Comparison of Abiotic-Biotic Responses of Tungsten Microwires, Pt/Ir Floating Arrays, and Utah Arrays in Chronic Neural Implants

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Chronically implanted electrodes in the nervous system undergo temporal degradation in signal quality over time as they can be affected by both biotic and abiotic factors ultimately resulting in electrode failure [1]. An interplay of these time varying factors affect the functional performance of implanted electrodes on different time scales ranging from hours and days following implantation surgery [2, 3]. We have been studying this time-varying relationship of the various electrode failure modes for three electrode types commonly used in humans, primates and rodents in a well-controlled surgical and testing environment designed for chronic electrode evaluation [4, 5]. In this study, we provide a comprehensive comparison between the electrodes to serve as an aid for choosing electrode types and materials in neuroprosthetic research. In this work, we focused on detailed abiotic and biotic characterization of tungsten microwires (Tucker Davis Technologies, Alachua FL) in 25 rats, Pt/Ir floating microelectrode arrays (MicroProbe, Gaithersburg MD) in 15 rats, and silicon shank arrays (Blackrock Microsystems, UT) in 10 rats. Abiotic characterization was performed via evaluation of pre-implant and post-explant scanning electron microscope (SEM) images of electrode recording sites to evaluate morphological changes at the electrode recording sites, corrosion, and insulation delamination for all electrodes. Electrical characterization was performed through daily electrode impedance spectroscopy before each recording session to provide insights into the dynamic nature of the electrode-tissue interface. Biotic characterization was performed via post-mortem histopathology to assess blood brain barrier (BBB) disruption, and microglial activation and degeneration. Finally, we coupled the chronic electrode functional performance (array yield, signal-to-noise ratio) with the abiotic and biotic responses to provide a more complete understanding of these interactions during the chronic lifetime of an electrode in the neural tissue. Comprehensive electrode characterization suggested that electrode recording characteristics are related to changes in impedance spectra and future electrode performance can be predicted using given impedance values. Abiotic analysis indicated progressive increases in electrode impedance in the first 2-3 weeks following implant where large changes in complex impedance spectra corresponded with poor electrode performance during this period. The Pt/Ir arrays exhibited greater daily variation in electrode impedance as compared to both the Utah arrays and the tungsten microwires. Post-explant SEM imaging indicated tungsten microwires were more prone to corrosion and insulation damage even on short-time scales of few weeks as compared to Pt/Ir arrays which indicated reduced corrosion and insulation damage even for the longest-term animals (6-months). Histopathology indicated that in general, there was reduced expression of microglial markers (Iba1, ED1) and ferritin (marker for BBB disruption) for the Pt/Ir arrays as compared to the tungsten microwire arrays. Functional performance for the Utah arrays was poor (<25% yield) whereas was moderate to good (>70% yield) and comparable among animals for both tungsten microwires and Pt/Ir arrays.

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