

Complications in laser dermatologic surgery Part I: Non-fractional non-ablative lasers

Complicações com o uso de lasers. Parte I: lasers não ablativos não fracionados

ABSTRACT

Laser procedures are currently widely used in dermatology due to their low aggressiveness, excellent results, and fast recovery time with few complications. They are indicated in the treatment of photoaging, for removing or attenuating vascular alterations and pigmented lesions, and treating scars and excessive hairs. These lasers offer high levels of safety, however they can cause serious complications if used improperly. The objective of this study is to describe the side effects caused by different lasers and how to manage them, since there are few studies on this topic. This knowledge is crucial for improving patient care and preventing morbidity and sequelae.

Side effects caused by non-fractional non-ablative lasers will be discussed in Part I of this paper. Fractional and non-fractional ablative lasers, as well as fractional non-ablative lasers, will be discussed in Part II.

Keywords: lasers; postoperative complications; hair removal; laser therapy; hyperpigmentation

RESUMO

Atualmente os procedimentos com laser são amplamente utilizados na prática dermatológica por serem pouco agressivos, proporcionarem ótimos resultados e pós-operatório com rápida recuperação. São indicados para o tratamento do fotoenvelhecimento e remoção ou atenuação de alterações vasculares, pigmentares, cicatrizes e pelos. Apresentam perfil de alta segurança; contudo, se utilizados inadequadamente podem causar complicações. O objetivo deste estudo é promover o reconhecimento dos efeitos colaterais que os diversos lasers e seu manejo podem causar, uma vez que existem poucos trabalhos a respeito. Isso é fundamental para o melhor atendimento do paciente, prevenindo morbidades e sequelas. Na parte I abordam-se os efeitos colaterais provocados pelos lasers não ablativos e não fracionados, e na parte II os relativos aos lasers ablativos fracionados e não fracionados e lasers não ablativos fracionados.

Palavras-chave: lasers; complicações pós-operatórias; epilação; terapia a laser; hiperpigmentação

INTRODUCTION

Most non-ablative laser systems emit light in the short-wavelength infrared portion of the electromagnetic spectrum. The absorption of these wavelengths by the water contained superficially in the skin is relatively weak, allowing them to penetrate more deeply in the tissue.¹ As a result, non-ablative lasers cause thermal damage at the dermis level (vessels, melanin, exogenous pigment) and do not remove the epidermis. In contrast, ablative lasers have a great affinity for water and thus remove the epidermis completely, and the dermis partially.²

This literature review evaluated dermatology articles published from 1983–2010, identified in a PubMed database search using the key words laser complications, laser's side effects and adverse effects of lasers. The review catalogs the side effects caused by non-ablative and non-fractional lasers (Table 1).¹⁻³

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Such devices can improve photoaging signs without the prolonged post-operative recovery typical of ablative lasers; they are effective and considerably safe due to their reduced aggressiveness. Nevertheless, non-ablative treatments do not produce results equivalent to those of ablative treatments and require a greater number of sessions. They are indicated for rejuvenation, scar treatments, and removal or attenuation of vascular and pigmentary alterations, including tattoos and hair.⁴

The safety and efficacy of modern laser systems are attributed to Anderson's and Parrish's selective photothermolysis theory, developed in the 1980s. According to this theory, the specific or target chromophore is selectively destroyed with minimal thermal damage to the adjacent tissue.⁵ In order to achieve this outcome, the following parameters must be correctly set: wavelength (depth reached by the laser beam in the tissue, usually measured in nanometers – nm); fluence (energy absorbed by the target in relation to the treated area – J/cm²), and pulse duration (time interval during which the energy is delivered to the tissue).^{4,6,7} These parameters are adjusted according to the laser device, the patient's skin type, and the condition to be treated.

Although they present lower rates of side effects than their ablative counterparts, non-ablative lasers have their own side effects profile. It is important to note that even the safest lasers can cause cutaneous damage if used inappropriately. The application of overlapping pulses, multiple passes, excessive

intensity in the parameters, and inadequate patient selection can potentially result in high morbidity rates in any laser system.^{6,7} Understanding the potential side effects of lasers is important in their prevention, early diagnosis and treatment, in order to minimize morbidities and sequels.

