Complications in Lasers, Lights, and Radiofrequency Devices

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Abstract

Lights, lasers, and radiofrequency are unique sources of energy that are increasingly utilized for therapeutic and cosmetic purposes. As the indications for these tools continue to increase and their use expands beyond physicians to aestheticians, physician-extenders, and technicians, the incidence of complications has also risen. It is imperative that operators of these tools be as familiar with the management of potential complications as they are with their usage and indications. This article serves as a review of potential complications encountered with usage of lasers, lights, and radiofrequency devices in dermatology.

Keywords
- lasers
- complications
- radiofrequency
- side effects

The use of lasers, lights, and radiofrequency in dermatologic surgery has rapidly advanced since the device was first introduced more than four decades ago.[1] Continued innovations in optical technology and refinement of existing devices have allowed for new developments to meet growing consumer demands for effective and safe laser therapies.[2] Such innovations include the expanding use of specific wavelengths, pulse durations, and cooling strategies; the introduction of nonablative rejuvenation techniques, including radiofrequency, intense pulsed light, and other light sources; the use of fractional resurfacing; and the combinations of laser, light, and radiofrequency technologies.

Continued refinement in laser, lights, and radiofrequency technology and technique has made safe treatment of photo-induced facial rhytides, dyschromias, lentigines, and atrophic scars possible, with low incidences of adverse sequelae. Derived from the principle of selective photothermolysis elucidated by Anderson and Parrish in 1983, an entire generation of lasers has been developed to improve tissue specificity.[1] Selective photothermolysis is accomplished through the use of appropriate wavelength and pulse duration best absorbed by specific chromophores such as melanin or hemoglobin. However, not all lasers, light, and radiofrequency sources adhere to this principle. Continuous wave lasers are least selective and may produce unwanted tissue damage and scarring through heat conduction to neighboring normal skin. Quasi-continuous wave lasers limit excessive thermal destruction by delivery of a series of brief laser pulses but still pose a higher risk of nonspecific tissue damage and thermal injury. The pulsed and Q-switched (QS) systems adhere most closely to the principles of selective photothermolysis and result in the highest degree of selective destruction with the lowest risk of scarring from excessive thermal diffusion.[4]

One of the greatest advances in laser surgery in recent years has been the development of skin-cooling technologies, which protect the epidermis from heat injury and allow for the use of higher fluences.[5,6] Failure of skin cooling, whether due to device or operator error, poses risks of thermal injury: misalignment of the cryogen spray tip, angling of the hand piece, and inadequate duration of cryogen spray have been described.[7,8]

Specific eye protection is essential for all treatments. The retina and cornea are targets for laser damage. Also, corneal abrasions may occur due to contact with topical numbing preparations, or inadvertent rubbing of the eye by the patient when the eyelid is numb. Management of all eye complications should involve a timely consultation with an ophthalmologist.

Although complication rates reported in association with cutaneous lasers, light, and radiofrequency are consistently low, many potential adverse reactions may occur; even in the hands of an experienced laser surgeon, unexpected side effects may result. Most complications are due to problems arising from these three categories: technique, mechanical defect, or patient compliance. Complicating factors include poor intraoperative technique, failure to adhere to a strict postoperative recovery regimen, the internal operations and

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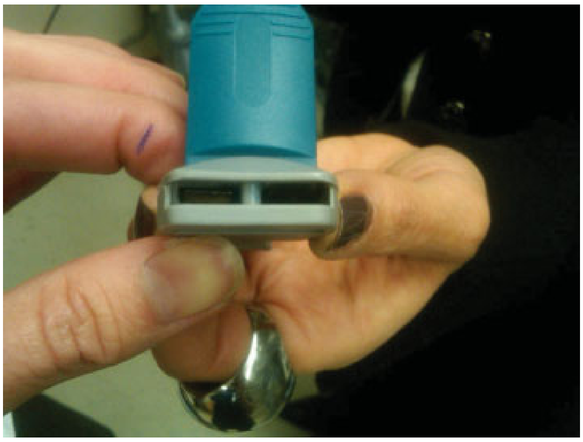

