TOWARDS WIRELESS HIGH-DENSITY SEEG:
SUCCESSFUL IMPLANTATION OF 6 PLANAR DEPTH PROBES WITH UNTETHERED RECORDING & STIMULATION IN A SEMICHRONIC PIG MODEL

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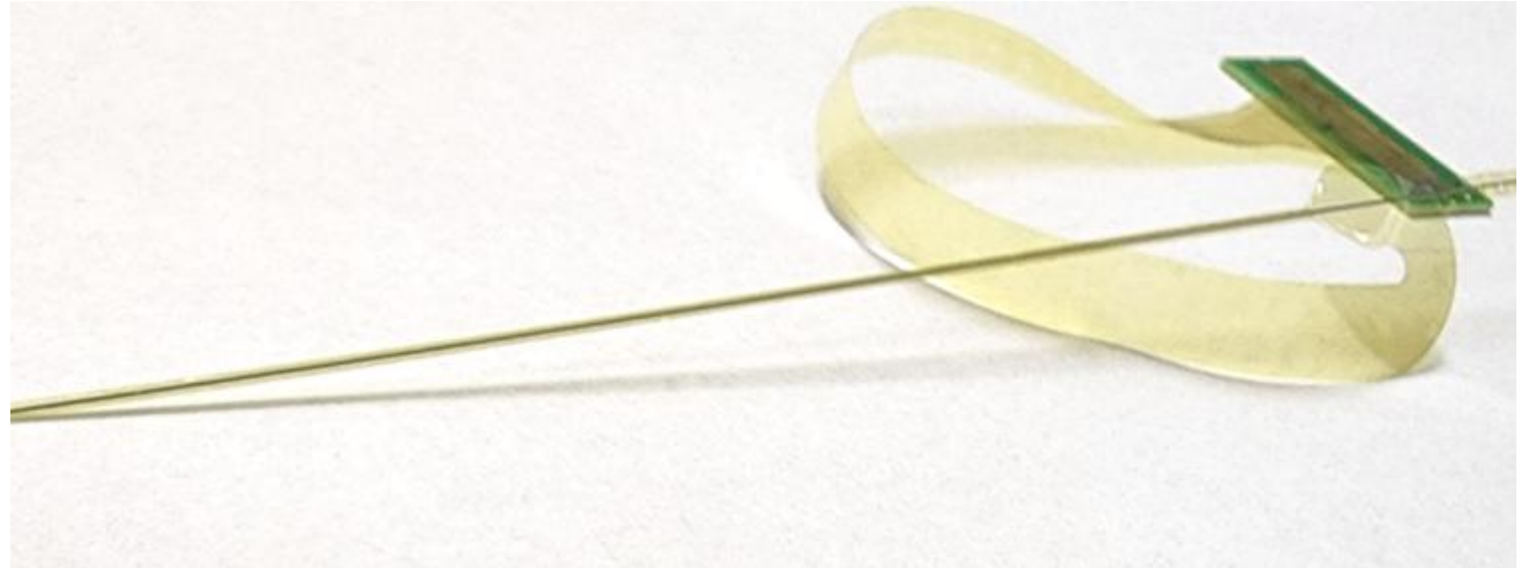
Background

Drug-resistant epilepsy severely interferes with patients' quality of life and carries significant associated morbidity and mortality. Planning surgical interventions for drug-resistant epilepsy benefits from Phase 2 evaluation with intracranial electrodes to map the epileptic network. The primary aims are to localize the epileptogenic foci, to characterize interictal activity in the irritative zone, and to establish boundaries of eloquent cortex. The ideal Phase 2 system would enable robust recording of many distributed sources with fine spatial scale – all while also freeing patients from their wired tether to the hospital bed. Traditional stereotactic depth electrodes provide excellent grid-like distribution of recordings but are only able to resolve local field potentials from relatively large tissue volumes. More recent approaches including microwires and superficial high-density mapping systems succeed in sampling small neuronal populations but sacrifice scope – making them less useful for epilepsy applications.

Objective

To achieve global microscale recordings of the brain, we have developed high-fidelity, low-impedance, micrometer-scale penetrating electrodes with wireless data transmission.



Here we present the first implantation of this full recording & stimulation system in a large animal survival model.