SIDE EFFECTS OF NON-ABLATIVE NON-FRACTIONAL LASERS

Discomfort or pain

Practically all laser procedures are somewhat painful. Many patients frequently complain about some discomfort or pain during and immediately after laser epilation treatments. In order to mitigate pain, local infiltrative and/or topical anesthesia and/or cutaneous cooling can be used.⁸

ERYTHEMA

Some degree of erythema occurs in nearly all laser procedures. Although there are reports of durations of up to seven days,⁹ it usually lasts a maximum of 24 hours after non-ablative laser treatment.² In 2004, Lapidoth and others¹⁰ described 10 cases of persistent reticulated erythema, mainly in the legs, after diode laser epilation. Figure 1 shows a 28-year-old female patient, treated with three sessions of 810 nm diode laser (60 J and 30 ms) who presented reticulated erythema in the treated region one month after the last session.

Table 1: Non-fractional non-ablative laser types and their indications*

Laser type	Wavelength	Indication
Alexandrite Q-switched	755 nm	Pigment and tattoo removals
Rubi Q-switched	694 nm	Pigment, tattoo, and melanocytic lesion removals
Nd:YAG Q-switched	532 nm	Tattoos with red, orange or yellow pigments
Nd:YAG Q-switched	1.064 nm	Tattoos with black or blue pigments
Pulsed dye (Dye laser)	585 ou 595 nm	Vascular lesions
KTP:YAG	532 nm	Acne
Nd:YAG	532 nm	Rejuvenation and PDT
Ruby	694 nm	Epilation
Diodo	810 nm	Epilation and vascular lesions
Diodo	940 nm	Vascular lesions, acne and epilation
Diodo	1.450 nm	Acne and acne scars
Alexandrite	755 nm	Epilação e lesões vasculares
Nd:YAG long pulse	1.064 nm	Vascular lesions, epilation and rejuvenation
Nd:YAG	1.320 nm	Dermal remodelling

Nd: Neodymium; YAG: yttrium-aluminium-garnet; PDT: photodynamic therapy.

* Table adapted from American Academy of Dermatology. 2006;55:482-9.

PURPURA

This condition usually occurs after the use of pulsed dye laser and lasts from 7 to 14 days. It is a practically inevitable effect of this first generation laser, and is even considered a parameter of effectiveness. The incidence of this phenomenon has been decreasing with the increasing availability of devices with longer pulse duration.¹¹

One of the complications of lasers in tattoo removals is the punctiform bleeding or purpura that can occur, particularly in deep lesions of patients who use aspirin or oral anticoagulants.⁷ Although not common, other devices, such as the Erbium glass laser and those used for epilation, can cause purpura.¹²

BLISTERS AND CRUSTS

These effects are a result of thermal damage in the epidermis, caused by the use of high fluences or an excess of chromophore. They can happen with any device, however they are more frequent in Q-switched (QS) lasers, since the device's basic principle is the destruction of the chromophore through "explosion."¹³ A study of the ruby laser for epilation verified that 14.9% of patients with phototypes IV to VI presented blisters.¹⁴

MILIA

Milia are small inclusion cysts that can appear during the healing process after ablative resurfacings with Erbium:YAG and CO₂ lasers. Rarely occurring in non-ablative procedures, milia can be treated with topical tretinoin or glycolic acid.¹³

FOLLICULITIS

Folliculitis can occur in treated areas after excessive sweating or physical exercise, with an increased risk when the patient takes a hot bath soon after a laser sessions.⁸



Figure 1:
Reticulate erythema in the thigh after 810 nm diode laser application

ACNEIFORM ERUPTION

In a study of 411 patients, a 6.4% incidence of post-epilation acneiform eruptions was observed in Nd:YAG and alexandrite lasers, with a higher frequency in the former.¹⁵

INFECTIONS

Infections are infrequent in non-ablative lasers. Herpes simplex is the most common infection, especially after epilation laser sessions. Although formally recommended in ablative lasers, antiviral prophylaxis is controversial in non-ablative lasers.¹¹ Bacterial infections are usually caused by *Staphylococcus epidermidis* and *aureus*. Fungal infections are caused by a species of *Candida*.²

DELAYED HEALING AND SCARS

Delayed healing is more frequent after the use of ablative lasers. However, some situations – such as collagen disorders, smoking and infections – can predispose that condition. After the most probable etiologies have been ruled out, delayed healing must be handled conservatively in order to avoid unattractive scars.¹¹ They can occur due to the inadequate adjustment of the laser device parameters (fluence and pulse duration) and also as a consequence of infections in the post-laser period.¹¹ Such scars can be treated with pulsed dye laser, corticosteroid infiltrations, or topical silicone gel.¹⁶ Although scars are the most feared complication of laser treatments, they are becoming less common due to the decreasing use of continuous wave lasers and the increasing use of cooling systems (Figure 2).

