Measurement of Edge Effects in Automatic External Defibrillation Electrodes using Current Density Imaging

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INTRODUCTION: Automatic External Defibrillator (AED) electrodes are flexible surface electrodes used to administer emergency defibrillation procedures. The electrodes used in this study have an elliptical shape with the ends of the long axis cutoff, as in fig. 1. Dimensions of the electrodes used in this study are 13.3 cm x 8.7 cm. A standard AED electrode design has a uniform conductor. Edge effects are known to occur whereby more current flows out of the edge of the electrode than from the central area [1]. An alternative design uses a high impedance perimeter to minimize edge effects [2]. This work describes using the MRI technique, current density imaging (CDI) [3, 4], to measure and compare edge effects of standard and high impedance perimeter "gradient edge" AED electrodes.

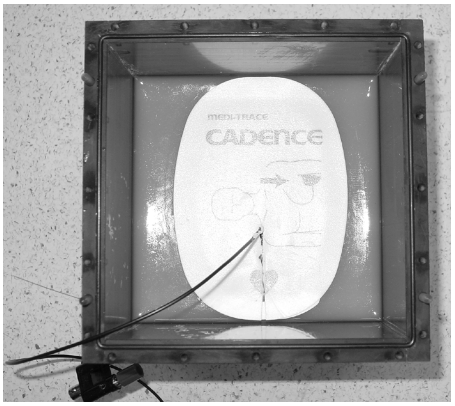

Fig. 1: Cube-shaped phantom partially filled with gel. AED electrode is placed on surface of gel with lead wire attached to center.

METHOD: A cube-shaped phantom with inside dimensions 16.4 x 16.4 x 16.4 cm with removable top and bottom lids was constructed, as in fig. 1. A 5.5 x 10 cm copper electrode was placed on the bottom lid. A gel (2250 mL H_2O, 450 g animal hide gelatin, 20.25 g NaCl, 30 mL Dettol) was poured into the phantom, filling to a 9 cm height. The AED electrode was placed on the top surface of the gel, as in fig. 1. Current pulses of 14 ms duration and 200 mA in amplitude were applied synchronous with the RF and gradient pulses of a spin echo sequence. Imaging was performed on a GE Signa® 1.5T MRI with 1.9 x 1.9 x 3.0 mm voxels using the body receive coil. Two cycles of phase data were acquired and processed into phase difference data. As per the CDI method [4], spatial derivatives of the phase difference data were taken for two orthogonal positions of the phantom and processed into one component of current density. Two AED electrodes were measured. The first electrode was a "solid silver" electrode that has a uniform Ag/AgCl conductor. The second electrode was a "gradient edge" electrode having a high impedance perimeter (Tyco Healthcare Ludlow, Meditrace® Cadence™). Both electrodes had identical dimensions.

RESULTS: One component of the current density was measured in the direction orthogonal to the surface of the electrodes. The CDI measurements for the two electrodes are compared in figs. 2(a) and 2(b). The CDI measurements in figs. 2(a) and 2(b) are located at a depth of 4 mm below the surface of the electrode. Data in the central areas was masked out due low SNR caused by RF shielding effects. The cross-sectional profiles indicated by arrows in figs. 2(a) and 2(b) are plotted in fig. 2(c) for direct comparison of the edge effects of the electrodes.

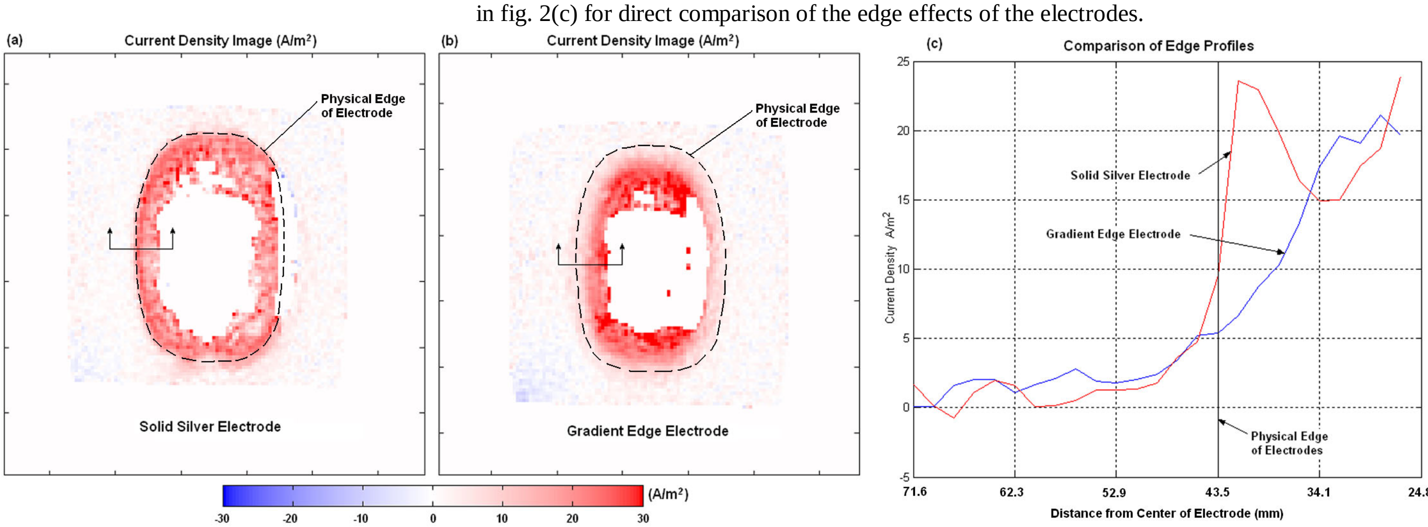

Fig. 2: 4 mm below surface of gel (a) CDI of uniform conductor electrode, (b) CDI of gradient edge electrode and (c) comparison of profile plots.

DISCUSSION: Edge effects of two AED electrode designs were measured and compared. As indicated in [2] by thermal measurement techniques, the edge effect in gradient edge electrodes is less than that of uniform conductor electrodes. At the peak edge value of the uniform "solid silver" conductor in fig. 2(c), the current density value is three times higher than the corresponding value of the gradient edge electrode.

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