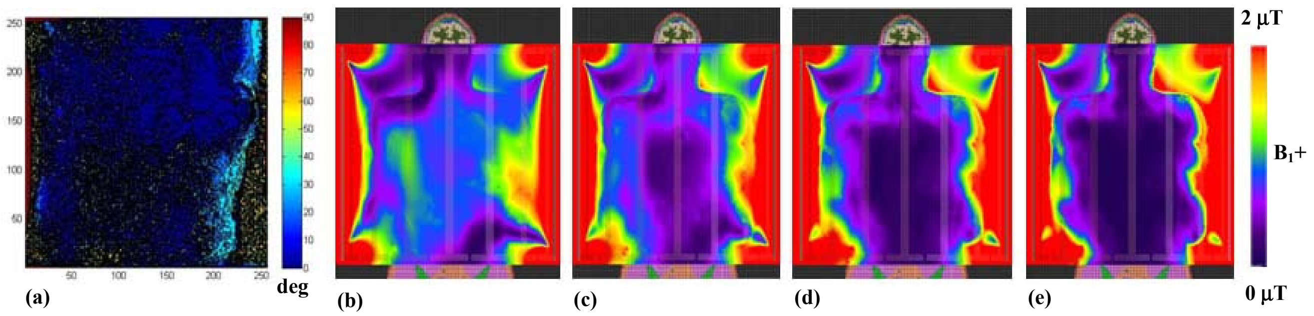

Fig. 1. (a) Flip angle map of a mid-coronal slice through a Thiel-embalmed human cadaver. Intensity levels proportional to flip angle; (b-e) numerical computed B1+ maps for male HBM for electrical conductivities of (b) 1 S/m, (c) 2.6 S/m, (d) 5.8 S/m, and (e) 10.6 S/m

Conclusions: Using computer simulations and MR scans of cadavers, we have demonstrated that the observed loss of signal and contrast when imaging Thiel-embalmed human cadavers could be attributed to the high conductivity of the embalming liquids. We have established that GRE-based MR sequences perform better compared to SE-based ones due largely to the possibility that they are less susceptible to imperfections in the flip angle which are inevitably present when imaging Thiel cadavers.

References:

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