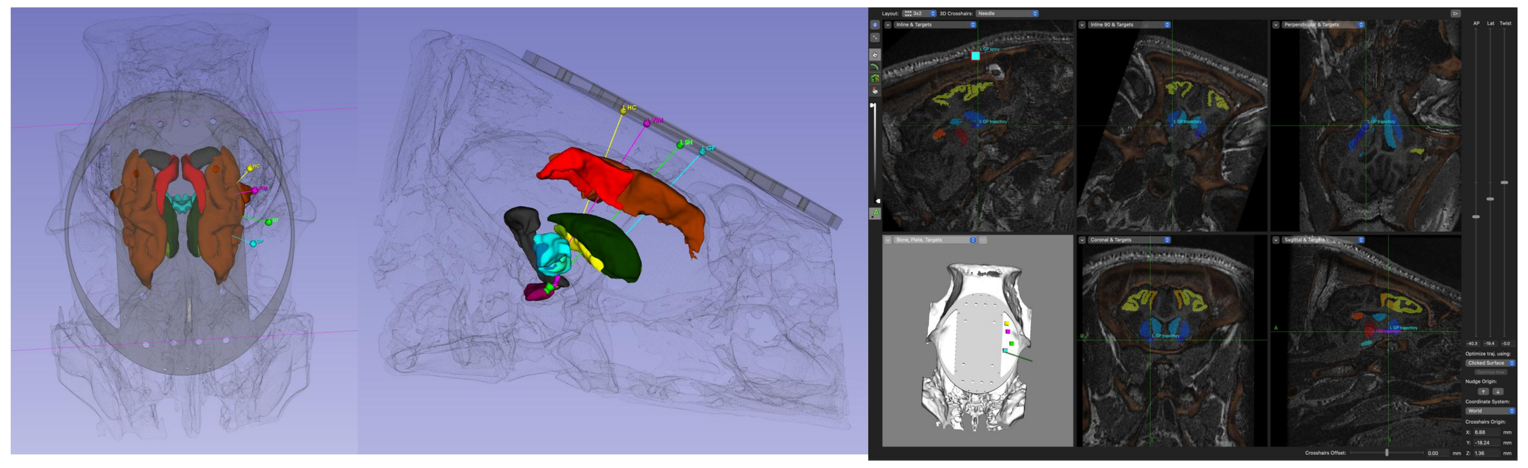
Surgical Design

Pigs were selected given their motor network homology to humans, large cerebral volume for a non-primate, and biologic tolerance of implanted hardware for semichronic experiments.

The pig underwent a first stage anesthetic event for CT and MRI imaging to facilitate surgical planning before a second stage implantation of stereotactic leads with neuronavigation.

Neuronavigation

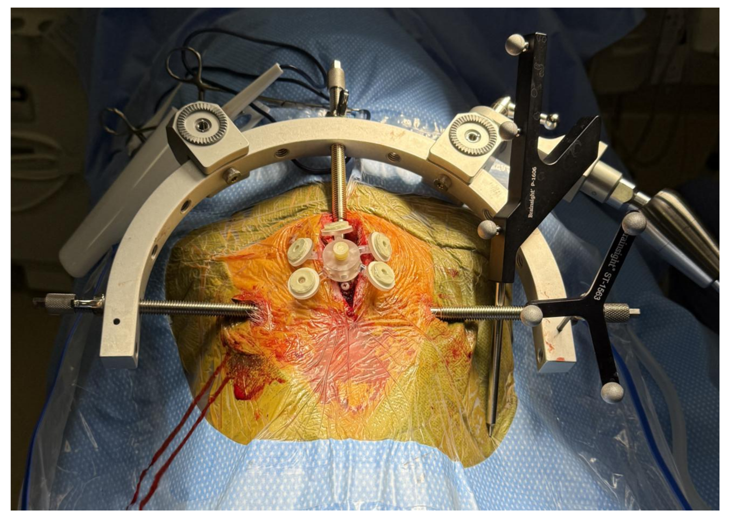
Preoperative CT and 3T MRI were obtained 3 days prior to electrode implant, allowing for 3D reconstruction of bony anatomy as well as nonlinear soft tissue registration to a histologically labelled atlas.

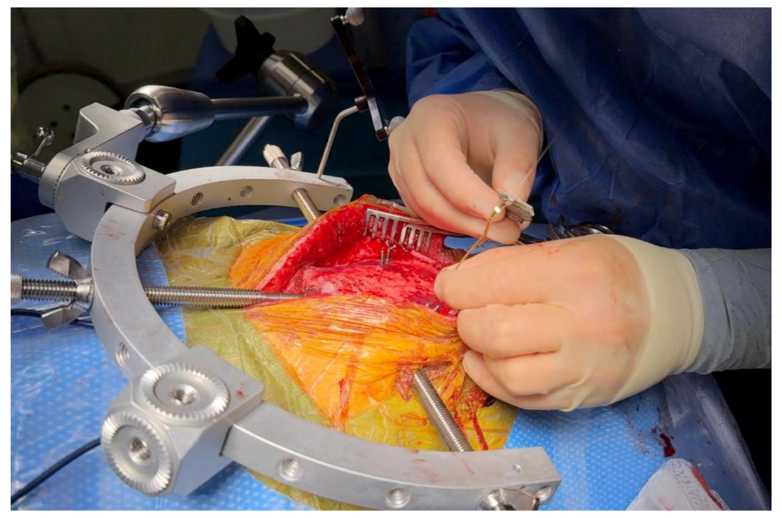


Stereotactic trajectories for each probe were prepared to enable intraoperative navigated electrode placement with millimeter precision.

