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Micro-Neuro-Sensor Recording of STN Neurons of the Human Brain

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Abstract-What cause to the neurons of the human brain cells when they are damaged. They become inactive. So damage to subthalamiuc ucleus (STN) neurons of the human brain causing larger involuntary movements and thereby attacking the Parkinson's disease (PD). Deep brain stimulation (DBS) of bilateral sub thalamic nuclei (STN) is an efficient method of rehabilitation technique in subjects with advanced idiopathic Parkinson's (or Parkinson) disease. Accurate targeting of STN neurons and placement of microelectrodes/ (neurosensors) are paramount importance for optimal results after STN-DBS method.In this paper, microminiaturized electrode recordings (MER) of STN neurons were detected in a mean of 3.5 ±1.1 channels on right hemisphere and 3.6 ±1.04 on left hemisphere.Final channel selected were most commonly central seen in 42.3% followed by anterior in 33.7%. When a high current is delivered to STN or GPi neurons of basal ganglia (a component of human brain), causing their inhibition and improved indication of symptoms. It is now known that there is a significant change in the firing pattern and a reorganization of the entire basal ganglia circuit with DBS. The MER of STN neurons has identified a specific high frequency irregular larger amplitude firing patterns seen only in disease states and hence used to detect the neurons of ST nucleus during functional surgery. Microelectrode recording is so useful to confirm the right path but has to be taken in consideration with effects on macro stimulation.

Keywords- Micro NeuroSensor Recording, SubThalamic Nucleus (STN), Deep Brain Stimulator (DBS), Target Neurons.

I. INTRODUCTION

Human brain contains billions of trillions of neuronalcells. Neural signals of such brain cells are massively curved data streams (signals and images) contain information about the understanding brain activity. Specifically, movement and movement intentions are encoded in the motor cortex, cerebral cortex and brainstem regions. Basal ganglion is central area of the brain with distinct circuits that link many parts of brain (Fig 1). Its functional architecture is parallel in nature and characteristic of the organization within each individual circuit. It is interlinked with several neurons of cerebral cortex, thalamus, brainstem, and at several other areas of brain coupled with a variety of functions, such as motor learning, control-of-voluntary motor-movements, procedural-learning, routine-behaviors-of-habits (bruxism), eye-movements, action [1]-[3], etc.

Experimental—studies shown that the basal-ganglia exert an inhibitory influence on a number of motor neuron systems, and that a release of this inhibition permits a motor neuron to become active. The behavior switching that takes place within basal ganglia is influenced by voluminous signals (big data) of motor neurons from many components of the brain, including prefrontal cortex which plays a fundamental key role in executive functions.

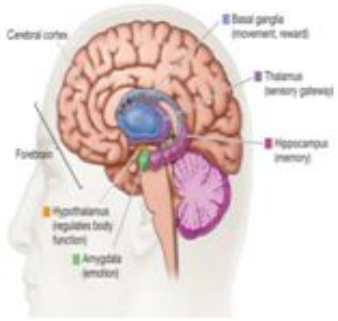

Fig. 1 Basal ganglia its parallel linkages to the five intellectual parts of the complex circuit of human brain.

During last quarter century, there were many models proposed on basal ganglia. The models [4][5] propose that hyperkinetic movement disorders (dystonia) are distinguished from hypokinetic movement disorders (Parkinson disease) based on the magnitude and pattern of the BG output (o/p) neurons in the globuspallidus-pars-interna(GPi) and substantianigra pars reticulate (SNpr, is the source of striated i/p of neurotransmitter dopamine plays significant role in BG function) [3]-[8]. DBS electrodes have been placed technologically by employing frame-based stereotaxy with MER and physiological mapping of target structures [12]. DBS is a stereotactic based computer aided functional neurosurgery and STN neurons cannot be clearly visualized on MRI/fMRI and the targeting based on Loznos Method is indirect and so MER gives proof of correct pointing of the electrodes for the target neurons. Thus, MER confirms the presence of (abnormal) STN neurons [6]-[12].

II. AIMS AND OBJECTIVES

The primary purpose of STN DBS is to augment the suggestive of symptoms control. To develop a computational modeling, and using the modeling design a new clinical experiment to record big-data of neurons of human brain with indigenously developed instrument, and to study the effectiveness of microelectrode recording in determining the final tract for placing DBS electrode during bilateral STN neurons. Finally to study the correlation of microelectrode recording with the final tract chosen during bilateral STN DBS performed at a tertiary care center—specialized hospital in South India.

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III. DESIGN METHODS AND TECHNIQUES

46 subjects with diagnosis of PD as per United Kingdom Parkinson disease society brain bank criteria were included. All the subjects were willing to undergo the procedure and fulfilled the following criteria to be eligible for STN-DBS i.e., they had disease duration of 6 years or more, good response to levodopa, able to walk independently in drug "on" state and had normal cognition. Surgery was performed in all by a qualified neurosurgeon. Stereotactic targets were acquired using a specialized system with a stereotactic frame (CRW) which has a luminant MRI localizer. The targeting was performed according to Lozano's technique – 2mm sections are taken parallel to the plane of anterior comissure-posterior commissure line and at the level with maximum volume of red nucleus, STN is targeted at 3 mm lateral to the antereolateral border of red nucleus.The co-ordinates are entered into a stereo-calc software which gives the co-ordinates of the STN.

