INVISIBLE DENSE-ARRAY EEG NET FOR SIMULTANEOUS EEG-PET/MR IMAGING

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Target Audience: Multi-modal imaging and EEG/PET/MR researchers.

Purpose: Non-invasive multi-modal human brain imaging has grown rapidly over the past decade as each modality offers a unique insight for neuroscience researchers and clinicians. The combined information obtained from dense-array electroencephalography (dEEG), functional magnetic resonance imaging (fMRI), and positron emission tomography (PET) may not only lead to advances in basic science (e.g., neuronal and neurovascular coupling with exploration of specific receptor occupancies), but also better assessment of neuropathologies (e.g., a more robust and reliable detection of epileptogenic foci compared to dEEG[1], EEG/fMRI[2] or PET[3] alone). However, one of the major challenges is that commercial dEEG caps contain metal structures, which cause RF inhomogeneity and susceptibility artifacts in MRI and signal loss due to photon attenuation in PET, which are difficult to correct for adequately in PET/MRI. In order to minimize these deleterious effects on the MRI and PET data, we designed a dEEG sensor net based on conductive polymers, and demonstrated its superior performance in terms of RF invisibility and reduced photon attenuation for the use in simultaneous EEG-PET/MRI.

Methods: The novel 256-electrode dEEG net (InkNet, Figure 1), was based on Polymer Thick Film (PTF) technology and was screen-printed on Melinex substrate. The first printed layer consisted of custom-blended Ag/C ink leads. Next, AgCl ink-pad electrodes were printed (layer 2). A dielectric coating (layer 3) was deposited on the entire PTF piece, with the electrode masked out, leaving the exposed electrode to make contact with an electrolyte-soaked sponge inserted into the electrode pedestal. The InkNet layout and structure was based on EGI's (Electrical Geodesics, Inc., Eugene, OR) 256 copper-wire HydroCel Geodesic Sensor Net (HCGSN 220 MR). The HCGSN had a total lead/wire resistance of 1Ω, thus highly conductive due to the copper wires. In contrast, the InkNet had a typical resistance (depending on the lead length) of 17 kΩ, due to the highly resistive Ag/C PTF ink blend.

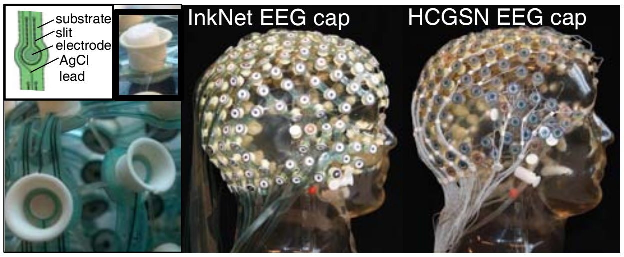

Figure 1: The dEEG InkNet based on PTF technology (left: close-up, center: entire InkNet) and a commercial, copper-wired HCGSN net (right).

Imaging data were acquired on a 3T MR scanner (human and phantom) and a simultaneous 3T PET/MR whole-body scanner (phantom only) in three configurations: (i) head-only (MR-only) or phantom-only data, (ii) with the InkNet or (iii) with the HCGSN placed around the head/phantom. Echo planar imaging data and B1 field maps were acquired on three subjects in a 3T MR system (Figure 2). For PET, the phantom was filled with ^{18}F solution (~0.4 mCi initial activity) and imaged in the same position for 15 min. Images were reconstructed with an iterative OP-OSEM algorithm, including correction for phantom attenuation, scatter and radioactive decay of the phantom. Additionally, CT data of the two EEG nets were acquired on a small-bore PET/SPECT/CT scanner at a resolution of 50 μm.

Results: Compared to the B1 field without any net, wearing the copper-wired HCGSN results in B1 field maps severely distorted, whereas the field distortions are minimal with the InkNet (Figure 2). Figure 3 shows 3D-rendered CT images of the InkNet and the HCGSN and clearly visualizes the high attenuation by the HCGSN, mainly due to the use of a large number of copper wires connecting the 256 sensors. Figure 4 shows the percent change in the PET images with the InkNet or the HCGSN, using the phantom-only as a reference. While the InkNet shows minimal artifacts compared to the phantom-only data, the HCGSN shows a loss of counts close to the walls inside the phantom. Overall, the loss in counts relative to the phantom alone is 2.6% with the InkNet but 4.8% with the HCGSN, not taking into account the surrounding artifacts.

Conclusion: We demonstrated improved MR and PET imaging capabilities for simultaneous imaging with a prototype 256-electrode PTF-based dEEG sensor net (InkNet) compared to a commercially available copper-wired dEEG sensor net (HCGSN). This novel PTF technology opens up the possibilities for functional brain mapping with high-quality simultaneous multimodality imaging using EEG-PET/MRI.

Figure 2: B1 field maps show severe distortions with the copper-wire HCGSN but not with the PTF InkNet cap.

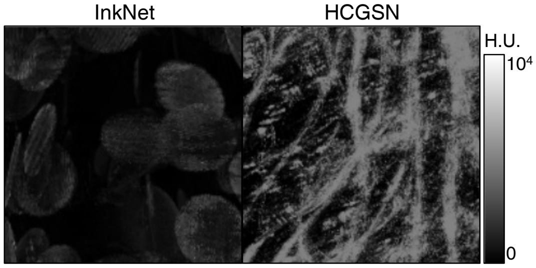

Figure 3: CT scans of the EEG nets show the increased attenuation due to the HCGSN compared to the InkNet.

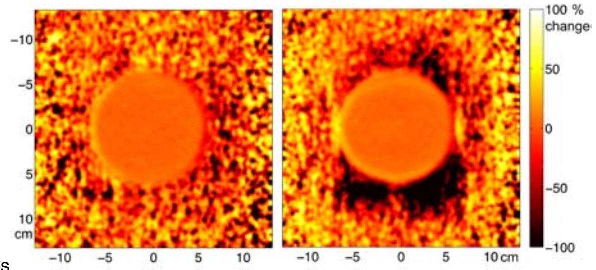

Figure 4: Percent changes from PET with the Inknet or HCGSN nets compared to no net being present around an ^{18}F phantom.

References: [1] Yamazaki M, Terrill M, Fujimoto A, Yamamoto T, Tucker DM. Integrating Dense Array EEG in the Presurgical Evaluation of Temporal Lobe Epilepsy. ISRN Neurol 2012;2012. [2] Thornton R, Vulliemoz S, Rodionov R, et al. Epileptic networks in focal cortical dysplasia revealed using electroencephalography–functional magnetic resonance imaging. Annals of Neurology 2011;70:822–837. [3] Casse R, Rowe CC, Newton M, Berlangieri SU, Scott AM. Positron emission tomography and epilepsy. Mol Imaging Biol 2002;4:338–351.