# CDII Performance at Low Conductivity Contrast

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**INTRODUCTION**: Current Density Impedance Imaging (CDII) is an imaging technique that can non-invasively measure the conductivity distribution inside a medium[1][2]. Previously, CDII has been successfully employed in both phantom and animal experiments[1][3]. However, the quantitative accuracy of CDII of both experiments remains undetermined due to several limitations. For animal experiments, bio-tissues display a wide range of conductivities at various frequencies; there is no authoritative method for measuring them. For phantom experiments, tissue-mimicking phantoms are very porous and susceptible to ion diffusions, hence sharp and constant contrast of conductivity is hard to maintain[1]. Also, chemical reactions due to high injecting currents through small electrodes potentially add another instability factor to CDII experiments. This abstract presents an experiment that is specifically designed to overcome the aforementioned difficulties. It enables us to quantitatively assess the performance of CDII technique.

**METHOD**: The theoretical basis of CDII technique was described in previous publications[1][2]. Two separate currents, $\mathbf{J}_1$ and $\mathbf{J}_2$, are required to be injected into the subject. Using Current Density Imaging (CDI)[4] technique and a magnetic resonance imaging system, CDII then measures these two current distributions. In regions where $\mathbf{J}_1$ and $\mathbf{J}_2$ are non-parallel, the internal conductivity can be calculated using an explicit equation.
In this experiment, an agar + TX151 gel in saline "popsicle" phantom was used as the imaging subject (see fig. 1). Unlike bio-tissues, conductivities of saline and agar-gel can be easily measured by a four-electrode impedance measuring device (Solartron, Wayne Kerr, IIRC BIS). Different ion concentrations in saline (0.9% NaCl, 0.1% $CuSO_4$) and agar-gel (2.9% agar, 1.6%TX151, 0.6% NaCl) create conductivity contrast. In order to maintain an invariant and sharp conductivity contrast, TX151 (Oil Center Research International) is used to putatively reduce ion diffusion. Also, in order to reduce the electrode-electrolyte interaction, the magnitude of injecting currents is lowered to 60 mA. One important objective of this experiment is to assess the accuracy and sensitivity of CDII. We therefore chose a much smaller conductivity contrast than all our previous experiments. Conductivity measurement shows that the contrast of conductivities between doped saline and agar-gel is 1.12 to 1.
Here, all MRI images were obtained on a 1.5 Tesla GE® EXCITE MR system; reference conductivity measurements were performed on a Wayne Kerr® 4230 LCR meter at 120 HZ and verified with a Solartron 1255 / 1286 system at frequencies from 100Hz to 100kHz. The Solartron measurements were made to assure that there were no errors due to protection circuitry at the Wayne Kerr meter input terminals.

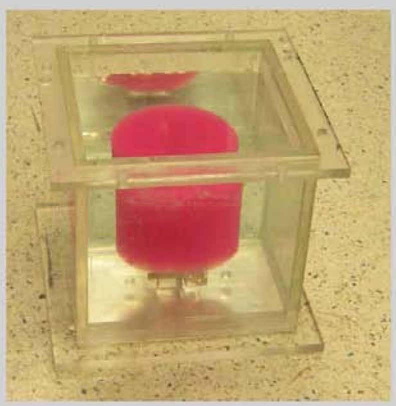

Fig. 1 Phantom Setup

A slab of agar gel was suspended in doped saline. Electrodes were placed on each of the top four corners to provide non-parallel current injections (top-left and lower-right form a pair, top-right and lower-left form another pair ).

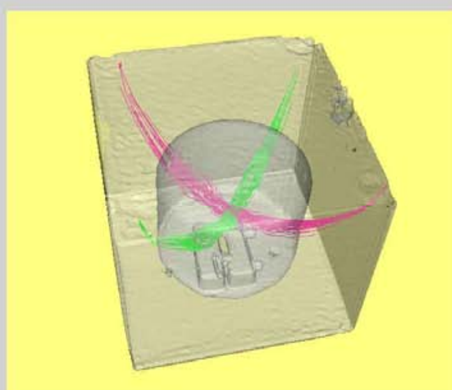

Fig. 2. Current Verification

Reconstructed currents were plotted so as to make sure that $\mathbf{J}_1$ (pink streamlines) and $\mathbf{J}_2$ (green streamlines) are not parallel to each other. Both streamline bundles start and end at opposite electrodes (not shown), which indicates a successful current reconstruction. (Image is plotted in MayaVi®).

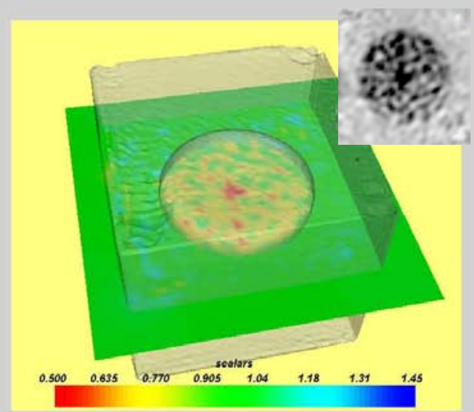


Fig. 3. Reconstructed Conductivity

A cross-sectional view of the reconstructed conductivity distribution inside the phantom. There is an obvious conductivity drop inside the gel, which corresponds to the Wayne Kerr conductivity measurement. The conductivity on the gel-saline interface is slightly increased but the sharp contrast remains. Figure on the top right corner: a 2D gray-scale image of the conductivity in the same cross-sectional plane.

**RESULTS**: Fig. 2 is the current streamline plot. This plot is used to verify whether the reconstructed currents are consistent with real current flows. Fig. 3 is the reconstructed conductivity image. The mean value of saline conductivity is 1.01 S/m, the mean of gel conductivity is 0.89 S/m, their ratio is 1.13 to 1. This is consistent with the Wayne Kerr measurement (1.12 to 1). The lower conductivity at the center was attributed to the wooden popsicle stick and crossbar used to support the gel. The source of the other variations is attributed to a combination of noise and phantom in homogeneity. The current density in the imaged slice ranged from 0.8 to 15.0 A/m$^2$.

**CONCLUSIONS**: With the help of the viscosity modifier (TX151), a sharp conductivity contrast can be created and maintained. CDII is able to non-invasively and accurately detect a 12% difference in average conductivity.

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