Figure 1 Thermage operational defect (missing a metal contact inside clip on right side). May have led to eyelid burn. Other major errors include failure to use coupling fluid, failure to ensure four corners of hand piece are in full contact with skin, treating areas of broken skin.

mechanical status of the equipment used (►**Fig. 1**), and the individual characteristics of each patient undergoing treatment (e.g., Fitzpatrick skin phototype, degree of ultraviolet light exposure, pretreatment, and medical condition).[3]

Resurfacing Lasers

The introduction of ablative laser skin resurfacing techniques with high-energy, pulsed carbon dioxide (CO_2) and erbium-doped yttrium aluminum garnet (Er:YAG) devices in the mid-1990s was met with great enthusiasm. They displayed excellent clinical outcomes in the treatment of atrophic scars and photodamaged facial skin, including rhytides, lentigines, and dermal elastosis, but the prolonged recovery and risk of potential side effects ultimately made them less attractive treatment alternatives.[9]

Resurfacing with either the high-energy, pulsed, or scanned CO_2 or Er:YAG laser results in complete epidermal ablation and upper papillary dermal destruction with collagen remodeling. As a result, newly resurfaced skin lacks an intact epithelium, producing an exposed weeping wound with copious serous discharge. Complete reepithelialization occurs within an average of 8.5 days for CO_2 laser-resurfaced skin, compared with 5.5 days for Er:YAG laser-treated skin. Complications of cutaneous laser resurfacing range from transient side effects to permanent disfigurement.[3]

Mild complications include prolonged erythema, acne, milia formation, contact dermatitis, and pruritus. Complications of moderate severity include reactivation of herpes simplex virus (HSV), superficial bacterial and fungal infections, postinflammatory hyperpigmentation, and delayed-onset hypopigmentation. The most severe complications associated with resurfacing include hypertrophic scar formation, ectropion, and disseminated infection.[3,4,8,10] Resurfacing treatment limited to the face, and excluding the neck and chest, was noted to leave a visible hypopigmented line of demarcation above the angle of the mandible unresponsive to tanning; this technique has recently fallen out of favor in many demographics.

Transient acneiform eruptions and milia are relatively common for nonfractionated laser resurfacing, with up to 80% of cases developing with the former and more than 14% developing with the latter.[9]

Rate of reactivation of HSV infection with traditional resurfacing laser treatment range from 2 to 7%, and requires a prophylactic antiviral treatment for patients with positive history of HSV. The rate of bacterial infection tends to be low (0.5 to 4.5% of cases) and includes the likelihood of pathogen overgrowth, primarily *Staphylococcus aureus, Pseudomonas aeruginosa*, and *Enterobacter cloacae*.[8,9]

The risk of these untoward side effects are significantly reduced when appropriate pretreatment patient selection is made, proper surgical technique is used, and the post-treatment recovery period occurs under optimal healing conditions.[4]

Fractional Photothermolysis

The concept of fractional photothermolysis, coined in 2004 by Manstein and colleagues, has revolutionized the field of laser skin resurfacing by providing the ability to obtain significant clinical results with minimal posttreatment recovery.[9,11] This technique generates microthermal treatment zones in the dermis, which are columns of thermally denatured skin of controlled width and depth.[9]

Side effects and complications of fractional laser resurfacing have been shown to be distributed among different age groups, body locations, cutaneous conditions, and skin phototypes.

Immediate posttreatment erythema or urticaria is an expected consequence of fractionated laser skin resurfacing that usually resolves within 3 to 4 days (►**Figs. 2**, **3**). Prolonged erythema is defined as posttreatment erythema that persists longer than 4 days with nonablative resurfacing and beyond 1 month with ablative treatment. It has been reported in fewer than 1% of nonablative patients and more than 12.5% of ablative laser-treated patients, although erythema typically resolves in these latter cases within 3 months.[9]

Viral, bacterial, and fungal infections are rare, but usually occur during the first postoperative week and require proper identification and treatment to avoid further complications.[9] The rate of HSV infection, the most common type of infection after fractional laser skin resurfacing, has been reported in 0.3 to 2% of cases.[9,12,13] Patients may not present with classic herpetiform vesicopustules but instead may demonstrate only superficial erosions that develop during the first week after treatment.[9,13] To minimize the risk of HSV reactivation with fractional resurfacing, antiviral prophylaxis should be administered when a prior history of facial HSV is documented or if full-face ablative laser procedures are performed.[9]

