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Research Article

Laser Therapy and Stroke: Quantification of Methodological Requirements in Consideration of Yellow Laser

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Every year more than 600,000 Europeans suffer a stroke. This burdens the health system and it can be assumed that the incidence of stroke will increase in the coming decades. In addition to conventional methods of drug therapy, stroke is sometimes treated with highly invasive methods. The non-invasive laser procedures on the other hand operate through the bony skull. Large-scale laser studies are being conducted with varying degrees of success around the world, and without the certainty that the corresponding laser beam even penetrates the bone. No one currently knows in detail the laser parameters that have to be chosen on the intact skull; so that the laser light can develop its possible efficacy inside the human skull. The present study demonstrates that the values for the wavelengths 810 nm and 658 nm correlate well with previous experimental findings however the information on the yellow laser was estimated incorrectly by a factor of ten by other authors. Further research on the topic is important so that one can be sure to apply the correct wavelength and parameters. This can open up new dimensions in transcranial laser therapy, not only in stroke patients.

1. Introduction

There are various treatment methods, which should lead to the improvement of clinical outcomes after a stroke. In addition to conventional methods like drug therapy, there are currently some new methods like laser therapy in the testing phases. Hennerici et al. published an overview review article including these methods in the renowned scientific journal Lancet [1].

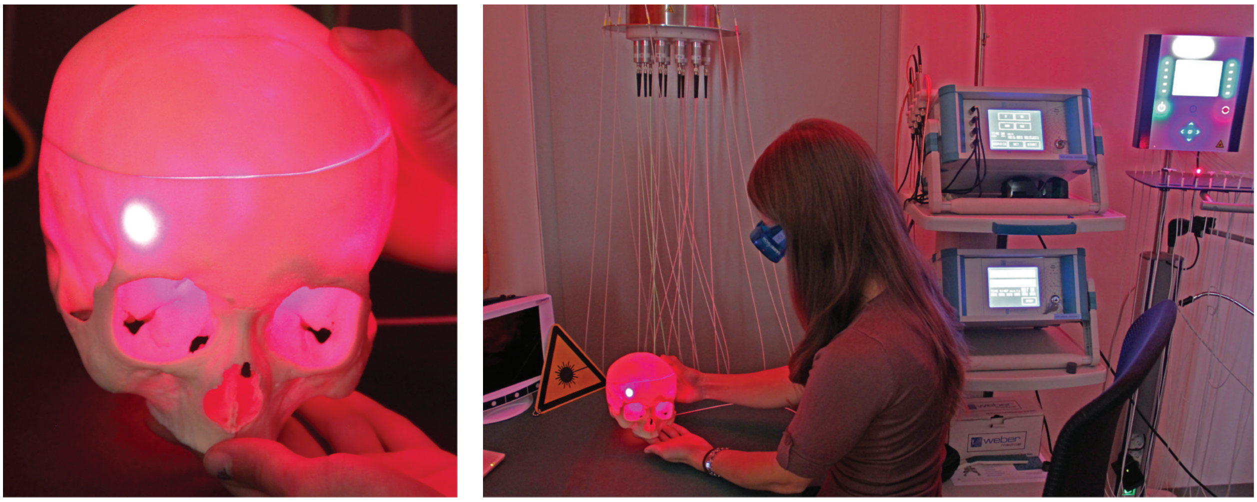
At the moment there is no certainty that the corresponding laser beam even penetrates the bone, so that the target (brain) can be reached. Currently no one knows laser parameters (wavelength, intensity, power, etc.) in detail, which should be selected on the intact skull, so that the laser light can show its potential efficacy inside the human skull.

The only study that could be found in the scientific literature for penetration of laser beam on the human skull dates from the year 1981 [2]. These authors investigated the so-called transmission of the laser radiation in the wavelength range from 400 nm to 856 nm, with some devices developed by them. No one has reviewed or quantified the penetration depth of the laser devices that are currently used for the planned large-scale stroke studies so far.

The goal of our present study was to calculate the transmission factors of different kinds of lasers through the human skull. For the first time the transmission of a yellow laser (589 nm, 50 mW) was tested.

