Neuromodulation

Neuromodulation is the physiological process by which a given neuron uses one or more neurotransmitters to regulate diverse populations of neurons. This is in contrast to classical synapse transmission, in which one presynaptic neuron directly influences a single postsynaptic partner.

Neuromodulators secreted by a small group of neurons diffuse through large areas of the nervous system, affecting multiple neurons. Examples of neuromodulators include dopamine, serotonin, acetylcholine, histamine and others.

Neuromodulation can be conceptualized as a neurotransmitter that is not reabsorbed by the pre-synaptic neuron or broken down into a metabolite. Such neuromodulators end up spending a significant amount of time in the cerebrospinal fluid (CSF), influencing (or “modulating”) the activity of several other neurons in the brain. For this reason, some neurotransmitters are also considered to be neuromodulators, such as serotonin and acetylcholine.

Neuromodulation is often contrasted with classical fast synaptic transmission. In both cases the transmitter acts on local postsynaptic receptors, but in neuromodulation, the receptors are typically G protein coupled receptors while in classical chemical neurotransmission, they are ligand-gated ion channels. Neurotransmission that involves metabotropic receptors (like G-protein linked receptors) often also involves voltage-gated ion channels, and is relatively slow. Conversely, neurotransmission that involves exclusively ligand-gated ion channels is much faster. A related distinction is also sometimes drawn between modulator and driver synaptic inputs to a neuron, but here the emphasis is on modulating ongoing neuronal spiking versus causing that spiking.

Ethics

As with any medical intervention, the use of neuromodulation raises ethical considerations. Some of the key ethical issues related to neuromodulation include:

Informed consent: Patients must be fully informed about the risks and benefits of neuromodulation, and must provide informed consent before undergoing the procedure. This requires careful consideration of how to communicate complex medical information in a way that patients can understand.

Privacy: The use of neuromodulation devices can involve the collection of sensitive data about patients, such as their brain activity or pain levels. It is important to ensure that this data is kept confidential and that patients have control over how it is used.

Equity: Neuromodulation devices can be expensive, which raises questions about access and equity. It is important to ensure that these devices are available to all patients who could benefit from them, regardless of their socioeconomic status.

Efficacy: The effectiveness of neuromodulation devices can vary widely between patients, which raises questions about how to determine who should receive them. It is important to carefully evaluate the evidence for the effectiveness of these devices and to ensure that they are only used in patients who are likely to benefit.

Long-term effects: The long-term effects of neuromodulation are not yet fully understood. It is important to carefully monitor patients who receive these devices over time and to continue to research their long-term effects.

Overall, the use of neuromodulation raises a number of ethical issues that must be carefully considered to ensure that patients receive safe, effective, and equitable care.

Mayberg H, Illes J. Considering Ethics and Neuromodulation Together. Can J Neurol Sci. 2023 Jun;50(s1):s1. doi: 10.1017/cjn.2022.295. Epub 2023 May 10. PMID: 37160677.

Tecniques

Neuromodulation techniques.

Books

The Neuromodulation Casebook

Innovative Neuromodulation From Academic Press

List Price: $99.95

Innovative Neuromodulation serves as an extensive reference that includes a basic introduction to the relevant aspects of clinical neuromodulation that is followed by an in-depth discussion of the innovative surgical and therapeutic applications that currently exist or are in development.

This information is critical for neurosurgeons, neurophysiologists, bioengineers, and other proceduralists, providing a clear presentation of the frontiers of this exciting and medically important area of physiology. As neuromodulation remains an exciting and rapidly advancing field—appealing to many disciplines—the editors' initial work (Essential Neuromodulation, 2011) is well complemented by this companion volume.

Presents a comprehensive reference on the emerging field of neuromodulation that features chapters from leading physicians and researchers in the field.