Bacterial infection is rarely observed after fractionated skin resurfacing, with only 0.1% of all treated cases documented to develop impetigo.[9,12,13] Excessive wound

Figure 2 Normal post-Fraxel erythema.

occlusion during the early postoperative period can enhance the likelihood of pathogen overgrowth, primarily *S. aureus* and *P. aeruginosa*.[9] Increased pain, focal intense erythema, increased exudate, and erosions with crusting should alert the physician to the possibility of bacterial superinfection that usually presents 1 to 3 days after treatment.[9,13] Treatment of bacterial infection includes topical antibiotics, such as mupirocin, or oral antibiotics, including antistaphylococcal penicillins, amoxicillin/clavulanate, cephalosporins, and macrolides.

Although rarely seen, cutaneous candidiasis induced by *Candida albicans* is the most common fungal infection reported after fractional laser skin resurfacing (usually 7 to 14 days after treatment) and should be treated with antifungal medications, such as topical ketoconazole, to prevent scarring.[9]

Acneiform eruptions have been documented (2 to 10%) with fractional skin resurfacing, and the incidence of milia development has been reported in as many as 19% of treated patients.[4,9,12] In some cases, this may represent a simple folliculitis due to the wound-healing response. Treatment remains primarily gentle acne medications or a medrol dose pack in more severe cases.

Figure 3 Normal post-Fraxel urticaria.

Postinflammatory hyperpigmentation is much less frequent with fractional laser skin resurfacing than with other ablative procedures, but is observed in 1 to 32% of patients, depending on the system used, parameters applied, and skin phototypes treated.[9,12] Patients with darker skin phototypes (Fitzpatrick III to VI) have a higher likelihood of developing postinflammatory hyperpigmentation. In general, fractional resurfacing of darker skin should use higher fluencies, lower-density settings, and longer treatment intervals. Hypopigmentation is an extremely uncommon complication of fractional laser skin resurfacing.[4,9]

Hypertrophic scarring is another known and rare complication of fractional ablative resurfacing. There are several potential explanations for hypertrophic scarring, including the use of excessively high-energy densities, postoperative infection of the skin, and lack of technical finesse. The neck is a well-recognized site that is especially susceptible to the development of scarring because of the small number of pilosebaceous units and poor vasculature in this region, which are essential for wound healing. In addition, the thin skin of the neck renders it more susceptible to thermal injury. Other scar-prone anatomic locations that require more conservative treatment protocols include the periorbital and mandibular regions and other areas over bony prominences.[9,14]

Other rare complications of fractional ablative resurfacing include cicatricial ectropion, multiple eruptive keratoacanthomas, and delayed purpura.[15,16]

Vascular-Specific Lasers

Vascular-specific laser systems target intravascular oxyhemoglobin to effect destruction of various congenital and acquired vascular lesions. Lasers and light sources that have been used to treat vascular lesions include the argon (488/514 nm), argon-pumped tunable dye (577/585 nm), potassium-titanyl-phosphate (KTP; 532 nm), krypton (568 nm), copper vapor/bromide (578 nm), pulsed dye laser (PDL; 585 to 595 nm), and neodymium:yttrium-aluminum-garnet (Nd:YAG; 532/1064 nm) lasers and the intense pulsed light (IPL) source (515 to 1200 nm).[4]

The most common complications of KTP are linear crusting of skin overlying treated blood vessels, transient pigmentary changes, mild fibrosis, cutaneous depressions, and hypopigmentation.[4,8]

The most common complications of PDL include transient purpura, erythema, edema, and dyspigmentation.[4] These complications are typically self-resolving and last days to months.

