Available online at www.sciencedirect.com
ScienceDirect
Medical Laser Application 23 (2008) 15–20
Medical Laser Application
www.elsevier.de/mla

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

Sabine Stangl*, Ina Hadshiew, Wolfgang Kimmig

Department of Dermatology, University Hospital Hamburg-Eppendorf, Martinistraße 52, 20246 Hamburg, Germany

Received 10 August 2006; accepted 12 November 2007

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

*Corresponding author. Tel.: +49 40 4280 34289; fax: +49 40 4280 34276.
E-mail address: s.stangl@uke.uni-hamburg.de (S. Stangl).

1615-1615/$ - see front matter
doi:10.1016/j.mla.2007.11.008

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

Fig. 1. Patient 1, left cheek. Crusts following treatment with too high energy density.

Fig. 2. Patient 1, right cheek. Magnification of overlapping pulses.

Fig. 3. Patient 1, left cheek. 8 weeks after ILP treatment.

Fig. 4. Patient 1, right cheek. Post-inflammatory hyperpigmentations 8 weeks after treatment.

Fig. 5. Patient 2. Hypopigmentations after treatment of pigmented skin.

thermal damage. Also, in this case, first vesicles and crusts developed, followed by hypopigmentation. Also, the treatment was performed with a lack of accuracy, as discernable by the wide spacing between the treated areas.

Fig. 6. Patient 2. Detail of Fig. 5.

Fig. 7. Patient 3, thigh. Erosions and crusting after treatment with IPL.

A third patient developed crusts after IPL treatment of the thigh for hair removal (Fig. 7). Treatment had been performed by a medical layman without supervision by a qualified physician.

Discussion

All dermatologic laser and IPL treatments have virtually the same range of complications; however, they differ in the rates of their occurrence [1–3]. Table 1 shows the most common adverse reactions in treatments with IPL and their likelihood.

While there is an abundance of publications on the treatment of skin disease with lasers, only few exist on IPL, and unfortunately, even fewer deal with the risk of side effects.

Moreno-Arias et al. [4] examined 49 patients with skin types I–IV, with a mean age of 31.4 years, who were treated with the IPL EpiLight™ (ESC Sharplan) . The number of treatments ranged between 3 and 9. Treatment was performed with cut-off filters of 695 or 755 nm and pulse durations of 3.5 or 3.8 ms with a delay of 20 or 30 ms and energy densities between 40 and 43 J/cm^2. Complications during and after the treatment were assessed by a questionnaire. Of the patients, 87.8% reported mild and 12.2% reported moderate pain during the treatment. Nobody complained of severe pain. Transient erythema for less than 72 h occurred in 61.2% of the cases, while in 6.1% of the cases the erythema persisted longer. Again 16.3% of the patients experienced transient hyperpigmentation that resolved spontaneously within 4–10 weeks and 2% experienced transient hypopigmentation that resolved within 16 weeks. Crusts developed in 18.4% of the patients and resolved within 5 days; vesicles occurred in 6.1%, minimal scarring in 2% and superficial burning also in 2% of the patients. No keloids or permanent pigmentary alterations were observed; however, a paradoxical effect that caused increased hair growth in untreated areas adjacent to the treated areas was reported. The authors speculate that the induction of hair growth

Table 1. Most common complications in treatments with ILP

Complications	Treatment indications			
	Pigmented lesions	Vascular lesions	Hair removal	Photorejuvenation
Likely	Hyperpigmentation	Hyperpigmentation	Hyperpigmentation	Persistent erythema
↓	Hypopigmentation	Hypopigmentation	Hypopigmentation	Transient hyperpigmentation
	Infection	Infection	Erosions	Hypopigmentation
	Dermatitis	Dermatitis	Crusts	Hypertrophic scars
	Skin texture changes	Skin texture changes		
Unlikely	Scarring	Scarring		

could result from the application of sublethal doses to the hair bulb and subsequent activation of dormant hair follicles.

In a different study, the rate of side effects was much lower. Sadick et al. [5] examined 67 patients who were treated with a non-coherent flash lamp with emission of wavelengths between 590 and 1200 nm. Pulse duration was 2.9–3.0 ms, energy density 40–42 J/cm^2. Hairs were counted before and after treatment and morphologic features were assessed. The only side effect was transient erythema in all subjects. There was no scarring.

