Clinical Neuromodulation Technology

Cameron McIntyre, Case Western Reserve University

The rapidly expanding field of clinically applying electrical stimulation and recording technology to the treatment of neurological disorders, commonly referred to as clinical neuromodulation, owes its origins to biomedical engineering pioneers from the 1960's and 70's that first developed the concepts of a "brain-machine" interface. Today the clinically available devices are primarily focused on spinal stimulation for the treatment of chronic pain, cochlear stimulation for the restoration of hearing, and brain stimulation for the treatment of movement disorders (e.g. Parkinson's disease). In addition, experimental systems are currently under development for brain signal based control of robotics. Clinical neuromodulation technology already represents a multi-billion dollar per year medical device industry and growth expectations are substantial, especially when considering their expansion into new clinical indications (e.g. epilepsy, depression, Alzheimer's disease). The fundamental concept behind neuromodulation devices is to use permanently implanted electrodes to: 1) record neural activity such that it can be used as a biomarker in a control system, and/or 2) stimulate neural activity to control the release of neurotransmitters in the nervous system. The currently available devices use a relatively small number of electrodes (~1-10) to achieve their goals. In turn, the degree of specificity and control is relatively low. Over the next 5 years, device technology will provide the opportunity to use far greater (~100s) numbers of electrodes to improve the fidelity and bandwidth of bidirectional communication with the nervous system. However, fundamental scientific questions remain to be addressed on defining, interpreting, and responding to a basic language that would be appropriate for such communications. In addition, it is currently unclear exactly where those electrodes should be placed in the nervous system to optimize those communications. Further, clinical application of the technology is limited by the biocompatibility of the available materials used to construct the devices, as well as the surgical realities of implanting the technology in the human body (getting electrodes to the right places and finding somewhere to house the device electronics). Assuming these engineering and scientific challenges can be overcome, the distant future could see neuromodulation technology not only improving the treatment of disease, but also changing the way humans communicate with each other and/or interface with information. However, such advances are wrought with ethical implications and questions of autonomy. Therefore, clinical neuromodulation is approaching a crossroads where the technology is capable of amazing things, leveraging impressive advances in science, but possibly at the expense of manipulating brain function in those patients.