PIGMENTARY ALTERATIONS

Post-inflammatory hyperpigmentation (PIH) is usually temporary, occurring as a result of melanin deposits caused by laser thermal damage. It can be observed in almost all laser



Figure 2:
Hypertrophic scar in the thorax after Nd:YAG long pulse laser for tattoo removal

procedures, though it is more common in high phototype patients.²

A study has shown that 480 patients who underwent laser epilation with Nd:YAG, ruby and alexandrite devices had few side effects. The author concluded that PIH was more common in high phototype patients and occurred less often with Nd:YAG laser.¹⁴ Brown and others¹⁷ evaluated 800 diode laser epilation treatments (810 nm) in 144 patients, observing transient PIH in 0.25% of the cases. A study on diode laser used in the treatment of benign pigmented lesions verified a PIH rate of 12.5%.¹⁸

To reduce the risk of PIH, the skin must be cooled. However, Goldman and others¹⁹ described four PIH cases attributed to dynamic cooling devices. They observed that in those cases, PIH was persistent, resistant to treatment, and limited to the area of contact of the handpiece, even occurring with the use of low energy.

Both hypopigmentation and hyperpigmentation are transient and result from alterations in the dermoepidermal junction's melanocytes. It is more frequent in lasers that use melanin or exogenous pigments as chromophores. In a retrospective study with 900 patients who used Nd:YAG, ruby and alexandrite lasers for epilation, Alster and colleagues²⁰ observed that around 10% of the patients treated with ruby and alexandrite lasers had hypopigmentation. Post-laser hypopigmentation occurs mainly following the use of high fluences, while hyperpigmentation can happen even with low fluences.

Among the lasers used for removing pigmented lesions, the ruby, alexandrite and Nd:YAG lasers (in order of decreasing frequency) cause the highest degree of hypopigmentation. The quasi-continuous krypton (520–530 nm), KTP (532 nm) and copper steam (511 nm) lasers were used to treat ephelides and lentigines. These green lasers produce excessive thermal damage in normal tissue, since their long pulses exceed the melanosomes' time of thermal relaxation, and they can potentially generate textural modifications and dyschromias.^{2,16}

The laser devices that cause the greatest number of complications in tattoo removals are (in descending order) continuous wave CO₂, QS ruby, QS alexandrite and QS Nd:YAG. The most frequent complication is hypopigmentation, occurring in 25–50% of cases.⁷ When exposed to the sun, hypopigmented areas regain their color in three to six months. Hyperpigmentation is rare, occurring in less than 1% of cases.^{7,16} Although intense pulsed light (IPL) can be used in the treatment of tattoos, its use (rather than that of QS lasers) appears to be more associated with hypochromias and hypertrophic scars.⁷

Brown, black or red color-cosmetic tattoos, for the outline of brows, eyes and lips, usually contain iron or titanium oxide and can darken the skin after the use of any pulsed or QS laser.⁷ The laser converts ferric oxide into ferrous oxide, producing a darkened pigment that "tattoos" the skin. This phenomenon was first described in relation to the QS ruby laser, but there are similar reports after using Nd:YAG, QS alexandrite and pulsed dye lasers. If skin becomes darkened by a laser procedure, its

appearance can be improved with QS Nd:YAG laser (1.064 nm). Nevertheless, that kind of "tattoo" can resist treatment and become permanent.²¹

MALIGNIZATION OF MELANOCYTIC LESIONS

There are no reports in the literature of the malignization of melanocytic lesions due to the use of lasers. Nevertheless, this type of treatment demands caution, given the severity of such a complication. Laser-irradiated melanocytic nevi were histologically examined, and a reduction in superficial nevus cells was verified – however the same reduction was not verified in the deep reticular dermis. In this way, a later clinical evaluation could be impaired.⁷

