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The Necessity of Near-Infrared Protection

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Over half of the solar energy consists of near-infrared (NIR), and in addition to natural NIR, humans are continuously exposed to artificial NIR from electrical appliances. A wide range of preventative mechanisms has been evolutionarily maintained in organisms to protect against the effects of NIR [1,2]. Humans have acquired protective mechanisms against NIR on multiple levels, including perspiration, blisters, vasodilation, hair, skin, adipose tissue, and cotton or wool clothing [1].

Previous studies regarding NIR have reported its application in the industrial and agricultural fields, but have not well investigated the effects of NIR exposure in the field of plastic surgery [3]. Although plastic surgeons have not been familiar with the effects of NIR, the potential for NIR effects appears to be high and significant.

We previously elucidated that NIR (1100-1800 nm together with a water-filter that excludes wavelengths 1400-1500 nm) non-thermally affects the deeper tissues [1-7]. In addition, we found that NIR is absorbed by water in the skin, hemoglobin in dilated vessels, myoglobin in the superficial muscle, and bone cortical mass, and is scattered by adipose cells [1-5]. The biological effects of NIR have both beneficial applications and deleterious effects [1-5].

NIR can stimulate wound healing [8-10] and treat malignant tumors [11-14]. NIR can also achieve skin rejuvenation and skin tightening [7], induce long-lasting vasodilation that is beneficial for ischemic disorders [3,5], and relax and weaken dystonic and hypertrophic muscles to reduce wrinkles and myalgia [3,5]. In addition to usefulness in cancer detection and imaging, NIR induction of DNA damage in cancer cells should be investigated further for an effective cancer treatment [6]. NIR can also activate stem cells, which may be beneficial in regenerative medicine [3].

However, intensive or long-term exposure to NIR induces deleterious effects similar to UV [1-4]. Various kinds of tissue damage and diseases, such as undesirable photoaging, long-lasting vasodilation, muscle thinning, skin ptosis, sagging, cataracts, and potentially photocarcinogenesis are induced by long-term NIR exposure [4,5]. Despite the wide prevalence of a variety of UV blocking materials, such as sunblock, sunglasses, films, and fibers, effective methods for blocking NIR are not currently established. NIR exhibits both wave and particle properties and is strongly absorbed by water, hemoglobin, and myoglobin [1]. NIR induces photochemical changes and affects a large volume and depth of tissue [15]. As a consequence, NIR can penetrate the skin and the sclera, and affect the deeper tissues, including muscles, lens, and retina, with its high permeability [1-3].

Chronic NIR exposure can induce rosacea, which affects all races, although it is more common in Caucasians and fair-skinned populations [16]. NIR should be considered a critical factor in the development and aggravation of rosacea [3-5].

Erythema ab igne can be induced by long-term exposure to sources of heat and NIR, such as fires and stoves [17], and exhibits histopathological changes similar to those seen in solar-damaged skin [18]. The occurrence of telangiectasia appeared to increase with age, increased sunbathing, and poor pigmentation ability [16]. These lesions may develop thermal keratosis, such as hyperkeratosis, keratinocyte dysplasia, and dermal elastosis, which are similar to the changes that occur in actinically damaged skin [19].

Apoptosis of vascular smooth muscle cells and degeneration of myoglobin are non-thermally induced by NIR, resulting in long-lasting vasodilation [1,4]. Muscles are easily damaged by NIR, as they contain hemoglobin and myoglobin [20], which are oxygen-carrying proteins with many hydrogen bonds and alpha helices [1,3-4]. Previous studies have shown that hydrogen bonds and helical structures are resonated by NIR [1,3-4,21]. Thus, it is possible that NIR induces resonance of helical structures in the oxygen-carrying proteins and degenerates proteins containing hydrogen bonds and helical structures, which results in damage to the storage and transport of oxygen [1,4]. This could be one of the mechanisms of apoptosis [1,4]. Humans have biological defense mechanisms in which hydrogen bonds and helical structures are resonated by NIR and absorb NIR to protect subcutaneous tissues against this radiation [1,3-4].

Superficial muscle thinning and the muscle extensions to the dermis are induced by chronic NIR exposure, which ultimately lead to superficial tissue aging and skin ptosis [1,3]. Additional factors thought to contribute to brow ptosis include the gradual loss of forehead skin elasticity and a reduction in the tone of the frontalis muscles [22,23]. The use of NIR treatment for smoothing forehead rhytids also causes brow ptosis [1,3]. Compared to darker skin with dense melanin and a thick dermis, fair skin with lower concentrations of melanin and a thin dermis might allow NIR to penetrate deeper into human tissue, and damage superficial muscles, resulting in muscle thinning and skin ptosis [1,3]. Fair skin tends to wrinkle and sag earlier in life [24,25], and characteristics of age-related changes occur at a more accelerated rate in Caucasians [26]. Accordingly, patients with fair skin and a habit of sunbathing tend to seek facelift operations.

Cataract and damages of the retina may be induced by chronic NIR exposure [1-3]. The optic nerve which is the only exposed component of the central nervous system also has defense mechanisms against NIR on multiple levels: rich blood flow in the retina, hyaluronic acid in the lens, tears in sclera, and fat in the eyelid [1-3]. These are effective protective mechanisms, as water, hemoglobin, and fat are all ideal materials for blocking the exposure to and consequences of NIR. NIR is transmitted through the ocular media with little loss of intensity, damaging the retina and contributing to cataracts [27]. Surgeons are intensively exposed to NIR from using the microscope for extended periods of time during microsurgery, thus surgeons should consider protection of eyes from NIR [3].

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Carcinomas arise from heat-induced erythema ab igne [28-30]. Similar to UV, NIR induces photoaging and potentially photocarcinogenesis [31]. In addition, skin tumors appeared faster after irradiation with the full lamp spectrum containing UV, visible, and NIR compared to irradiation with UV alone [32].

Subcutaneous adipocytes may be induced by NIR to protect the underlying tissues, including the panniculus carnosus in animal and superficial muscles in human, against NIR damage. Subcutaneous adipocytes located above superficial muscles are effective and reasonable for the temperature retention and protection from NIR, because fatty tissue can scatter NIR optically [3,33] and fatty acids are the major NIR absorbing materials in soft tissues [34].

Although various kinds of UV blocking materials are often used to prevent tissue damage from UV exposure, these materials do not block visible light or NIR [1-3]. Therefore, we should protect ourselves with clothing or sunscreen, and glasses that not only block UV, but also NIR, in order to prevent photodamage and photoaging. Additional studies are required to investigate the generally quantified dose limit for the body and the necessity of NIR protection.

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