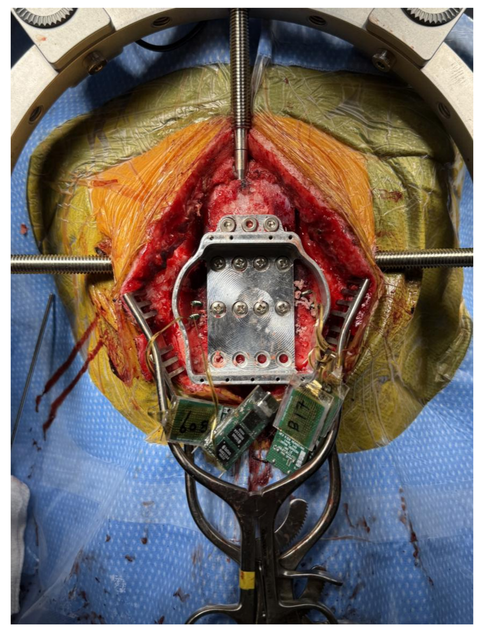
Hardware Design & Implant

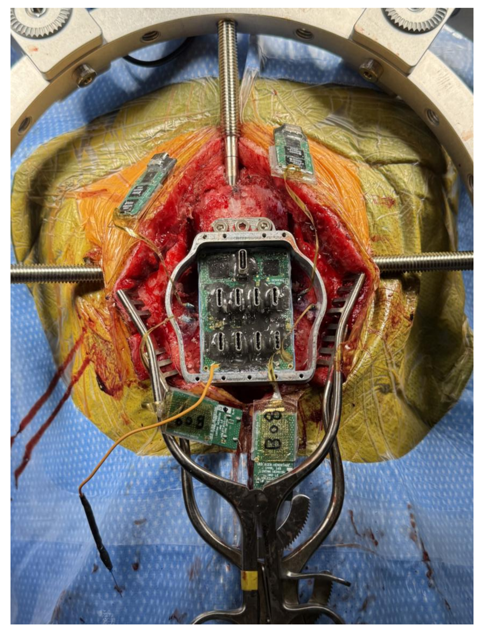
After placing a standard cranial bolt with neuronavigation along each planned trajectory, a tract was created in standard fashion with an obturator. The probe was then manually inserted with a polished stainless steel stylet which was subsequently removed.

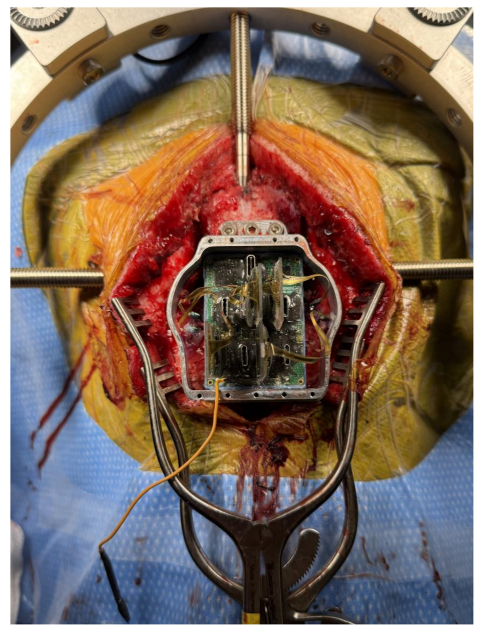




Each of the implanted leads comprised 128 microcontacts and 16 macrocontacts distributed over 3cm. Head-mounted acquisition and stimulation hardware enabled wireless recordings at 30kHz and current injection of up to 96 channels by chronometric or closed-loop triggers.