PARADOXICAL HYPERTRICHOSIS

This complication has been described as a result of laser epilation.^{22–26} It is characterized by the development of hair in glabrous areas before treatment. Areas with paradoxical hypertrichosis are usually located adjacent to an area treated by laser.²⁴ Several cases of post-epilation hair growth (using IPL), with an incidence between 0.01% and 10.2%, have been described.^{25,26} Alajlan and others²² conducted a retrospective study evaluating 489 patients who underwent epilation with alexandrite laser over four years. From the sample, three patients (0.6% of the cases) presented paradoxical hypertrichosis.

Another study reviewed 543 cases of epilation with alexandrite and Nd:YAG 1.064 nm lasers, and with IPL. It was observed that 10.9% of the patients presented growth of thick and dark hairs (terminal hairs) in previously treated areas that contained thin hairs. Also, paradoxical hypertrichosis was verified to occur more frequently after alexandrite laser and IPL treatments. The authors believe that one of the causes of this side effect is the dissipation of the subtherapeutic thermal energy to areas adjacent to the treatment, with the consequent stimulation of hair follicles. Based on this review, a protocol was created recommending the cooling of areas adjacent to the treated region, in addition to two passes in the treated area, in all patients. A new study including that protocol did not observe cases of paradoxical hypertrichosis.²⁷

LEUKOTRICHIA

The development of permanent or temporary leukotrichia has been described after the use of laser or IPL post-epilation. Nonetheless, more studies are necessary to determine whether leukotrichia in fact occurs, or whether only fair hairs remain after dark hairs have been removed.²³

OCULAR COMPLICATIONS

Ocular complications are among the greatest concerns after laser epilation procedures, especially when treating the periocular area. The majority of the damage caused by laser radiation is due to the heating of the tissues that absorb it. Some cases of atrophy of the iris and one case of post-brows epilation uveitis after the use of diode lasers have been described.^{28,29} To protect the patients' eyes during laser procedures, intra- or extra-

ocular protectors should be used (as appropriate), and the laser beam should not be positioned towards the eyes.³⁰

ALLERGIC REACTIONS

Local, urticariform and systemic allergic reactions have already been described in the removal of tattoos using lasers. It is believed that such reactions are caused by the diffusion of the pigment after it is fragmented.^{7,31} Since there are reports of allergic reactions developing up to 6 days after laser treatments, patients should be instructed to seek treatment immediately after symptoms appear.³¹

Sackes and colleagues³¹ described a case in which a patient underwent 11 IPL sessions for removing a tattoo, without satisfactory results. A 1.064 nm Nd:YAG long pulse laser removal session was then applied. Forty minutes after the end of that session the patient presented anaphylaxis, with urticaria and progressive dyspnea treated with promethazine and intramuscular corticosteroid.

FINAL CONSIDERATIONS

Developed based on the theory of selective photothermolysis, lasers are capable of destroying specific tissular targets and minimizing the risk of scars or pigmentary alterations. However, there are several common complications resulting from the use of non-ablative lasers, including pain or discomfort during the procedure, some degree of erythema lasting less than 24 hours, the occurrence of purpura in pulsed dye laser, the formation of crusts in QS lasers, and temporary PIH, especially in patients with higher phototypes.

Scar formation and ocular complications are serious causes for concern. Excessive intensity of parameters, lack of cutaneous cooling, and complications in the post-operative period, such as infections, increase the risk of scars, and laser-based epilation in the periocular region increases the risk of ocular lesions. Nevertheless, post-non-ablative laser infections are infrequent.