Provides commentary for perspectives on different technologies and interventions to heal and improve neurological deficits

Contains 300 full-color pages that begin with an overview of the clinical phases involved in neuromodulation, the challenges facing therapies and intraoperative procedures, and innovative solutions for better patient care

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Editorial Reviews

From the Back Cover

Edited by two prominent clinical experts in the field, Innovative Neuromodulation 1e will serve as an extensive reference that includes a basic introduction to the relevant aspects of clinical neuromodulation followed by in-depth discussion of the innovative surgical and therapeutic applications that currently exist or are being developed at present. This information contained is critical for neurosurgeons, neurophysiologists, bioengineers, and other proceduralists, providing a clear presentation of the frontiers of this exciting and medically important area of physiology.

As neuromodulation remains an exciting and rapidly advancing field, appealing to many disciplines, the editors' initial volume (Essential Neuromodulation, 2011) will be well complemented by this companion volume. Innovative Neuromodulation stands on its own, capturing the up-to-date advances and inspiration that currently grip the field.

About the Author Jeff Arle, MD, PhD, FAANS Dr. Arle is currently the Associate Chief of Neurosurgery at Beth Israel Deaconess Medical Center in Boston, the Chief of Neurosurgery at Mt. Auburn Hospital in Cambridge, and an Associate Professor of Neurosurgery at Harvard Medical School. He received his BA in Biopsychology from Columbia University in 1986 and his MD and PhD from the University of Connecticut in 1992. His dissertation work for his doctorate in Biomedical Sciences was in computational modeling in the Cochlear Nucleus. He then went on to do a residency in neurosurgery at the University of Pennsylvania, incorporating a double fellowship in movement disorder surgery and epilepsy surgery under Drs. Patrick Kelly, Ron Alterman, and Werner Doyle, finishing in 1999.

He edited the companion text Essential Neuromodulation with Dr. Shils, the first edition published by Elsevier in 2011. He has now practiced in the field of functional neurosurgery for 17 years and is experienced in all areas of neuromodulation from deep brain stimulators to vagus nerve, spinal cord, peripheral nerve, and motor cortex stimulators, contributing frequent peer-reviewed publications and numerous chapters to the literature on many aspects of the neuromodulation field. He currently serves as an associate editor at the journals Neuromodulation and Neurosurgery, is the co-chair of the Research and Scientific Policy Committee for the International Neuromodulation Society, and is on the Board of Directors for the International Society for Intraoperative Neurophysiology. His longstanding research interests are in the area of computational modeling in the understanding and improved design of devices used in neuromodulation treatments.

Jay L. Shils, Ph.D., D.ABNM, FASNM, FACNS is the director of intra-operative neurophysiology and associate professor in anesthesiology at Rush University Medical center in Chicago, IL. He received his Bachelor of Science degree in electrical engineering from Syracuse University, and both his masters and PhD in Bio-Engineering at The University of Pennsylvania investigating higher order signal extraction and processing techniques on human EEG data to investigate interactions in the visual system and in epilepsy.

He began his work in the field of intraoperative neurophysiology in 1995 specializing in single unit recordings during surgery for movement disorders in the department of Neurology at the University of Pennsylvania School of medicine. Dr. Shils' research interests include investigating methods for improving real-time intraoperative neurophysiologic techniques as well as theoretical research in neuromodulation mechanisms of action. Dr. Shils has published over 30 peer reviewed papers and multiple chapters on intraoperative neurophysiologic surgical technique, post-operative management

of movement disorders patients, and computational modeling as related to neuromodulation effects on various neural circuits. He is the co-editor of two books: “Neurophysiology in Neurosurgery: A modern approach” with Dr. Vedran Deletis; and “Essential Neuromodulation” with Dr. Jeffrey E. Arle. Prior to going to graduate school Dr. Shils was an electrical engineer at the Electric Boat division of General Dynamics where he was involved in various modifications to existing electrical systems.

Dr. Shils is the past President of the International Society for Intraoperative Monitoring and was the founding secretary of the society. He is a past board member of and past chairman for the American Society of Neurophysiologic Monitoring ethics committee and is the 2106/2017 president of the ASNM. He is an associate editor for the Journal of Neurosurgery and Journal of Clinical Neurophysiology.