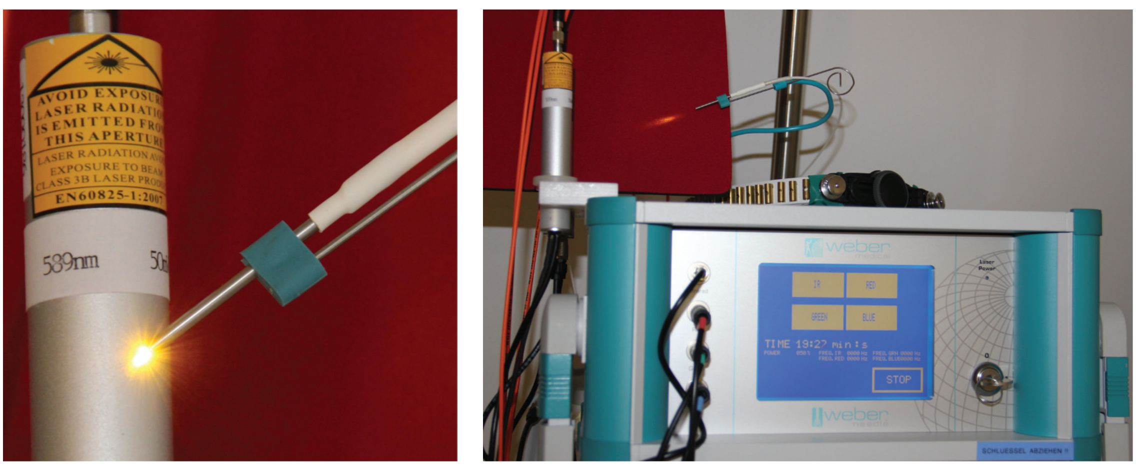
2. Materials and Methods

For the application of laser light to human skulls (provided by the Department of Anatomy, Medical University of Graz) red, infrared, violet, green, and for the first time yellow lasers were used (Figure 1). The proof that these types of laser light penetrate the human skull was achieved with commercially available methods (BL-10 L lux meter, volt Craft, Hirschau, Germany). The measurements at the highest point of the skull (electroencephalogram (EEG) position C_z) were reproducible and in total nine measurements were performed per laser modality. The yellow laser is currently only available from weber medical (Lauenförde, Germany)



(a) (b)

Figure 1: Different kinds of laser equipment for transcranial laser stimulation.



(a) (b)

Figure 2: First yellow laser (589 nm, 50 mW) for future medical applications at the Medical University of Graz.

and for research purposes at the Medical University of Graz (Figure 2).

2.1. Statistical Analysis. Data were analyzed using SigmaPlot 12.0 software (Systat Software Inc., Chicago, USA). The data are graphically presented as box plots.

3. Results

The results of this study are shown as box plot graphs and compared with the results of the only previous study on the subject [2]. Transmission is shown as a function of wavelength. In this way the percentage of the laser light which penetrates the skull bone can be measured. It can be seen that the values for the wavelengths 810 nm and 658 nm correlate well with the previous experimental findings (Figure 3).

The information on the yellow laser was estimated incorrectly by the authors of the only existing paper mentioned before [2]. The values vary by a factor of ten.

4. Discussion

Stroke is one of the leading causes of death worldwide. According to very recent data, which were presented at the 21st World Congress of Neurology at the end of September 2013 in Vienna, every year more than 600,000 Europeans suffer a stroke. There are more and more young people among the patients. Even if someone survives a stroke, he or she often remains permanently disabled and so almost every third person concerned becomes a severe nursing case. Mainly because of the movement in the age pyramid, one can assume that the incidence of stroke will increase in the coming decades.

