Mechanics of neuronal probe insertion at micrometer scales.

Alicia M. Ortega[1], Ken Gall[2], Diego Restrepo[3] and Andrew A. Sharp[3]

[1]Dept of Mech Eng, Univ of Colorado, Boulder, CO, [2]Sch of Materials Sci and Eng, GIT, Atlanta, GA, [3]Dept of Cell and Dev Biol, UCDHSC, Aurora, CO.

Recently, there has been significant advancement in the methodology for chronic recording and stimulation of the central nervous system. This provides an excellent opportunity for the expantion and improvement of functional stimulation treatments for disorders of the nervous system. However, in order to develop, design and optimize the next generation of neuronal probes, it is necessary to understand the mechanics of probe insertion at relevant length scales. Little work has been done at micrometer scales to understand the mechanical interaction of neuronal probes with brain tissue during implantation. The purpose of this study was to investigate micrometer scale penetration mechanics of brain tissue *in-vivo*. Cylindrical stainless steel probes were inserted (1.5 mm) into the brain of anesthetized mice. The resulting forces were measured throughout the insertion and removal of the probe. The following parameters were changed: probe size (100 μm vs. 200 μm diameter), probe geometry (flat vs. sharpened tip), insertion rate (822, 104, or 11 μm/s), insertion location (olfactory bulb vs. cortex) and the presence or absence of dura. A decrease in probe diameter resulted in an overall decrease in penetration forces. Flat probe tips produced a two-part loading path upon insertion. First, the probe only compressed the tissue resulting in a near linear increase in force as a function of depth. Then, the probe penetrated the tissue and began to tear through it resulting in either a plateau or decrease in the loading-displacement slope. The sharpened probe tips produced a more constant loading-displacement slope during insertion and lower forces overall. Due to the viscoelastic properties of the brain tissue, slower insertion rates caused a decrease in tissue modulus and lowered the initial loading slope for the insertion of the flat probe. Interestingly, probe insertion into the cortex required higher penetration forces compared to that of the olfactory bulb. Lastly, removal of the dura resulted in a dramatic decrease in penetration forces. Mechanical properties of the brain tissue were extracted from the force displacement curves and knowledge of the probe shape and stress/strain fields. This study provides a basic understanding of how simple design and insertion method modifications influence the insertion mechanics and mechanical properties of brain tissue and will aid in design optimization for future chronic electrodes.

Supported by: The Coleman Institute for Cognitive Disabilities and NIH/NIDCD DC00566 to D.R.