Another neuro navigation software –frame link is also used toplot the course of the electrodes and to avoid vessels. The surgery is performed with two burr holes on the two sides based on the co-ordinates. Five channels with are introduced with the central channel representing the MRI target while medial (nearer the centre) and lateral (away from the centre) are placed in the X- axis while anterior(front) and posterior (back) are placed in the Y- axis to cover an area of 5 mm diameter.

Intra-operative recording was performed in all 5 channels. All five microelectrodes are slowly passed through the STN and recording is performed from 10mm above to 10mm below the STN calculated on the MRI. STN IS identified by a high noise with a large baseline and an irregular discharge with multiple frequencies. For each neuron of STN, the DBS stimulation was done with 130Hz frequency – the electrical pulses per second (PPs), 70 microsecond pulse width and voltage response was seen with increasing amplitude and the best responded channel was chosen (whichever channel shows the best response, that was chosen) the first level of MER recording was used to determine the depth of DBS electrode placement, i.e., if the recording starts at -5 level, the lead was placed from that level.

Tungsten microelectrode (polyamide coated of Medtronic, impedance 1.1±0.4MegΩ (MegaOhm) measured at 220 Hz at the beginning of the each trajectory) . The waveforms/signals were recorded with the amplifiers of the Lead point system of Medtronic using bootstrapping principle and were analog band-passed filtered between 0.5Hz to 5kHz, variable gain - 3dB, 12dB/oct. The signals were sampled at 12kHz with a 16-bit A/D converter and later up sampled to 24kHz.The following techniques were used - Stereo tactic assessment, Intra-operative microelectrode recording and intra-operative stimulation, CRW frame and Frame link software.

IV. RESULTS AND DISCUSSION

The STN was identified by a high noise with a large baseline and an irregular discharge with multiple frequencies (Fig 2, neurons 3, 4, 5, and 6) and was distinguished from the dorsally located zonaincerta and lenticular fasciculus by a sudden increase in background noise level and increase in discharge rate typically characterized by rhythmic bursts of activity with a burst frequency between 10 to 30Hz. Deeper in to the STN rhythmic burst activity shifted to higher frequencies lying between 30 to 60Hz. And there were more irregular firing patterns were observed

The channel with maximum recording and the earliest recording were recorded on both sides. Intraoperative test stimulation was performed in all channels from the level at the onset of MER recording. Stimulation was done at 1mv, 3mv to assess the improvement in bradykinesia, rigidity and tremor. Appearance of dyskinesias was considered to be associated with accurate targeting. Side effects were assessed at 5mv and 7mv to ensure that the final channel chosen had maximum improvement with least side effects.We assessed the role of microelectrode stimulation in selection of the final channel. Compared to the anatomical localization based on MRI where the final tract was seen only in 42.3% the microelectrode recording was associated with final channel in 64 %. This is similar to a previous study wherein by using MER, an average pass through the STN of 5.6 mm was achieved compared to 4.6 mm if central tract was selected as per imaging . [11]

MER by itself is not a complete tool to clearly differentiate the optimal target as the line of the DBS lead may not correspond to the axis of the STN. Further the impedance of the microelectrode may vary as they may be influenced by the brain tissue and may not show a clear recording.Still MER definitely confirms the clear position of the electrodes and bolsters the confidence of the neurosurgeons that they are in the target. Further the availability of microelectrode recording results in a vast data regarding the functioning on the neurons situated deep in the brain and may help in further unscrambling the mysteries of the brain.

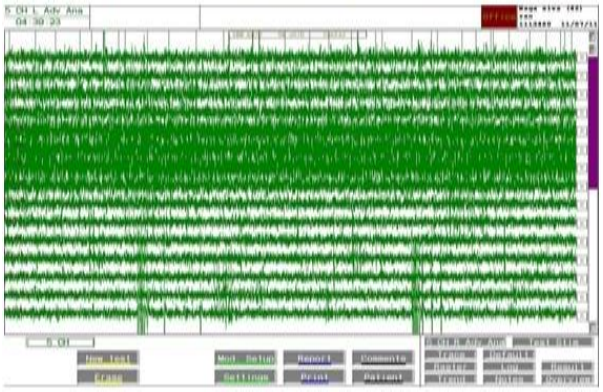

Fig. 2 The signal patterns of STN neurons for various depths. The STN was detected by a high noise with a larger baseline and an irregular discharge with multiple frequencies. It may be noted that the superficial part of the STN is recognized by an increase in background noise and a sudden increase in discharge rate characterized by the rhythmic bursts of activity withhigher frequencies (neurons 3, 4, 5, and 6). Deeper layers of STN showing high frequency irregular patterns.

The following Figure (3) obtained by the MER shows the microelectrode recording which is obtained from STN nucleus.

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Figure 3 –Picture of the microelectrode recording –the panel in the top left shows recording in a single level in a single channel; bottom left shows microrecording in central channel and shows the typical firing pattern with irregular firing and broad baseline noted from -1.00 level; the top right shows the typical histogram frequency and the Fast Fourier Transformation (FFT) graphs of a typical STN neurons.

V. CONCLUSIONS

Correlation was assessed between the aspects of MER and the final channel chosen in 46 subjects (92 sides).Microelectrode recording is so useful to confirm the right path but has to be taken in consideration with effects on macrostimulation. Future research involves recording of the GPi, GPe, SN, SNpc, and other neurons of basal ganglia and the analysis of those data will yield the better diagnosis which is highly beneficial to medical doctors/surgeons, neurologists and radiologists. And also it is more helpful to model, to simulate the MER signals.

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