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Quantitative Analysis of Transcranial and Intraparenchymal Light Penetration in Human Cadaver Brain Tissue

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Background and Objective: Photobiomodulation (PBM) also known as low-level light therapy has been used successfully for the treatment of injury and disease of the nervous system. The use of PBM to treat injury and diseases of the brain requires an in-depth understanding of light propagation through tissues including scalp, skull, meninges, and brain. This study investigated the light penetration gradients in the human cadaver brain using a Transcranial Laser System with a 30 mm diameter beam of 808 nm wavelength light. In addition, the wavelength-dependence of light scatter and absorbance in intraparenchymal brain tissue using 660, 808, and 940 nm wavelengths was investigated.

Study Design/Material and Methods: Intact human cadaver heads (n = 8) were obtained for measurement of light propagation through the scalp/skull/meninges and into brain tissue. The cadaver heads were sectioned in either the transverse or mid-sagittal. The sectioned head was mounted into a cranial fixture with an 808 nm wavelength laser system illuminating the head from beneath with either pulsed-wave (PW) or continuous-wave (CW) laser light. A linear array of nine isotropic optical fibers on a 5 mm pitch was inserted into the brain tissue along the optical axis of the beam. Light collected from each fiber was delivered to a multichannel power meter. As the array was lowered into the tissue, the power from each probe was recorded at 5 mm increments until the inner aspect of the dura mater was reached. Intraparenchymal light penetration measurements were made by delivering a series of wavelengths (660, 808, and 940 nm) through a separate optical fiber within the array, which was offset from the array line by 5 mm. Local light penetration was determined and compared across the selected wavelengths.

Results: Unfixed cadaver brains provide good anatomical localization and reliable measurements of light scatter and penetration in the CNS tissues. Transcranial application of 808 nm wavelength light penetrated the scalp, skull, meninges, and brain to a depth of approximately 40 mm with an effective attenuation coefficient for the system of 2.22 cm^{-1}. No differences were observed in the results between the PW and CW laser light. The intraparenchymal studies demonstrated less absorption and scattering for the 808 nm wavelength light compared to the 660 or 940 nm wavelengths.

Conclusions: Transcranial light measurements of unfixed human cadaver brains allowed for determinations of light penetration variables. While unfixed human cadaver studies do not reflect all the conditions seen in the living condition, comparisons of light scatter and penetration and estimates of fluence levels can be used to establish further clinical dosing. The 808 nm wavelength light demonstrated superior CNS tissue penetration.

Key words: central nervous system; isotropic optical fibers; low level light therapy; photobiomodulation; transcranial light therapy; 808 nm wavelength