Laser Mechanisms of Action

Fundamental Mechanisms of Laser Biomodulation

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Therapeutic Laser Industry Overview

As has been the case with technology throughout history, this field was pioneered by engineers, not academics, and it's a good thing. After all, if we waited until we understood why something works before we used it, we would be in the stone-age, literally (people were eating vegetables before they knew why plants grew and warming their bodies with fire before they knew about combustion). This young field has therefore suffered from the zeal of its boosters; people had found a way to make money, and to their defense, improve patient quality of life, and so were much less interested in learning why this therapy worked. In this last decade, the research community has been catching up and we have ever-growing insight into the mechanisms of this highly successful field.

The Well-Oiled Human Machine

By far the most obvious and fortunate conclusion we have been able to extract from in vivo studies (not only with respect to laser phototherapy) is that our immune system is capable of handling an extraordinary range of pathologies. The time scale and degree to which our cells can react and combat these contaminants is the subject of much study, but it is clear both that lasers do stimulate the immune system and that the restoration of healthy function continues well after the initial irradiation. The amount of healing done during the minutes of laser irradiation is minuscule compared to the time it takes to relieve the body of disease or infection. This leads to one very important piece of information: the body does most of the work itself and so the target for an effective laser treatment is NOT the pathology itself, but rather to stimulate the appropriate cell compartments that lead to the body's natural repair mechanisms. Basically, we want to stimulate the cell's metabolism (i.e. its ability to use oxygen to create energy).

Mechanisms

Identifying Targets

The most fundamental thing to keep in mind is that the cell (and the body as a whole) is comprised of more than 80% water. The variation in water content between different kinds of cells (with the exception of bone cells) is negligible and so laser therapy as a whole is highly non-selective. Cells do, however, contain some heavier elements that can act as a contrast agent against water, and which can therefore be targeted with laser radiation; the most relevant examples are iron and copper. Not surprisingly, these elements are the ones that exist at the core of the two most important photoacceptors in the body: hemoglobin at the core of blood cells and cytochrome c oxidase in the mitochondria. By and large these complexes are the principle absorbers of mammalian tissue by light in the near infrared (NIR) range of the electromagnetic spectrum (other than melanin in the skin). As such, and before any attention to their function, the characterization of absorption of these complexes was of paramount importance, and the subject of much study.

Understanding the success of the K·LASER USA

Circulation

Recall the first goal of an effective therapy was to increase the amount of oxygen available for the cell to process. This means increasing blood circulation since the hemoglobin in red blood cells are the transporters of oxygen from the lungs to the cells. On the macroscopic scale, this relies on increasing the heart rate, which in turn slightly increases body (and blood) temperature. This is why exercise is good therapy for almost any ailment; increasing blood flow increases metabolism and stimulates the immune system. Locally around a wound, however, topographical heating does very little, resulting in neither an increase in circulation nor metabolism. This type of thermal effect is not the mechanism for laser stimulation of circulation. Laser irradiation instead creates local temperature gradients; that is, temperature differences on the molecular level that create potentials along which blood cells are more likely to flow. The stronger and more numerous the gradients, the more local circulation of oxygen can be stimulated.

What is the most efficient way to cause these temperature fluctuation? Recall that the cell is more than 80% water. If you can target the absorption of water by a particular wavelength of radiation, you can cause local resonances that reinforce themselves. In the entire NIR region (i.e. from 700-1000 nm) the strongest and most distinct peak in absorption is at 965 nm; the right side of Figure 1 shows the absorption spectrum of brain tissue in the NIR. Look whose laser sits right at that peak (970 nm)!!

Hemoglobin Deoxygenation

Once the increased circulation gets the blood to the cell, the hemoglobin that carry the oxygen in the blood have to drop off their oxygen supply. Oxygenated and deoxygenated hemoglobin have very distinct signatures in the NIR. We are not concerned with the process of re-oxygenating the hemoglobin, because this occurs in the lungs. Instead we are interested in the absorption spectrum of oxygenated hemoglobin HbO_2 whose deoxygenation can be stimulated by the absorption of a photon of radiation.Figure 1 shows the rather broad peak that covers the higher end of the NIR. The peak of this absorption lies at 905 nm, where the **K-Laser** Cube's additional wavelength resides. Notice that there is still significant absorption by hemoglobin at **K-Laser's** 800 and 970 nm beams as well.

Cytochrome c Oxidase Redox

As discussed earlier, the terminal enzyme in the respiratory chain of a cell, cytochrome c oxidase, is the principle absorber of radiation in the entire cell and governs the rate at which oxygen is processed into ATP. Unlike the one-way deoxygenation of hemoglobin, cytochrome receives and delivers its oxygen in cycles within the cell and so we need to stimulate both processes in order to maximize efficiency. It turns out that laser irradiation does both, depending on the oxidation state of the enzyme. When deoxygenated, laser irradiation will stimulate oxygenation, and vice versa [redox]. This effect has resounding implications and is thought to be the universal validation of laser therapy. The different oxygenation states of this enzyme have peaks throughout the visible-NIR spectrum, which is why virtually all wavelengths used have shown to be useful.

K-Laser goes one step better. Laser phototherapy with wavelengths throughout the NIR spectrum enhances cellular metabolism, but there exists a peak in the absorption spectrum that can maximize this effect. Figure 1 shows the difference spectrum in the absorption of oxygenated vs. deoxygenated cytochrome. Remember, when the enzyme is either fully oxygenated or fully deoxygenated, irradiation will push the cycle along in the right direction, so we want to stimulate the process at both endpoints. The peak in the difference spectrum reflects the wavelength at which laser irradiation will have the greatest effect to change the oxygenation state, which will subsequently turn the wheels on the cellular metabolism most efficiently. This is analogous to firing the spark plugs at the exact time in the engine cycle to get the maximum effect. Notice in amazement that the shorter wavelength of the **K-Laser** (800 nm) sits right at this peak in absorption.

All Three Mechanisms in One

The wavelengths employed by **K-Laser** are fine-tuned for success. We have one wavelength (970 nm) that coincides with a peak in water absorption; again the cell is 80% water and so this will have the effect of most efficiently creating temperature gradients that will increase local blood flow and therefore oxygen flow. **K-Laser's** 905 nm wavelength, along with the others at 800 nm and 970 nm, lies at the peak of the broad absorption curve of oxygenated hemoglobin; this means once the blood gets to the cells, **K-Laser** irradiation will most efficiently stimulate the passing of oxygen from the hemoglobin into the cells for use in metabolism. Finally, the 800 nm beam lies at the peak in the cytochrome c oxidase redox cycle; once the oxygen is in the cell, **K-Laser** irradiation will most efficiently stimulate the cyclic process of using and replenishing oxygen, thereby maximizing the ATP (energy) throughput of the cell. Remember, the name of the game is oxygen: getting into the cell, getting the cell to use it faster to make more energy, and then letting the cell's natural processes boost the body's immune system. This will result in curative and analgesic effects upon every administration of treatment as well as continued relief in the future.