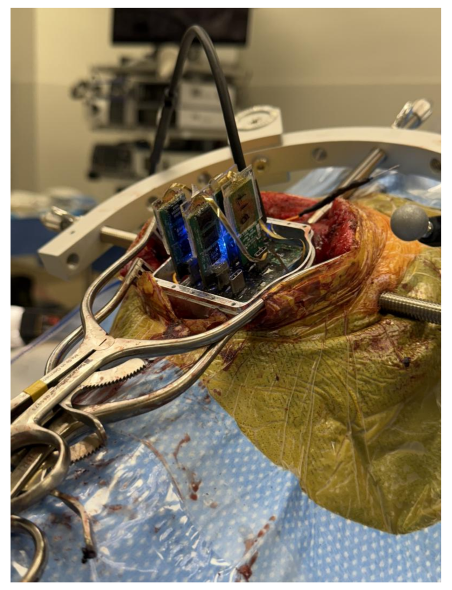


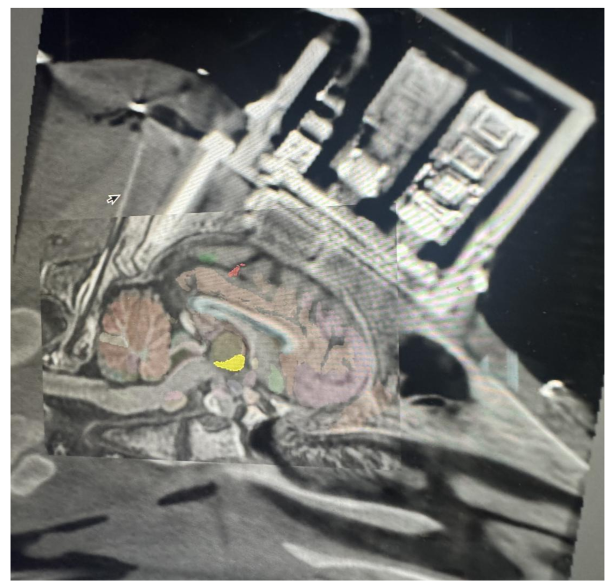


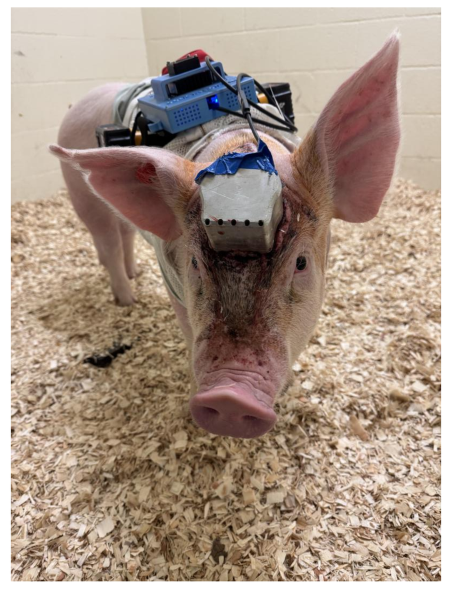


Outcomes

The pig was neurologically intact after successful surgical implantation of 6 microelectrode leads (864 total contacts) to subcortical and cortical targets: hippocampus, thalamus, and somatosensory cortex. Normal ambulatory, feeding, and socializing behavior were observed.







The micro- and macro-contacts maintained preimplantation efficacies for both recording and stimulation across superficial and deep targets.

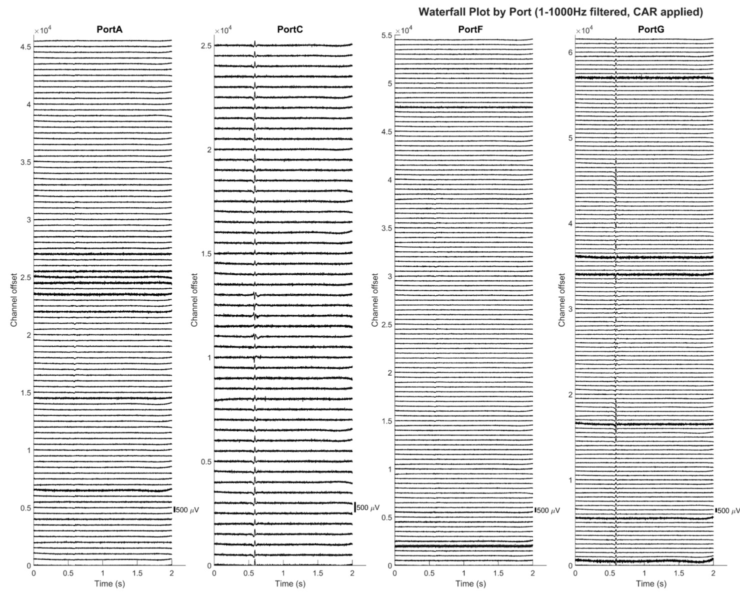
Preimplantation

	B03	B08	B09	B17
Recording	115 (90%)	120 (94%)	108 (84%)	112 (88%)
Stimulation	16 (100%)	6 (38%)	10 (62%)	10 (62%)

Postimplantation

	B03	B08	B09	B17
Recording	109 (85%)	119 (93%)	90 (70%)	117 (91%)
Stimulation	16 (100%)	6 (38%)	5 (31%)	13 (81%)

Wireless transmission of intracranial electrophysiology was successful with the jacket worn power & communication hardware connected to the headworn unit by a single detachable cable. Sustained 2 kHz recordings of global sensorimotor network activity demonstrated that single-pulse stimulation induced evoked responses.



Postmortem explant of the brain revealed no gross injury from implant, no reactive gliosis to the foreign material, and minimal residual tract.

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