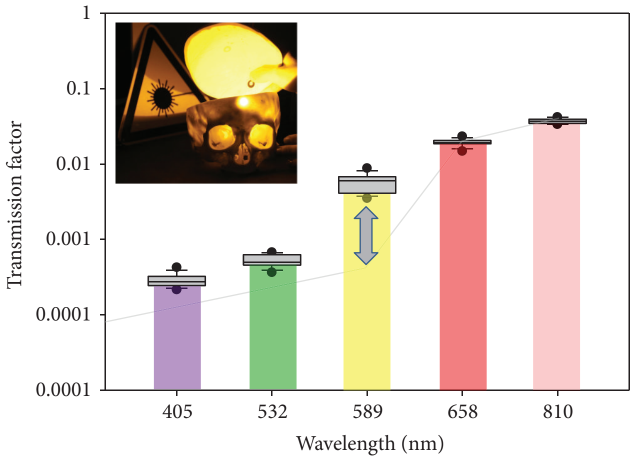


FIGURE 3: Box plot diagram showing measurement values (box plot) and the schematic results of the previous study (light grey line) concerning the violet (405 nm), green (532 nm), yellow (589 nm), red (658 nm), and infrared (810 nm) laser. The lines in the boxes represent the median, the ends of the boxes define the 25th and 75th percentile, and the error bars define the 10th and 90th percentile. The arrow indicates the variation between our measured values and the estimated values of the previous study [2].

In most cases, a so-called ischemic stroke, caused by an acute circulatory disorder in the brain vessels, occurs. The acute care, for example, in Austria, takes place in the so-called stroke units, which should be normally reachable after 45 to 60 minutes. After intensive investigation, the treatment can be started 2 hours after the stroke.

Among other things, scientists are working with highly invasive methods, such as craniotomies (for pressure relief) or partial occlusion of the aorta in the abdomen (with the aim of making a larger volume of blood available in the area above the occlusion). Another method is the so-called sphenopalatine ganglion stimulation. Therefore an electrode will be implanted in the patients jaw, which stimulates the pterygopalatine ganglion electrically, and because of this, the cerebral blood flow should be improved. However, a significant disadvantage of all these methods is the high degree of invasiveness [1].

Furthermore, there are some additional nonpharmacological methods, like the therapeutic hypothermia and the transcranial laser irradiation [1]. In connection with the transcranial laser irradiation, invasive and noninvasive tests are currently taking place. In the invasive variant, a piece of the skull is removed and replaced by transparent plastic, through which laser irradiation takes place afterwards [3].

The noninvasive laser procedures stimulate through the cranial bone. Currently, patients are treated with different lasers. Scientists try to demonstrate a possible therapeutic success with the collection of complex clinical scores and by using highly complicated measuring methods (e.g., near-infrared spectroscopy) [4, 5]. The studies with laser and partly "light-emitting diodes" (LED) [6–21] are currently being conducted worldwide with different success.

New LED-based systems use special physical effects, the so-called QIT-effect (quantum optical induced transparency), or optomechanically induced transparency [22–24]. Quantum interference effects in the amplitudes of optical transitions in atomic medium can lead to strong modifications of its optical properties. This effect well-known as electromagnetically induced transparency (EIT; [22]) has become an important tool to control the optical properties of dense media and has the potential to enhance the transparency contrast by a factor of five [24]. This means that bones like the skull, the spine, or joints can be penetrated even if the applied light is of relatively moderate intensity. Due to the QIT effect, the radiation should be able to reach deep tissue layers in muscles, connective tissue, and even bone, thus enabling noninvasive transcranial treatments, for example, for neurodegenerative diseases or stroke. However, to the best of our knowledge, no publications are available concerning light stimulation systems using this effect on human skulls.

This study is the first to prove that yellow laser light can penetrate the human skull. As photodynamic therapy (PDT) is one of the most promising treatment options for many kinds of tumors, the principle of PDT might also be used for treating brain tumors in future. It is well known that drugs like hypericin can stop or slow down the growth of brain tumors, but with yellow laser it can be used also for necrosis and apoptosis of such tumors, and this could open up a new strategy against brain tumors [25]. However, there are still many open questions, for example, the kind of photosensitizer [26] and especially the laser parameters like wavelength, intensity, dosage, and so forth.

5. Conclusion

Laser therapy is a promising new approach in poststroke treatment; however, there are still some methodological problems. We found that our own data concerning the human skull transmission factor correspond quite well to those of the researchers from 1981, apart from the data for the yellow laser, so this is certainly a question that deserves close attention. Further basic research on the entire topic is very important so that we can be sure to apply the correct kind or color of laser with the correct parameters. This can open up new dimensions in transcranial laser therapy.

Conflict of Interests

The authors declare that there is no conflict of interests regarding the publication of this paper.

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