Light assists in monitoring brain injuries

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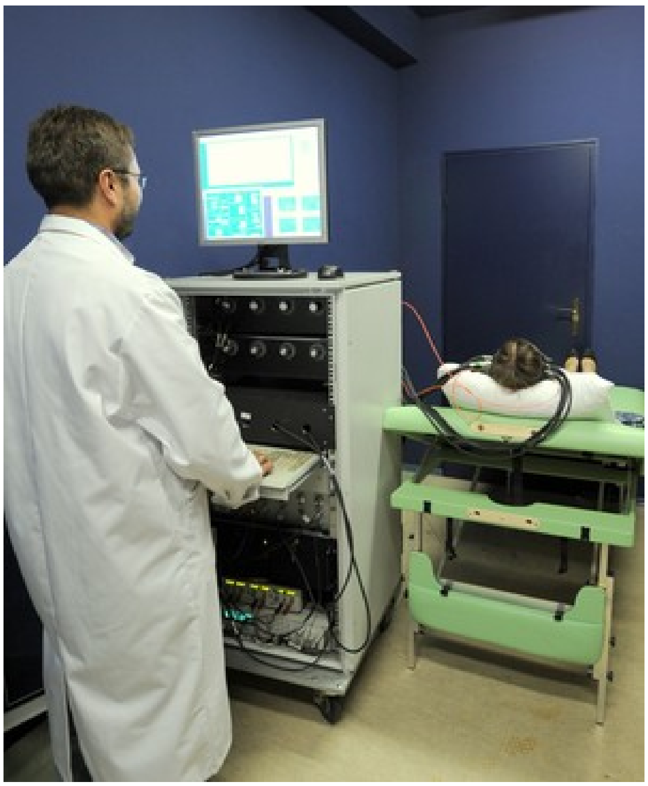

The information about alterations in cerebral perfusion is of crucial importance in treatment of patients with severe neurological injuries. The medical equipment used in clinics does not allow, however, for continuous measuring of brain activity in critically ill patients. This may change – due to an instrument allowing for assessment of brain perfusion with light that is being developed at the Institute of Biocybernetics and

Biomedical Engineering of the Polish Academy of Sciences.

Light will enable physicians to gain information about alterations in brain perfusion in critically ill patients, as follows from the research conducted at the Institute of Biocybernetics and Biomedical Engineering of the Polish Academy of Sciences (IBBE PAS) in Warsaw. Earlier work on optical methods for brain perfusion analysis, carried out in clinics worldwide, yielded ambiguous outcome. "The results of our research have been obtained with advanced optoelectronic equipment are more convincing", says Dr Adam Liebert, professor at the IBBE PAS.

The work on the instrument for brain perfusion assessment has been initiated at the IBBE PAS by Prof. Roman Maniewski as early as in the 1990s. At present, the research is continued by the team headed by Prof. Liebert.

Optical methods for brain monitoring make use of the fact that skull bones are to some extent transparent for light, in particular from the near infrared range, with wavelengths between 650 and 850 nanometer. The properties of hemoglobin are of essential importance here, and especially the fact that oxygenated form of hemoglobin interacts with light differently than the reduced form. The phenomenon allows for estimating the degree of oxygenation in the observed region of the body by analysing the intensity of light penetrating the tissue.

The essential elements of optical diagnostic devices are small light sources (laser diodes) and highly-sensitive detectors. The sources and detectors, usually placed at a distance of 2-5 cm from each other, are paired. Simultaneously, from a few to over a dozen of such pairs can be put at the patient's head, which potentially allows for examining a substantial part of human brain. Signals recorded by the detectors are transmitted via optical fibres to photomultipliers. After amplification, they are transmitted to a PC equipped with cards allowing for counting single photons.

"The volume penetrated by light inside the skull resembles a banana in shape, with one end at the light source, and the other at the detector. At the place where the depth of photon penetration in the skull is at its maximum, we reach the cerebral cortex. This means that a fraction of recorded photons has interacted with hemoglobin from the blood circulating in blood vessels of the external layers of the brain", explains Prof. Liebert.

The researchers have recently carried out measurements for a record-breaking distance between the light source and the detector, equal to 9 cm. The brain perfusion was assessed using indocyanine green – a low-toxic optical contrast agent, well known in the clinical environment. The contrast agent was administered in patients by intravenous injection during the measurement.

Optical signals recorded during the monitoring of brain activity not only provide information on what's going on in the cerebral cortex, but are also contaminated by data originating from perfusion of extracerebral tissues, including skin. There are a few methods for separating the information originating from intracerebral tissues from undesired interference signals. The instrument from the IBBE PAS is among the most technologically advanced devices, recording the time of flight of single photons in the tissue. In this technique, the light source emits many short (picosecond) light pulses. The longer time between photon emission and detection means the higher chance that the photon has interacted with deeper intracranial tissue structures – and so with the cerebral cortex.

"In the highest resolution, the images of both brain hemispheres obtained with our instrument consist of 32 pixels corresponding to source-detector pairs on the surface of the head", says Daniel Milej, a PhD student at the IBBE PAS, and explains: "A not high spatial resolution is due to physical constraints. In optical observations of the brain, the phenomena related to light scattering dominate those resulting from light absorption. That's why the resolution of these images is significantly lower than that of tomography-based medical imaging methods".

It is, however, not only the image resolution that decides about the usefulness of the equipment. The primary advantage of the instrument from the IBBE PAS is that the measurements are non-invasive. Light emitted by laser diodes is absolutely safe and does not induce changes in tissues. Equally important is the simplicity of examinations. The measurement requires only that a cap with fixed optical fibres is placed on the patient's head and the patient is injected with a small dose of a contrast agent. The very examination lasts for a few minutes only and can be repeatedly carried out during the day. Moreover, the size of the measurement equipment in a lab, and so in a still non-miniaturised version, resembles a refrigerator. It is mobile and applicable at the bedside, even in critically ill patients treated in intensive care unit environment. It can also be used in an operating room.

The advantages of optical methods of brain observation are obvious when compared with other imaging techniques used in hospitals. Computer tomography and magnetic resonance require large, stationary equipment. The patient must be transported to special diagnostic rooms, which often results in necessary disconnection from other medical equipment. In addition, the patient must be immobilised and the examination is expensive. In practice, the hospitals do not have any equipment that would allow for a continuous bedside monitoring of alterations in cerebral microperfusion.

In collaboration with the Medical University of Warsaw and the Praski Hospital Department of Intensive Care in Warsaw, the researchers from the IBBE PAS have recently carried out optical measurements of brain perfusion in patients with post-traumatic brain injuries. Patients with cerebral edema and subcortical hematoma were included in the study. In both cases, differences with respect to signals collected in healthy volunteers have been observed. The results of the research have been recently published in a reputable *NeuroImage* journal.

"The possibility of continuous monitoring of the brain perfusion parameters may be of key importance in treatment of patients with severe neurological injuries. The results of our work suggest that the optical method can be useful in clinical practice", says Dr Wojciech Weigl, an anaesthesiologist who coordinated clinical studies on the new measurement method. Further studies are, however, needed before the instrument from the IBBE PAS could be delivered to hospitals and clinics.

Provided by IBIB

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