Abstract — Magnetic stimulation has gained relatively wide application in studying nervous system structures. This technology has the advantage of being a non-invasive technique of stimulating neural tissue, causing minimal discomfort. In the latest years, the interest for magnetic stimulation has grown considerably because the method has proven utility and applicability both in diagnostic and treatment. This paper presents the evaluation of nerve pathway integrity using magnetic stimulation for a patient with spinal cord injury. The experiment was conducted by the authors at the Medicine University of Vienna.

Keywords: magnetic stimulation applications, TMS.

1. INTRODUCTION

Magnetic nerve stimulation is a painless method for cortical stimulation or for the activation of deep lying peripheral nerves. The excitation of neural tissues by means of time varying magnetic fields (magnetic stimulation) is attracting more and more attention both as a clinical and a research tool. Worldwide this method is clinically applied (or is in advanced stages of testing) in cases as [1], [2], [3], [4], [5], [6]:

• Early diagnosis of neurological degenerative diseases (Parkinson, sclerosis);
• Creation of a functional map of the brain, by stimulation of different parts of the cortex and registration of the responses. Nowadays, TMS (Transcranial Magnetic Stimulation) proves to be useful in the study of neurological and psychical diseases. TMS is important because it can prove causality in neurosciences and represents a powerful cartographic instrument for the functions of the brain. It can be used for the study of the organization of the brain in terms of centers used for different functions - like language, memory, attention, etc. TMS does not have the disadvantages of functional magnetic resonance which allow identification of different regions during an activity, but does not prove that the region is used for that specific task. TMS can suppress activity in associated regions, leading to reduced performances in fulfilling certain tasks, which is a strong proof for the implication of certain zones in solving certain tasks. Especially interesting for TMS would be to use it on healthy subjects to confirm / infirm the supposition according to which this technique would increase certain mental abilities and even creativity;
• Determination of neural track integrity after a trauma (a stimulating coil placed near the head of healthy human individual generates hands spasms, indicating the integrity of the neural track from brain to the hand);
• Treatment (treatment of depression, insomnia; stimulating the upper thorax nerves and cervical ones, in order to enlarge the volume of inspired air and, this way, ameliorating the respiratory function for patients with cervical tetraplegia; treating patients with urinary problems as a result of spinal cord injury; stimulating cortical areas for recuperating different patients with dysfunctions after vascular accidents, etc.).

Being a new medical instrument, scientific research in this domain continuously brings substantial improvements, especially by controlling the stimulus’ parameters (amplitude, duration) and by accurate stimulus localization. Even though, in Romania, this technique is still not used in medical units, many studies proposed solutions for the coils’ design, in order to improve focusing and energetic transfer from the stimulator to the target tissue.

The paper starts by emphasizing the principle of magnetic stimulation, and then advantages and disadvantages of this stimulation over the electrical stimulations are presented. Using an experimental study, the neural track integrity from brain to the entire body is determined, for a patient with spinal cord injury and the muscles response is recorded using electromyography. At the end, some important conclusions are drawn.

2. PRINCIPLE OF MAGNETIC STIMULATION

The physical phenomenon of magnetic stimulation is based on electromagnetic induction principle, discovered by Faraday, and is a method for stimulating excitable tissue with an electric current induced by an external time-varying magnetic field produced by a coil. Its principle is illustrated in Figure 1:
Figure 1. The concept of magnetic stimulation of a nerve fiber according to Faraday’s law.

Starting from the electromagnetic induction law, because the magnetic field is a field without sources, one can define the magnetic vector potential \( \vec{B} = \nabla \times \vec{A} \), and the electric field vector is given by:

\[
\vec{E} = -\frac{\partial \vec{A}}{\partial t} - \nabla V
\]

This electric field induced in the tissue has two components: a solenoidal component and a second component that it is due to the electric charge accumulation at the air–tissue surface. The field in the conductor medium is computed by integrating the two field components over the entire outline of the coil:

\[
\int \int \vec{E} \cdot d\vec{l} = \frac{1}{R} \int \vec{E} \cdot d\vec{l}
\]

3. **(Dis-) Advantages of Magnetic Stimulation**

As no direct contact of the stimulating coil with the skin is needed, the magnetic stimulation offers the following advantages over electrical stimulation [7]: painless stimulation is possible, as no current is passing the skin. The magnetic field readily passes even high resistive layers, as for instance the skull. This opens up new possibilities for cortical and peripheral stimulation.