Another publication by Sadick et al. [6] investigates treatment of 34 patients (8 men and 26 women) with hypertrichosis. Here, wavelengths between 615 and 695 nm were applied with a pulse duration of 2.6–3.3 ms and a fluence of 34–42 J/cm^2. The treatment spot size was 10 mm × 45 mm. Before each treatment, a cold gel (1 °C) was applied. Side effects were mild and transient in only a few patients. There was transient hyperpigmentation in 3 patients (9%) and superficial crusting in 2 patients (6%).

Troilius et al. [7] present a safe and efficient method for hair removal. Ten women with dark hair and skin types II–IV were treated in the bikini area with IPL with an emission between 600 and 1200 nm. Hair removal was excellent and only minimal side effects were noted. Patients had no pain or other discomfort during the treatments.

IPL can also be applied for various other indications using different cut-off filters which allow for choosing the desired wavelengths. One indication that is suitable for treatment with IPL is photodamaged skin. Bjerring et al. [8] performed treatments with an IPL device that was equipped with either a 555–950 nm filter (VL) or a 530–750 nm filter (PR). Visible telangiectasias were cleared in 81.8% (PR) and in 58.8% (VL) of the patients. Also treatment of diffuse erythema and irregular pigmentation showed excellent results. No skin atrophy, scarring or pigment changes were noted after the treatments. Swelling and erythema were reported by two-thirds (PR) and one-third (VL) of the patients.

Treatment of facial telangiectasias by IPL is also possible. Another publication by Bjerring et al. [9] describes the treatment of 24 patients with facial telangiectasias. In this study, a special IPL system was used to eliminate wavelengths longer than 950 nm to avoid unspecific heating of the tissue by water. Side effects were moderate erythema and oedema immediately after the treatment. Purpura, as commonly observed after the treatment with pulsed dye lasers, did not occur. There were no long-term adverse effects such as scarring or pigmentary changes.

Greve et al. [10] assessed the increasing number of treatments performed in cosmetic and aesthetic dermatology. In 2000, there were approximately 3.4 million cosmetic treatments, with the number steadily rising. Potential earnings are high and therefore, also inexperienced people buy IPL devices. The various reasons for malpractice are elucidated: deficient training, lack of documentation, inadequate and inexact information of patients, incorrect determination of indications and diagnoses, failure to perform test treatments and incorrect operation of IPL. The authors suggest implementation of rules and regulations to minimize treatment errors. They also point out the necessity to undergo dermatological training additionally to a laser or IPL specific training, before obtaining permission to perform cosmetic treatments, as tumors can often be found on sun-damaged skin that require adequate diagnosis and treatment. Furthermore, the importance of patient information and documentation, especially in regard to potential legal disputes is pointed out [10].

A recently published clinical report emphasizes the necessity to correctly diagnose a pigmented skin lesion before treatment [11]. A woman had developed metastases of a malignant melanoma in her parotid gland. The initial tumor was probably a pigmented lesion on the right cheek that was treated by a CO_2 laser, 3 years earlier.

Conclusion

The base for IPL treatment, as for any other treatment, is correct diagnosis. If necessary, a punch biopsy and subsequent histological examination should be performed, to verify the diagnosis. Also, the right IPL cut-off filter needs to be chosen to minimize the risk of potential negative side effects. Drosner et al. [12] state in their guidelines for laser- or flash lamp-assisted hair removal that both devices are well tolerated and effective for this indication. However, as these devices are very popular, practitioners need to be careful to avoid permanent negative side effects, instead of the desired permanent hair reduction. The ideal patient for laser hair removal is light skinned with black coarse hair. Individuals with dark skin, and especially tanned patients, are at a higher risk of pigmentary changes and side effects. Pre-, parallel and post-cooling, as well as a reduction of the fluency, may prevent adverse effects such as pigment alterations and scar formation.

In Germany, guidelines by the German Dermatologic Laser Society (DDL, see www.ddl.de) and the Work Group for Dermatological Laser Treatment (Arbeitsgemeinschaft für Dermatologische Lasertherapie (ADL)) for laser treatment as well as recommendations of the commission of radiation protection (Strahlenschutzkommission, see www.ssk.de) exist. Unfortunately, similar guidelines for the treatment with IPL are still

lacking. Therefore, side effects after treatment with IPL are more likely. However, all standards developed for laser treatment are valid for treatment with IPL, too. Treatment by medical laymen should be restricted to treatment under medical supervision.

