Evidence for the existence of low-energy laser bioeffects on the nervous system

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Abstract

The reported effects of low-energy laser irradiation on the nervous system are manifested in alterations in cellular and extracellular biochemical constituents and reactions, as well as in changes in cell division rates. These bioeffects were observed in both in vivo and in vitro experiments. Other observed phenomena relate to the function of the nervous system and consist mainly of induced alteration in electrical conduction, stimulation thresholds, and behavioral effects. Clinical aspects of low-energy laser bioeffects relate mainly to pain mitigation and postponement of the posttraumatic neural degeneration processes. Many of the reported observations were obtained by experiments apparently conducted according to less than rigorous scientific criteria, and some could not be duplicated. On the whole, however, there is little doubt that low-energy laser irradiation exerts some effects on the nervous system under specific conditions of irradiation and tissue exposure via a mechanism which is probably photochemical in nature.

Keywords: Helium-neon, laser bioeffects, low-energy laser irradiation, neural trauma, neurochemistry, pain relief.

1 Introduction

The biological and medical effects of laser irradiation (known erroneously as biostimulation) at energies which, according to conventional laser biology, are below the threshold of effectiveness, have now achieved some scientific and medical credibility, probably because some of the claims made in this field [33], although previously disparaged, have now proved to be at least partially correct. Most of the research in this area, especially in connection with the treatment of disease, has been conducted according to less than rigorous scientific criteria and is therefore still beyond the sphere of conventional science and medicine. There is, however, a considerable body of literature dealing with the biological and medical consequences of low-energy laser irradiation [3, 4, 7, 8, 26], which apparently produces some bioeffects, although only when administered according to certain precise specifications.

In view of these bioeffects which can no longer be denied, and because a considerable proportion of them are neurobiological, we chose to present the available data to the neurobiology community. The findings may help to reduce the degree of skepticism and perhaps encourage further proper scientific research on these interesting and promising phenomena.

In the following we will critically review the literature dealing with the interaction of this type of irradiation with the nervous system. Since the focus of this review is on the effects of low-energy laser irradiation on neural tissues, several other aspects of laser energy in relation to the nervous system will not be dealt with. These include the use of high-energy surgical lasers for cutting neural tissue [13] and low-energy lasers for nerve fusion [1], photoradiation therapy (also known as photodynamic therapy), in which tissues are photosensitized by light-absorbing compounds and later destroyed by laser irradiation of appropriate
wavelength [24]; microbeam studies, in which laser beams of high-energy density are used to destroy cells or parts of cells [41]; and excitation of pain receptors by far infrared high-power laser irradiation [10].

Furthermore, we will not discuss the devastating effects of high-energy pulsed lasers, even when applied through the bone, on animal brains [12], or the destructive thermal effects of lasers on neural tissue [63]. Also beyond the scope of this article is the use of the laser as a substitute for the acupuncture needle [25]; the subject of our review is sufficiently unorthodox without the introduction of yet another controversial aspect.

We found it impossible to include in this review the vast amount of potentially relevant literature published in languages other than English and stemming mainly from Eastern Europe, since most of it is available to us only as titles of articles or as short abstracts.

2 Biochemical and cellular phenomena

The first recorded observations in this area were by Rounds and Olson [46], who subjected explants of newborn rat cerebellum to unfocused nanosecond pulses of frequency doubled neodymium laser irradiation (532 nm, 1 mW/cm²; no other data provided) and found after 18 h that all of the explants had died. They then exposed brain cell suspensions from 2-month-old rats to 10 flashes of the same laser and found that oxygen consumption in the suspensions was 30–40% lower than in nonirradiated controls. Red ruby-laser irradiation (693.4 nm) of similar energy and power density failed to reduce oxygen consumption in the suspensions. The authors suggested that the mechanism of the laser action is photochemical in nature, with the cytochrome system as chromophore, since cytochromes C₁–C₃ failed to act as hydrogen acceptors following green radiation and cytochromes a + a₃ were similarly affected by irradiation of the Raman-shifted ruby laser at wavelengths of 609.6 and 601.3 nm.

Further evidence for the photochemical nature of the bioeffects of low-energy laser irradiation was reported by Karu [23], who demonstrated (in a nonneural system) an action spectrum for these bioeffects. Such a spectrum is essential for proving a photochemical mechanism with peaks of the effect at certain wavelengths and a gradual diminution at wavelengths at increasing distances from the peaks.

Shen-Zheng et al. [48, 49] conducted biochemical studies of the bioeffects of low-energy laser irradiation. Both helium-neon (He-Ne) (20 mW) and nitrogen (337.1 nm, 1 mJ/pulse, 10 pps) laser irradiation, delivered through a light guide to either the caudate nucleus or the frontal cortex of rats, caused changes in the corpus striatum levels of various monoamines and amino acids. In vitro experiments demonstrated that direct photolytic effects of the irradiation contributed only minimally to these changes. The authors suggested that the changes probably result from irradiation-induced alterations in brain metabolic activity. In further experiments, using the same experimental model to evaluate behavioral effects of the radiation, it was shown that He-Ne irradiation of the caudate nucleus resulted in an increase in the conditional avoidance response.

Similar types of experiments were carried out by Rossetti et al. [45]. He-Ne laser (5 mW) irradiation of 9 spots in a 1-cm² area of the rat sinciput received 0.12 J (1.08 J/cm²) and the total dose per animal was 1.08 J. In comparison with sham-irradiated or untreated animals there was a significant increase in superoxide dismutase and a decrease in cytosolic aspartate transferase in whole brain tissue. No changes were observed in mitochondrial aspartate amino transferase and glutamate dehydrogenase.

Walker [55] reported that the analgesia observed following laser irradiation of nerves associated with painful conditions was accompanied by an increased urinary excretion of the serotonin degradation product 5-hydroxyindoacetetic acid, which started even before the onset of analgesia. The author postulated that the reduction in serotonin production, which is not induced by other forms of analgesia, might be associated with the laser-induced analgesia.

Naveh et al. [35] used a 15-mW He-Ne laser for 2 min for transocular irradiation of rat optic nerves which were subjected to a moderate crush injury. Since most of the visible irradiation traversed the eye, it can be assumed that at least