



Editorial

Neurochips: Considerations from a neurosurgeon's standpoint

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ABSTRACT

A neurochip comprises a small device based on the brain-machine interfaces that emulate the functioning synapses. Its implant in the human body allows the interaction of the brain with a computer. Although the data-processing speed is still slower than that of the human brain, they are being developed. There is no ethical conflict as long as it is used for neural rehabilitation or to supply impaired or missing neurological functions. However, other applications emerge as controversial.

To the best of our knowledge, there have not been publications about the neurosurgical role in the application of this neurotechnological advance. Deliberation on neurochips is primarily limited to a small circle of scholars such as neurotechnological engineers, artists, philosophers, and bioethicists. Why do we address neurosurgeons? They will be directly involved as they could be required to perform invasive procedures.

Future neurosurgeons will have to be a different type of neurosurgeon. They will be part of interdisciplinary teams interacting with computer engineers, neurobiologist, and ethicists. Although a neurosurgeon is not expected to be an expert in all areas, they have to be familiar with them; they have to be prepared to determine indications, contraindications and risks of the procedures, participating in the decision-making processes, and even collaborating in the design of devices to preserve anatomic structures. Social, economic, and legal aspects are also inherent to the neurosurgical activity; therefore, these aspects should also be considered.

Keywords: Brain-machine interface, Cyborg, Human enhancement, Neuroethics, Neuromorphic chip

INTRODUCTION

A neurochip, or neuromorphic chip, is a small implantable device in the central nervous system that may allow the interaction of certain areas of the brain with a computer. The neurochips have brain-machine interfaces (BMIs) that emulate the functioning of synapses; although the data-processing speed is still slower than that of the human brain, they are being developed.^[27]

Discussions about neurotechnology are predominantly limited to a small circle of academics such as neurotechnological engineers, science fiction enthusiasts, artists, philosophers, and bioethicists. Why do we address neurosurgeons? Because they will be directly involved; neurosurgical skills will be necessary and will be required to perform procedures.

It seems reasonable from a neurosurgical point of view, starting to reflect about the participation of neurosurgeons in interdisciplinary teams, providing the concepts of medical indications,

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contraindications, decision-making process, techniques to prevent or reduce complications, and even participating in the design of devices to preserve normal structures. Consideration of social, political, economic and legal aspects of invasive procedures are also inherent to the neurosurgical activity and these aspects should be taken in consideration.

To the best of our knowledge, there have no been publications about the neurosurgical role in the application of this neurotechnological advance. The aim of our communication is to promote reflections and debate between neurosurgeons to anticipate the scenarios to come.

TECHNOLOGICAL EVOLUTION OF ARTIFICIAL SYNAPSES

The functional basis of the system is an artificial synapse unit composed of what is known as “memristor” or memory resistance. First descriptions date back to 1808 by Sir H. Davy, and to 1960 by B. Widrow who in fact coined the term memristor to describe the components of an artificial neural network. Subsequently, numerous technical experiences were carried out until León Chua considered a new element of two terminal circuits with a link between the electrical charge and the magnetic flux.^[7,44]

Modern memristors have excellent qualities, can reproduce the mechanism of synapses, and can be adapted to the technical requirements of the neuromorphic computing systems.^[6,20,40] The most advanced prototypes of memory circuits and architectures are so fast that some memristors and new BMI make it possible to modulate brain activity.^[1,27,31,38] Musk and Neuralink have reported an experimental neurochip based on the properties of these modern memristors that can process the brain activity, through the functional measurement of millions of neurons and their synapsis, allowing communication channels with the environment^[27] [Figure 1]. The system is capable of translating the nervous system activity into real interaction; for example, could provide a sense of touch or proprioception to modulate the movement of a prosthetic limb of the human body.