Despite being a stimulation method causing less discomfort, magnetic stimulation also has a few disadvantages compared with electrical stimulation. The equipment is expensive and the high power dissipation heats up the coil and makes it difficult to achieve fast repetition rates of the stimulus. However these are engineering problems which might be overcome in the near future. The most important drawback of magnetic stimulation is the uncertainty about the actual stimulation site. This is due to the relatively large dimensions of the coils, which makes it difficult to achieve a focused region of high electric field strength. Specially shaped coils or multiple coil designs might help to obtain a better defined stimulation site. Combination of circular coils – butterfly, four leaf, eight coil or slinky coil – has been imagined to obtain a better focalization and an increasing energy.

4. **Experimental study**

4.1. **Materials and method**

Functional magnetic stimulation of the spinal nerves has recently developed as a useful therapeutic tool in patients with spinal cord injury. Our experiments were (AKH).

The team was composed by researchers from the Medicine University of Vienna and from the Technical University of Cluj-Napoca.

The patient, who took part at the experiment, agreed that the data can be used for the scientific research. The patient suffered by paraplegia of the inferior limbs and the aim of the test was to evaluate the integrity of the nerve pathways and to localize possible interruptions. In medicine it is well known that the complete detachment of a nervous bunches from the central nervous system damages those nerves, because these are not fed any more. The existence of the nervous pathways in the human body, even if these are not directly connected with the brain and cannot be controlled by it, is very important especially when the patient is subduing to functional stimulation therapeutic procedures. Thus, when the nervous pathways are still working, the used devices will directly stimulate the nerve, which is easier to activate than the muscle (the amplitude of the applied voltage impulse is reduced). When the nerve is permanently damaged, the only stimulation possibility aims to activate the muscles.

Figure 2-a) explains the principle of the experiment: a stimulation coil is placed over the head for TMS. The nervous impulse generated in that area is propagated through nervous pathways to the hands and legs, commanding muscular contractions. The muscular response was recorded through electromyography.

In Figure 2-b) we observe the positioning of measurement electrodes on the patients body.
coils (circular, rectangular, etc.) [8]. This leads to precise stimulation, in any area of the motor cortex. Figure of eight coils induce an electric current in a specific area of the brain, as somatosensitive cortex or occipital cortex [9].

First, we perform transcranial magnetic stimulation and then lumbar magnetic stimulation (stimulation coil placed in that area); the response was recorded using an electromyography.

4.2. Results and discussions

For the TMS, electrodes were placed in following locations (in the right -R- and left -L- side of the body): the biceps brachial muscle (RBIC and LBIC), the adductor muscle of the palm big finger (abductor policies brevis – RAPB and LAPB), the right abdominal muscle (RABD and LABD), the muscles of the vertebral ditches - lumber level (RPARS and LPARS), the quadriceps thighbone muscle (RQ and LQ), the biceps thighbone muscle (Hamstring – biceps femora, RH and LH), the muscles of the anterior shank group (tibia anterior – RTA and LTA) and the triceps surae muscle (the posterior shank muscles – RTS and LTS).

In Figure 4 some electromyographical recorders, during the TMS, are shown.
The muscular response registered on the left muscle tibia anterior is presented in Figure 5-a) and 5-b). The investigated patient had a spinal cord lesion, which made the muscular response from the TMS to be null - Figure 5-a). On the other hand, after lumbar magnetic stimulation (stimulation coil placed in that area), the muscular response is present – Figure 5-b). In this way we can identify the area where the nervous pathways have lesions. Also, the conduction speed can be determined in the same way, speed which can be an important indicator of the health of the patient.

5. CONCLUSIONS

Through this experiment one can concluded that the investigated patient has a spinal cord injury, so he cannot control his inferior limbs. The nerves from this area are still connected at the central nervous system, because they record a response during the lumbar stimulation. In this case, the patient could be electrical stimulated, this stimulation acting directly over the nerves and not over the muscles.

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7. REFERENCES