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Side effects and complications using intense pulsed light (IPL) sources

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Abstract

Lasers have been well known for about 50 years, while flash lamps, also called intense pulsed light (IPL) sources, have been available for clinical applications for less than 20 years. There are many differences between lasers and IPL: a laser emits monochromatic light, whereas an IPL emits a whole range of wavelengths between approximately 250 and 1200 nm. Cut-off filters reduce this range and enable the treatment of different skin conditions. Water acts as a cooling agent by absorbing the emitted infrared light. As a broad spectrum of wavelengths is not absorbed by the chromophores of skin, unspecific heating of the surrounding tissue occurs when using therapeutic energy densities. Flash lamps are used for a variety of indications, such as hair removal, treatment of vascular and pigmented lesions and photorejuvenation. All these applications can be performed with one device by changing the cut-off filters; however, the therapeutic range is rather small and therefore, negative side effects such as burns, blisters, vesicles, erosions and crust formation, as well as hypo- and hyperpigmentations are common. All precautions pertaining to laser treatment of the skin have to be observed with flash-lamp applications as well; in particular, a clear diagnosis has to be established before treatment, and if treatment is performed by non-medical staff it has to be supervised by a physician.

Keywords: IPL; Adverse side effects; Lasers; Hair removal; Flash lamps; Intense pulsed light sources

Introduction

The first working laser was built by Maiman in 1960 based on a ruby crystal. In 1983, Anderson and Parrish established the principles of selective photothermolysis and from this time onward, specific treatment modalities of dermatologic indications with various lasers were developed to this present day.

The first intense pulsed light (IPL) source, called "Photoderm" was created in 1985. The most commonly used flash lamps are xenon–chloride lamps, which produce a very short, intense impulse of incoherent, full-spectrum white light. The lamp is comprised of a sealed tube, often made of fused quartz, which is filled with a mixture of gases, primarily xenon, while electrodes carry the electrical current to the gas mixture. A high-voltage power source is necessary to energize this gas mixture. This high voltage is usually stored in a capacitor to allow fast delivery of a very strong electric current when the lamp is triggered. The glass envelope consists of a thin tube with the electrodes protruding into each end of the tube. They are connected to a capacitor which is charged with a relatively high voltage, usually between 100 and 2000 V depending on the length

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of the tube and the specific gas mixture. A flash is initiated by first ionizing the gas mixture with a high voltage and then an intense pulse of current is sent through the tube. Ionization is necessary to decrease the electric resistance of the gas so that a pulse measuring as much as thousands of amperes can travel through the tube. The initial ionization pulse or trigger pulse may be applied to one of the internal electrodes or to a metal band or wire that is wrapped around the glass tube. When the trigger pulse is applied, the gas becomes ionized and the capacitor immediately discharges into the tube. When this pulse travels through the tube, it excites electrons surrounding the xenon atoms elevating them to higher energy levels. The electrons immediately drop back to a lower energy level, producing photons in the process.

As with all relatively cold ionized gases, xenon flash lamps emit light in various spectral lines. For xenon, the spectral lines are distributed across the spectrum and thus appear white to the human eye. Other inert gases like krypton and argon are also used occasionally. The discharge time for common flash lamps is in the microseconds range and can have repetition rates of hundreds of hertz. One single pulse thus consists of many impulses that are repeated in very short intervals.

Only few publications exist about the side effects in treatment with lasers and even fewer reports are available on IPL treatment. Therefore, we can only speculate on the percentage of side effects and adverse reactions in general treatment with IPL. However, as we provide expert opinion on malpractice suits in German courts, we have gained insight into some severe cases of side effects. Most of them are caused by a lack of experience in operative skills. With our article we want to give an overview about typical side effects and complications in treatments with ILP.

Fundamentals of tissue optics

In treatment with lasers, the most important parameter is the selection of laser type in order to achieve the best therapeutic results and avoid negative side effects. Knowledge and application of the principle of selective photothermolysis and specific absorption qualities of chromophores in the skin allow minimizing of negative side effects [1]. In treatment with IPL, it is also necessary to be aware of the interactions between tissue and applied energy doses to achieve satisfactory results without side effects. However, here the most important factor is the observation of the absorption qualities of the cutaneous chromophores, e.g. melanin, hemoglobin and water. The absorption of melanin lies within 400 and 700 nm with a sharp decline at higher wavelengths. Hemoglobin has an absorption maximum at 410 nm and also a good absorption between 500 and 600 nm. Water absorbs wavelengths shorter than 230 nm and longer than 2800 nm. As there are overlaps in the absorption spectra of melanin and hemoglobin, targeting one specific chromophore is not possible. Thus, the energy density has to be exactly calculated for each specific therapeutic indication, taking into account the patient's pigmentation and other factors.

An IPL emits a large range of wavelengths and therefore often induces absorption by hemoglobin and melanin despite the chosen filter. The unspecific heating of epidermal melanin is the reason for most side effects. In UV-stimulated melanocytes, there is a risk of causing permanent damage to melanocytes leading to persisting hypo- or depigmentation of the skin. Hypopigmentation appears in the shape of rectangles that result from the applicator crystal. Irradiation of pigmented epidermis with inadequate energy densities leads to burns with the formation of vesicles, blisters, erosions, crusts and the potential risk of infections and post-inflammatory hyperpigmentation. The latter may resolve after extended, consequent sun blocking. Damage to the skin beyond the papillary dermis leads to severe, deep trauma resulting in scar formation. Scars reflect a permanent destruction of healthy tissue and replacement with fibrotic material. Although they may improve in appearance, they never resolve. Rarely, do keloids or hypertrophic scars develop, which can be painful and cosmetically very disturbing.

Treatment of vascular lesions may result in a permanent damage to hair follicles (depilation) as absorption ranges of hemoglobin and melanin overlap. Also here, it is of utmost importance to take into account individual epidermal pigmentation, as excessive energy densities in dark skin cause thermal damage, leading to hypo- and hyperpigmentation, blisters, crusts, erosions and scarring.

Case studies

The following case studies illustrate typical side effects and complications using IPL.

The first patient we would like to present was treated with excessive energy densities. In some areas, severe damage occurred due to an overlap of treated area as discernable by the mark of the crystal applicator (Figs. 1 and 2).

Several hours after treatment, crusts and vesicles appeared which healed with pronounced hyperpigmentation that might resolve in time (Figs. 3 and 4).

Patient 2 had undergone treatment with an IPL after a vacation in the sun (Figs. 5 and 6). As the epidermis and dermis had increased amounts of melanin, energy absorption was enhanced and the tissue sustained