Any laser system can potentially result in scars and tissue damage when incorrectly used. Therefore, it is crucial that the laser operator is appropriately trained and skilful. In addition, side effects and complications resulting from lasers can be significantly reduced if diagnosed and treated early. ●

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QUESTIONS FOR CONTINUING MEDICAL EDUCATION (CME)

- 1. Which of the following is a non-ablative laser characteristic?**

 - Improves photoaging signs with a prolonged post-operative recovery period.
 - Is as effective as ablative lasers in treating photoaging.
 - Is indicated for rejuvenation, removal or attenuation of vascular and pigmentary alterations (including tattoos), and scars and hairs.
 - Presents a high rate of side effects.
 - None of the above.
- 2. Which of the following factors DOES NOT increase the potential for complications with non-ablative lasers?**

 - Overlapping pulses.
 - Multiple passes.
 - Excessive intensity of parameters.
 - Inadequate selection of patients.
 - Post-laser use of topical corticoid.
- 3. Mark the correct alternative regarding the laser type, wavelength and its indication:**

 - Nd:YAG long pulse/1,064 nm/vascular lesions, epilation and rejuvenation.
 - Alexandrite Q-switched/694 nm/tattoos and pigment removal.
 - Nd:YAG Q-switched/532 and 1,064 nm/epilation.
 - Pulsed dye/755 nm/vascular lesions.
 - Diode/532 nm/epilation and vascular lesions.
- 4. Regarding the pain caused by non-ablative lasers, it is correct to state that:**

 - Almost all devices are practically painless.
 - Cutaneous cooling can be used to relieve the pain.
 - The majority of patients do not tolerate the procedure because it is extremely painful.
 - The use of topical or infiltrative anesthetic is not recommended because it hampers the visualization of the results.
 - All of the above are correct.
- 5. Purpura and erythema are possible side effects of non-ablative laser treatment. Which of the alternatives below is INCORRECT regarding these effects?**

 - Erythema usually lasts a maximum of 24 hours.
 - Cases of persistent reticulate erythema, mainly in the legs, were described after epilation using alexandrite laser.
 - Purpura occurs more frequently after the use of pulsed dye laser.
 - Patients using oral anticoagulants can present punctiform bleeding and purpura in the laser-based removal of tattoos.
 - None of the above.
- 6. Regarding the formation of blisters and crusts in non-ablative laser procedures, it is correct to state that:**

 - The formation of blisters and crusts occurs due to thermal damage in the dermis.
 - They occur due to the use of high fluences or an excess of chromophore.
 - They occur only with some devices.
 - They are more frequent with diode lasers.
 - All of the above.
- 7. Regarding infections caused by non-ablative lasers, it is correct to state that:**

 - It is a frequent complication in the use of non-ablative lasers.
 - Herpes simplex is the most frequent agent.
 - Antiviral prophylaxis is mandatory in the use of non-ablative lasers.
 - Bacterial infections usually occur due to *Pseudomonas aeruginosa*.
 - Infections are more frequent in non-ablative than ablative lasers.
- 8. Regarding scars, it is INCORRECT to state that:**

 - Delayed healing is more frequent with ablative lasers.
 - Factors such as collagen disorders, smoking and infections can increase the risk of scars.
 - Delayed healing almost never causes permanent scars; therefore patients must be reassured and instructed to return in 3 months.
 - Scarring is the most feared and increasingly present complication due to the decrease in the use of continuous wave lasers and the increasing use of cooling systems.
 - They are caused as much by the inadequate adjustment of the device's parameters (fluence and pulse duration) as by post-laser complications, such as infections.
- 9. Mark the correct alternative regarding post-inflammatory hyperpigmentation (PIH):**

 - In general, PIH is definitive.
 - It occurs due to melanin deposits as a response to the dermal damage caused by lasers.
 - There is no difference in PIH incidence between phototypes.
 - It is impossible to decrease the risk of PIH.
 - Studies demonstrate an average PIH rate of 20% in non-ablative lasers.
- 10. Regarding paradoxical hypertrichosis, it is INCORRECT to state that:**

 - Paradoxical hypertrichosis is a complication resulting from laser epilation procedures.
 - It is characterized by the development of hair in areas that already had hair before the treatment.
 - Areas with paradoxical hypertrichosis are usually adjacent to those epilated by the laser.
 - Post-epilation PIH cases have already been described after using IPL, alexandrite and 1,064 nm Nd:YAG lasers, among others.
 - It possibly occurs due to the dissipation of subtherapeutic thermal energy in regions adjacent to the treated area, which stimulates the hair follicles.

Key

Facial anatomy and the application of fillers and botulinum toxin – Part 2. 2010;2(4):291-303.

1-a, 2-a, 3-a, 4-d, 5-a, 6-b, 7-b, 8-a, 9-b, 10-a

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