Zusammenfassung

Nebenwirkungen und Komplikationen bei Anwendung hochenergetischer Blitzlampen

Mittlerweile werden Laser seit ungefähr 50 Jahren eingesetzt; hochenergetische Blitzlampen hingegen sind erst in den letzten 20 Jahren im medizinischen Bereich in Gebrauch. Es bestehen allerdings beträchtliche physikalische Unterschiede zwischen hochenergetischen Blitzlampen und Lasern: das Emissionsspektrum von hochenergetischen Blitzlampen liegt zwischen 250 und 1200 nm, während Laser monochromatisches Licht emittieren. Eine Einschränkung des Emissionsspektrums kann durch die Benutzung von Filtern erzielt werden, die dann auch die Behandlung von verschiedenen Problemen der Haut ermöglichen. Das abgestrahlte Licht im infraroten Wellenlängenbereich ist jedoch nicht vollständig zu eliminieren. Dies bewirkt eine Erhitzung des umliegenden Gewebes bei therapeutischen Energiedichten. Hochenergetische Blitzlampen werden für eine Vielzahl von Indikationen eingesetzt: Haarentfernung, Behandlung von vaskulären und pigmentierten Hautveränderungen und Hautverjüngung. Alle genannten Indikationen können mit dem gleichen Gerät durchgeführt werden, wenn der entsprechende Cut-off-Filter eingesetzt wird. Der therapeutische Bereich ist allerdings klein. Nebenwirkungen wie Verbrennungen, Blasen, Krusten, Hyper- und Hypopigmentierungen und Erosionen sind demnach häufig. Alle Vorkehrungen, die für die Behandlung mit Lasern im medizinischen Bereich gelten, müssen auch bei der Behandlung mit hochenergetischen Blitzlampen eingehalten werden. Dazu gehört vor allem die Sicherung der genauen Diagnose vor Therapiebeginn und eine genaue Überwachung der Behandlung durch ärztliches Personal, wenn die Therapie von Assistenzpersonal durchgeführt wird.

Schlüsselwörter: Hochenergetische Blitzlampe; IPL; Nebenwirkungen; Behandlungsfehler; Laser; Haarentfernung

References

[1] Raulin C, Kimmig W, Werner S. Lasertherapie in der Dermatologie und Ästhetischen Medizin – Nebenwirkungen, Komplikationen und Behandlungsfehler. Der Hautarzt 2000;51(7):463–73.

[2] Lanigan SW. Incidence of side effects after laser hair removal. J Am Acad Dermatol 2003;49(5):882–6.

[3] Alster TS, editor. Manual of cutaneous laser techniques. Philadelphia: Lippincott-Raven; 1997.

[4] Moreno-Arias GA, Castelo-Branco C, Ferrando J. Side effects after IPL photoepilation. Dermatol Surg 2002; 28(12):1131–4.

[5] Sadick NS, Shea CR, Burchette JL, Prieto VG. High-intensity flashlamp photoepilation: a clinical, histological, and mechanistic study in human skin. Arch Dermatol 1999;135(6):668–76.

[6] Sadick NS, Weiss RA, Shea CR, Nagel H, Nicholson J, Prieto VG. Long-term photoepilation using a broad-spectrum intense pulsed light source. Arch Dermatol 2000;136(11):1336–40.

[7] Troilius A, Troilius C. Hair removal with a second generation broad spectrum intense pulsed light source -a long-term follow-up. J Cutan Laser Ther 1999;1(3):173–8.

[8] Bjerring P, Christiansen K, Troilius A, Dierickx C. Facial photorejuvenation using two different intense pulsed light (IPL) wavelength bands. Lasers Surg Med 2004;34(2): 120–6.

[9] Bjerring P, Christiansen K, Troilius A. Intense pulsed light source for treatment of facial telangiectasias. J Cosmet Laser Ther 2001;3(4):169–73.

[10] Greve B, Raulin C. Professional errors caused by lasers and intense pulsed light technology in dermatology and aesthetic medicine: preventive strategies and case studies. Dermatol Surg 2002;28(2):156–61.

[11] Gottschaller C, Hohenleutner U, Landthaler M. Metastasis of a malignant melanoma 2 years after carbon dioxide laser treatment of a pigmented lesion: case report and review of the literature. Acta Derm Venereol 2006; 86:44–7.

[12] Drosner M, Adatto M. Photo-epilation: guidelines for care from the European Society for Laser Dermatology (ESLD). J Cosmet Laser Ther 2005;7(1):33–8.