**In vivo conductivity imaging of canine male pelvis using a 3T MREIT system**

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**Abstract.** The prostate is an imaging area of growing concern related with aging. Prostate cancer and benign prostatic hyperplasia are the most common diseases and significant cause of death for elderly men. Hence, the conductivity imaging of the male pelvis is a challenging task with a clinical significance. In this study, we performed **in vivo** MREIT imaging experiments of the canine male pelvis using a 3T MRI scanner. Adopting carbon-hydrogel electrodes and a multi-echo pulse sequence, we could inject as much as 10 mA current in a form of 51 ms pulse into the pelvis. Collecting magnetic flux density data inside the pelvis subject to multiple injection currents, we reconstructed cross-sectional conductivity images using a MREIT software package CoReHA.Scaled conductivity images of the prostate show a clear contrast between the central and peripheral zones which are related with prostate diseases including cancer and benign prostatic hyperplasia. In our future work, we will focus on prostate cancer model animal experiments.

Keywords: MREIT, conductivity image, canine pelvis, prostate

1. **Introduction**

Magnetic resonance electrical impedance tomography (MREIT) is a new bio-imaging modality providing cross-sectional conductivity images from measurements of internal magnetic flux densities produced by externally injected currents [1-6]. Recent experimental studies of MREIT have shown its feasibility as a new bio-imaging method with a spatial resolution of a few millimetres [7-9].

Following the recent postmortem and **in vivo** imaging experiments of the canine brain, we have performed imaging experiments of the **in vivo** canine pelvis. The pelvic region with a relatively large field of view (FOV) and various organs imposes a new challenge when it is chosen as an imaging domain. Especially, the prostate is a growing concern imaging area related with aging. Prostate cancer and benign prostatic hyperplasia are the most common diseases and significant cause of death for elderly men [10]. This paper reports our first conductivity images of the **in vivo** canine pelvis. Showing MREIT images of the canine pelvis, we will discuss future research directions.
2. Methods

2.1. Animal preparation

To prevent dribbling during experiments, we injected 0.1 mg/kg of atrophine sulfate. Ten minutes later, we anesthetized the dogs with intramuscular injection of 0.2 ml/kg Tiletamine and Zolazepam (Zoletil 50, Virbac, France). Twenty minutes later, we clipped hair at four locations on the pelvis where we attached four carbon-hydrogel electrodes. With four electrodes attached, we positioned the dog inside the bore of our 3 T MRI scanner (Magnum3, Medinus, Korea) as in figure 1. The experimental protocol was approved by the Institutional Animal Care and Use Committee (IACUC) of Konkuk University, Seoul, Korea.

Inside the shield room, we intubated the dog using an endotracheal tube of 8.5 mm diameter and began the general anesthesia using a veterinary anesthesia machine system (VME, MATRX, USA). We used 2% isoflurane mixed with oxygen at 800 ml/min flow rate. Ventilation was machine-controlled by using a ventilator (M-2002, Hallowell EMC, USA) with the respiration rate of 15 bpm and tidal volume of 200 ml. Using our custom-designed MREIT current source, we injected currents through different pairs of recessed electrodes to confirm the electrode contacts.

2.2. Imaging experiment

We injected the first current $I_1$ between one opposing pair of electrodes. The multi-echo pulse sequence was used with $TR/TE=900/20$ ms. The number of averaging was 24 and the injection current amplitude was 10 mA with the total pulse width of 51 ms. The slice thickness was 4 mm with no slice gap and the number of slices was 8 producing an imaging region with 32 mm thickness centered at the electrode plane. The image matrix size was 128×128 with the field-of-view of 180×180 mm$^2$ and the pixel size was 1.406×1.406 mm$^2$. After acquiring the first magnetic flux density ($B_z$) data set for $I_1$ in 8 axial slices, the second injection current $I_2$ with the same amplitude and pulse width was injected through the other pair of opposing electrodes to obtain the second data set.

![Figure 1. (a) Carbon-hydrogel electrode and (b) imaging setup inside the bore.](image)

2.3. Conductivity image reconstruction

Jeon et al. lately developed an MREIT software package with an efficient graphical user interface [11]. They called it CoReHA which stands for conductivity reconstructor using harmonic algorithms. Since CoReHA automated most parts of data processing tasks in MREIT, we utilized it to process in vivo canine pelvis experiment data and produce conductivity images. We used the harmonic $B_z$ and local harmonic $B_z$ algorithm for conductivity image reconstructions [12-14].

3. Results

Figure 2(a) is a typical MR magnitude image of a canine pelvis. Figure 2(b) and (c) are measured $B_z$...
images in the same slice subject to current injections in two different directions. Figure 3 shows enlarged images of the canine prostate. Figure 3(a) is an anatomical structure of the prostate and (c) shows a reconstructed conductivity image in comparison with the corresponding MR magnitude image in (b). Conductivity images of the prostate showed clear contrast between central and peripheral zones which are related with prostate diseases including cancer and benign prostatic hyperplasia.

![Figure 2](image2.png)

**Figure 2.** (a) Typical MR magnitude image of the canine pelvis. (b) and (c) are magnetic flux density images subject to the horizontal and vertical injection currents, respectively.

![Figure 3](image3.png)

**Figure 3.** Magnified images of the prostate: (a) anatomical structure, (b) MR magnitude image and (c) reconstructed conductivity image.

4. Discussion

The MREIT technique has to be advanced beyond the stage of showing its feasibility. To support its clinical significance, we should demonstrate that the conductivity image provides meaningful diagnostic information that is not available from other imaging modalities. This requires accumulated experience and knowledge on how to interpret a conductivity image in relation with anatomy and pathology of a specific organ. Choosing the pelvis as an imaging region, we tried to provide such an example in this paper.

The prostate is a growing concern imaging area related with aging. Prostate cancer and benign prostatic hyperplasia are most common diseases and significant causes of death for elderly men. Conductivity imaging of the pelvis region is a challenging task. Its size is large to result in a reduced current density in some local regions. It contains various organs with different proton densities and there are local regions with low signal-to-noise ratios (SNR). Since the amount of noise in measured $B_z$ data is inversely proportional to the MR magnitude image SNR, reconstructed conductivity images in such local regions are noisy. To handle this kind of technical problem, we may apply a denoising algorithm, inpainting method and/or the local harmonic $B_z$ algorithm [6]. Based on our results, we can see conductivity contrast between central and peripheral zones, which are related with prostate diseases including cancer and benign prostatic hyperplasia. Considering clinical applications, future work should be focused on disease model animal experiments.
Acknowledgments

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