IMPLANTATION OF THE DEVICES

The minimally invasive implantation of the devices has been proposed through stereotactic with robotic guides in a similar way to deep brain stimulation (DBS)^[27] [Figure 2]. Inherent complications of the invasive procedures such as scars, glial reactions, infection, or bleeding should be expected; and also, as it happens with DBS, could have technical limitations to maintain a stable interface between electrodes for a long time.^[19,21,22,25,27,37]

To minimize risks of the implantation procedure, Raza *et al.* are studying other ways to reach the brain utilizing the

endovascular connection.^[34] Endovascular neuromodulation is an emerging technology that represents a synthesis between interventional neurology and neural engineering. The prototypical endovascular neural interface is a stent-electrode array which can be implanted into the superior sagittal sinus through percutaneous catheter venography, and transmits signals through a transvenous lead to a receiver located subcutaneously in the chest. Given the proximity of cerebral vessels to numerous important brain regions, the cerebrovascular system is a promising conduit for a neural interface. Although a transvenous lead has never been previously implanted in the human brain, lessons about the safety and design characteristics of transvenous leads can be taken from the literature on cardiac electrotherapy devices. The intracranial venous system represents a promising field for neuromodulation devices. The ongoing SWITCH trial, which will test the feasibility and safety of stent-electrode array in five patients over a follow-up period of 12 months is expected.^[28,34]

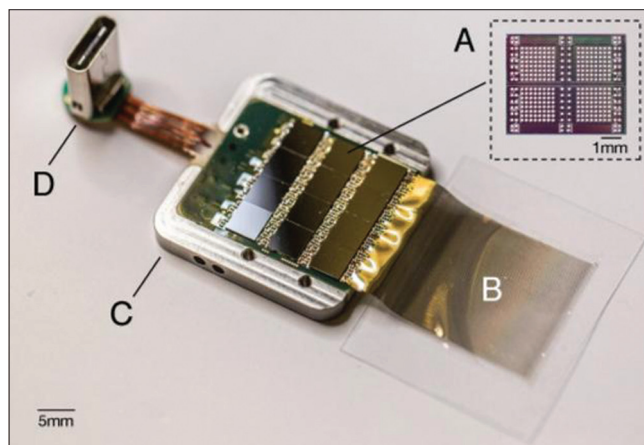


Figure 1: Neurochip (obtained from Neuralink-Internet).

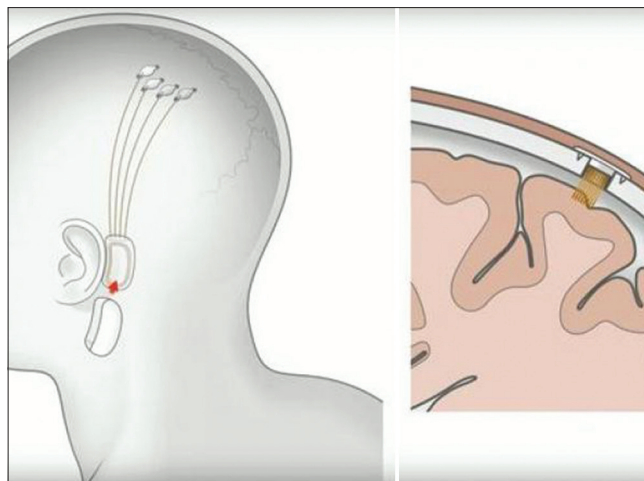


Figure 2: Schema to show how is expected to look the neurochip implantation in human brain (obtained from Neuralink-Internet).

Moreover, it is not completely unrealistic to speculate about the contribution of the nanotechnology in the future design of the brain implants and endovascular devices.

FUTURE DIRECTIONS OF NEUROCHIPS APPLICATIONS

The BMI using neuromorphic chips is maintained at an experimental level; technology is not completely developed yet but it is evolving. Future directions of neurochips' applications are based on the results of the following well known technological procedures: DBS, invasive non-DBS implants, and the noninvasive transcranial magnetic stimulation (TMS).

