Short Communication

Physiology of Brain mapping

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Abstract

Brain mapping is a group of techniques where normal or abnormal activities of the brain can be projected as spatial representations called as maps. A variety of techniques and therefore a number of physiological principles are operational in brain mapping techniques. These include some older methods such as mapping the electrical activity by electroencephalography or electrocorticography. Computerised tomography though offers a three dimensional picture by projecting focused x-ray beams has the disadvantage of depicting mostly the structure of the brain. Therefore newer methods like positron emission tomography [PET]andfunctional MRI give an idea of the actual spatial organisation during cerebral activity. These methods are based on the principle that cerebral blood flow alters as a result of function and therefore methods which pick up and map alterations in blood flow can help in neurophysiological studies or help us comprehend the progression of disease. Many novel methods like immunohistochemistry which can track antigen antibody reactions in specific cerebral areas or nanotechnology which can track atoms within neurotransmitters can help us map and study brains functions as well as abnormality more precisely. Research is ongoing in these areas for the early detection and management of many neurodegenerative and psychiatric disorders. This article attempts to give an overview of the various brain mapping techniques in their order of discovery, the drawbacks or advantages of individual methods and the physiological concepts behind the same.

Key words: brain mapping, physiology,electroencephalography, functional MRI, positron emission tomography

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Brain mapping can be defined as a group of neuroscience techniqueswhere biological quantities or properties of the human or non human brain can be predicted by mapping onto spatial representations called as maps.As per the Society for Brain Mapping and Therapeutics (SBMT), established in 2013, brain mapping has been summarized as the study of the structural organization and functions of the central nervous system through the application of imaging,molecular & optogenetics, immunohistochemistry, engineering, stem cell technology, neurophysiology and nanotechnology[1].This article attempts to describe the history of various brain mapping methods and physiological principles underlying them.

There has been tremendous understanding in the field of cognitive neuroscience for the past fifty years. Cognitive neuroscience helps us to study the physiological changes in the brain during mental activities through experimental strategies. The

commonly used techniques in normal humans are related to functional brain imaging such as positron emissiontomography (PET) and functional magnetic resonanceimaging (fMRI), supplemented withelectroencephalography (EEG), electrocorticography (ECoG) etc.

The hypothesis that local cerebral blood flow alters as a result of function is quite old. The famous 19th century Italian physiologist Angelo Mosso had meticulously monitored the brain pulsations in adults through surgically created bony defects in the skulls of patients. He had documented that when subjects engaged in tasks such as mathematical calculations the pulsations increased in the concerned cortical areas. Such findings made him conclude thoughtfully that, cerebral blow changed in response to function [2]. Mosso has been called as the Da Vinci of modern brain science. The actual physiological relationship between cerebral function and blood flow was first investigated by Charles Roy and Charles Sherrington in 1890[3]. After a long quiescent period interest in brain mapping was resumed when Fulton reported the presence of a bruit from the occipital cortex in a patient during dark adaptation.

Pneumoencephalography was a brain mapping technique used by neurologists and neurosurgeons until the arrival of CAT scan to localize mass lesions such as tumours and blood clots in and around the brain. This was discovered by Dandy in 1919[4].The technique consisted of replacing spinal fluid with air and taking x - ray contours of the brain with the patient in the upright position. Patients often complained of intense headaches after the procedure and needed very experienced professionals to treat them.

EEG OR electroencephalogram discovered by Hans Berger in 1924 is the summated electrical activity of various neurons and is widely used to diagnose various disorders particularly epilepsy based on the frequency, amplitude and the site of origin of brain waves[5].But EEG has the disadvantage of limited spatial resolution. Quantitative EEG (qEEG) is a method of analyzing the electrical activity of the brain to derive quantitative patterns that may correspond to diagnostic information and/or cognitive deficits[6].qEEG has been used for a variety of clinical disorders such as post-concussion syndrome, schizophrenia, depression, mild-to-moderate head injury, learning disability, attention deficit disorders, psychotic states, and substance abuse. In fact the first original brain mapping was by qEEG, which was developed in the 1960's where the EEG is subjected to spectral analysis using digital computers.

In 1971, Hounsfield introduced the three dimensional transaxial tomographic images of an intact object by passing highly focused X-raybeams through the object and recording their attenuation. This was a welcome technique for brain mapping but had the demerit of giving only anatomical details.

The first quantitative method to measure cerebral circulation and brain metabolism in humans was developed by Kety in 1948[7].But Kety's discovery was not suitable for brain mapping since it did not consider the local variations.But their introduction to in vivo tissue autoradiographic measurement of regional blood flow in laboratory animals [8,9]provided the first quantitative evidence of co-relating brain function with regional changes in cerebral blood flow.This discovery laid the foundation of PET many years later.

The signals received with PET [Positron emission tomography]and fMRI are due to the changes in circulation, oxygen uptake and glucose consumption that interestingly co -relate very precisely to the cellular activity of the brain, both neurons as wells as glia. In PET,the brain mapping technique discovered in 1975, radiotracers in tissue provided a means to quantify the spatial distribution instead of invasive

autoradiography.Most of the functional brain imaging with PET and MRI, along with the earlier non tomographic techniques, is because of local changes in the cerebral circulation as a consequence of cellular activity [10]. Deoxygenated haemoglobin found in veins disrupts the magnetic field which helps to deduce images.

The utilization of glucose as a metabolite during cognitive or psychomotor tasks laid thefoundation for functional magnetic resonance imaging [fMRI] after 1986.BOLD[blood oxygen leveldependant]-fMRI is a technique for determining the parts of the brain which are activated by various types of stimuli (sight, sound) or by performing cognitive tasks[11]. A sequence of MRI scans, detect the enhanced blood flow to the activated areas of the brain.

Some of the more recent techniques are immunohistochemistry and nanotechnology. Immunohistochemistry is the process of imaging antigensselectively through their binding with antibodies tagged to fluorescein or peroxidise and visualising the antigen-antibody reaction [12].This brain mapping method helps in the study of functional histology of individual neurons.
This method can be specifically used in the diagnosis and prognosis of CNS tumors and other disorders requiring histopathological studies. Optogenetics utilises neuromodulation techniques, such as using light to modify activity of neurons and express light sensitive ion channels.

Nanotechnology is manipulating atoms or molecules present in neurotransmitters [13].Therefore the change in neurotransmitters can be tracked temporally, example tracking a molecule of dopamine.This brain mapping technique requires a receptor that can attach to the nanoscale sensor and emit light or electric signals

To conclude brain mapping is a fast developing field in neuroscience which helps us comprehend the functioning of the brain in normal as well as many pathological conditions. Newer developments may throw light on the disease process as well as the management of many intractable neurodegenerative and psychiatric disorders.

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