Correlation of imaging connectivity with electrophysiological connectivity using intracranial electrodes

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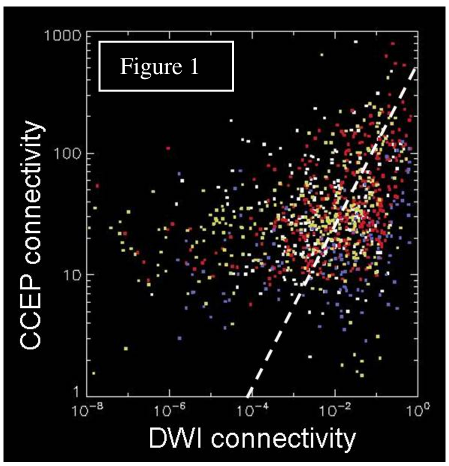
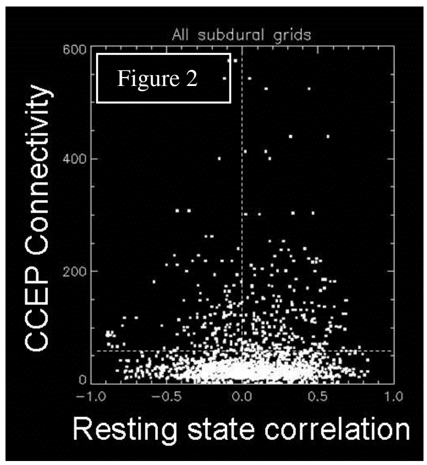
Target audience: Diffusion MRI, tractography, intracranial electrodes/EEG, epilepsy

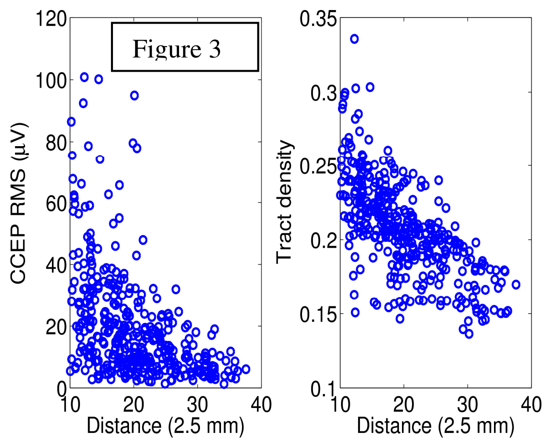
Purpose: Diffusion weighted imaging (DWI) can non-invasively infer neural tractography and connectivity, which can reasonably delineate major known pathways. Regarding accuracy, there is continued interest is how well DWI measures of imaging connectivity (IC) correlate with electrophysiological connectivity (EC)—a question of clinical relevance. One standard for measuring EC is cortico-cortical evoked potentials (CCEPs), which uses intracranial electrodes to stimulate and record electrical activity[1]. Here, we compare IC and EC between pairs of regions in the brain varying in space. Although significant correlation between these two measures has been reported[2], our results indicate that the relation between IC and EC is modest and still uncertain.

Methods: CCEP data was obtained in epilepsy patients from both surgically implanted deep stereotactic electroencephalography (SEEG) electrodes, and subdural grid electrodes. EC was evaluated by directly stimulating an electrode contact pair and recording voltage at all other contacts. A measure of EC between contacts X and Y was taken to be the root mean square (RMS) of the recordings at Y, from 10 to 20 ms after X was stimulated.

Prior to implantation, the patient underwent pre-procedural imaging at 3T (2.5mm voxels), which included 61 direction diffusion imaging (HARDI)[3], and resting-state connectivity. All electrode positions were coregistered to anatomic imaging. We have developed a fast probabilistic tracking method[4], which was used to compute pathways from each stimulus contact to every other contact, to parallel the CCEPs stimulus. Various IC measures include either mean tract density along pathways, mean tract FA or TD, or mean component along FOD. Data has been obtained from four patients so far.







Results: Fig. 1 shows a scatter plot (log-log) of the relation of EC and IC (DWI connectivity) for over 600 contacts in 4 patients; each data point represents a pair of points in the brain. Although there is a significant correlation, there are many points showing high IC with low EC, and visa versa. Fig. 2 shows a similar scatter plot comparing EC with resting-state connectivity, which shows only a mild correlation of EC with IC. Fig.3 shows a significant distance effect whereby both IC and EC diminish with distance, an effect that further confounds the direct correlation of EC with IC.

Discussion: Today, IC is extensively used to study the brain, but there is little evidence supporting various measures of IC. We attempt to derive a measure of IC by comparing values against the presumed gold-standard of EC. We find only a modest correlation with DWI and a minimal correlation with rsMRI. Many pairs of points in the brain have high IC and low EC, or have low IC with high EC. We have explored many variations of both EC and IC measures, and this trend is always observed. Possible causes include incompatibly low MRI resolution, distance effects of both IC and EC, poor co-localization of MRI voxels with electrical contact points, or intrinsic brain functionality whereby a solid structural path between two points does not necessarily imply a strong concordant electrophysical response. Our results lead us to believe that the connection between EC and IC is tentative. This discordance could be inherent to brain physiology, or it could indicate that our current methodology is not fully understood.

Conclusion: An extensive comparison of diffusion MRI and electrophysiological data indicates an uncertain correlation between these two measures of brain connectivity.

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