DBS was traditionally performed to relieve a variety of neurological symptoms refractory to medical treatment (pain, tremor, severe depression, obsessive compulsive disorder, anorexia, disorders of consciousness, the use of brain signals to control a prosthetic arm for motor assistance in cases of quadriplegia, terminal phase of lateral amyotrophic sclerosis, or the locked-in syndrome).^[4,8,9,11,15,24,26,29]

Invasive non-DBS implants were also used for many years. For example, cochlear implants for partial restoration of hearing can under specific circumstances, such as in a very noisy environment, endow the patient with better than human hearing capabilities, when the microphone and software of the cochlear implant can filter out human voices from background noise; bionic eyes for retinitis pigmentosa to partially restore vision.^[16,22,39] Some controversial uses of implants are to obtain new sensory perceptions such are the cases of the cyborg artist Neil Harbisson and the dancer Moon Ribas.^[12,18] Harbisson was born completely color blind, but with an antenna implanted in his skull translates colors to sounds; but also he perceives infrared and ultraviolet light that are not part of the human visual spectrum. Another example is the dancer Moon Ribas, a woman who has implants connected to online seismographs in her feet; any time there is an earthquake somewhere on the planet, vibrations course through her body and the data are recorded online; then she can transform that data into dance.^[12,18]

The other technological advance that has provided a basis for future applications of neurochips is the experience with noninvasive TMS. Nowadays, it was used to treat some difficulties in learning; in other cases are simply used to experiment new experiences, or even to obtain pleasure, for example, increasing erotic experiences.^[9,12,18,21,35,36,39,43] A promising and exciting field of TMS is the medical application of personalized drug release responding to external commands (magnetic fields, temperature, or biochemical signals) for the management of oncological or metabolic diseases.^[5,10] Particular attention should be paid to a research that is being performed in animals connecting the brain of rats through the network.^[23,30,45,46]

DBS, invasive non-DBS, TMS, and neurochips share the objective of improvement the people's quality of life, but neurochips would speculatively have the advantage of an expected more sophisticated neuromodulation.

NEUROETHICAL CONSIDERATIONS

There would not be ethical conflict in the use of neurochips for rehabilitation purposes to replace or improve missing or impaired neurological functions. Negative ethical aspects would undoubtedly lead to its use for manipulation or other despicable reasons. Neuroethical conflict may arise when gray areas appear; when the objective is not to cure or rehabilitate but to seek for neurocognitive enhancement or new modalities of sensory perceptions.

Some questions naturally arise such as what would be the long-term effects on the human brain? Who would regulate the improvement? Who would be chosen for their application? And in any case, who would cover the costs? Would this increase of cognition or perceptions be for everyone? or just for some?^[33,43]

There are also concerns about the way in which these devices could affect the basic aspects of the human being: autonomy, free will, responsibility, intentionality of the acts; allowing to question the moral values of cyborgs in our society.^[13,14,21,32,41] Regarding legal and moral features, should they be considered as a kind of new subspecies?^[14,42]

The impacts of neurotechnology in the near future have been foreseen in 2013 by the European Commission for Emerging Technologies which supports the Human Brain Project, and also by the National Institutes of Health that simultaneously started the Brain Initiative (Brain Research through Advancing Innovative Technologies).^[3,17] Both projects have dedicated millionaire budgets to support the research on neurotechnological advances; and both have included Neuroethics Counselling Committees anticipating their previsible consequences.^[2,3,17]

Science neither stops nor moves backwards and its progress has acquired an accelerated rhythm. Therefore, these issues require reflections that may help neurosurgeons to act responsibly in a new and constantly changing environment. Perhaps worldwide ethical recommendations should be anticipated by the neurosurgical community, even in collaboration with the WHO, considering the possible impact of the neurochips on the multiple dimensions of the human being.

FINAL REFLECTION

Neurosurgery is facing new challenges. The future neurosurgeon will have to be a very different type of neurosurgeon, a master of many fields. The neurosurgical societies, and especially directors of training programs,

should prepare young doctors to anticipate these kinds of neuroethical issues.

Declaration of patient consent

Patient's consent not required as there are no patients in this study.

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Conflicts of interest

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