Because absorption of both oxyhemoglobin and melanin is reduced in the near-infrared region of the electromagnetic spectrum, significantly higher fluences are required for photocoagulation of deeper vessels. The use of proper cooling methods and avoidance of overlapping pulses is essential with long-pulsed 1064-nm lasers to prevent injury associated with inadequate dissipation of heat.[2] The most common complications of Nd:YAG are purpura, vesiculation, superficial thrombosis, transient hyperpigmentation, and atrophic scarring, most notably over the perinasal area.[4]

To minimize the risk while using different kinds of vascular lasers, the lasers should be used with extra caution on patients with recent sun exposure or in those with intrinsically dark skin tones, particularly with KTP and IPL. Avoid applications of excessive energy densities and/or pulse stacking except when indicated (e.g., PDL stacking while treating warts).

Intense Pulsed Light

The IPL system emits noncoherent broadband light in the range of 515 to 1200 nm. Indications for IPL treatment are numerous and include pigmented and vascular lesions, photoaging, and photoepilation.[17]

Common side effects after treatment with IPL include mild postoperative erythema, edema, and ecchymosis (►**Fig. 4**). More serious superficial burns and scarring can occur with aggressive treatment parameters.[4,17] Because of the potential for competition between different chromophores with IPL systems, this device should be used cautiously in type III to VI skin and suntanned skin.[8,17]

Care should be taken to maintain slight overlap between pulses to ensure confluent treatment of the target area and avoid "skip" (untreated) areas. These "skip" areas may leave a footprint of dyspigmentation in contrast to neighboring treated areas.[17]

Most complications can be minimized by use of appropriate treatment settings, cooling methods, and proper patient selection. Patients should also be advised regarding photoprotection with sun avoidance and sunscreen to minimize postinflammatory hyperpigmentation after an erythematous treatment response.[8,17]

Figure 4 Ecchymosis after a recently calibrated intense pulsed light laser. Resolved in 10 days.

Patients should be informed of all potential and oft-seen complications before they are anaesthetized. It is also recommended to discuss postprocedural care instructions before any numbing or procedures are performed to ensure understanding by the patient and to address questions they may have regarding postprocedural practice.

Pigment-Specific Lasers

High-energy, ultrashort pulsed laser systems can successfully lighten or eradicate a wide variety of benign epidermal and dermal pigmented lesions and tattoos with minimal risk of untoward effects. Epidermal lesions (solar lentigines, ephelides, café au lait macules, and seborrheic keratoses), dermal and mixed epidermal/dermal lesions (melanocytic nevi, blue nevi, nevi of Ota/Ito, infraorbital hyperpigmentation, drug-induced hyperpigmentation, Becker's nevi, and nevus spilus), and tattoos (amateur, professional, and traumatic) have all been shown to be amenable to laser treatment.[4]

The three most common types of QS lasers used in practice today are the 694-nm ruby, 755-nm alexandrite, and 532/1064-nm Nd:YAG. Each produces an immediate ash-white epidermal tissue response when targeting cutaneous pigment or tattoo ink. Other possible treatment side effects include punctuate bleeding, tissue splatter, edema, pruritus, vesiculation, textural changes, skin crusting, and transient hypopigmentation.[8]

Potential complications reported from QS laser irradiation of tattoos include generalized cutaneous allergic reactions (to cadmium- or mercury-containing inks), hemorrhagic bullae formation (particularly in the distal extremities), irreversible darkening of cosmetic tattoos (particularly white, flesh-tone, pink/red inks due to presence of iron oxide or titanium dioxide pigments that undergo a laser-induced oxidation reduction reaction), and rarely scarring and tissue fibrosis (particularly with inadequate wound management).[8] Laser conversion of ferric oxide to ferrous oxide in tattoo ink leads to formation of the insoluble black pigment. Patients who have received gold therapy in the past and undergo QS laser treatment may also experience hyperpigmentation due to alteration of gold particles still present in the skin.

Treatment of allergic reactions may be managed with oral or midpotency topical corticosteroids and oral antihistamines. Rarely, a granulomatous allergic reaction can occur with subsequent hypertrophic scar formation. Intralesional steroid injections or occlusion and pressure therapy can be used to reduce the bulky nature of such lesions without further worsening of the inciting allergic reaction. Skin dyspigmentation that results from QS laser irradiation is managed in much the same way as dyspigmentation caused by other forms of laser treatment.[4]

Laser Hair Removal

The most common lasers used for the reduction of hair include the long-pulsed ruby (694 nm), alexandrite (755 nm), diode (800 nm), and Nd:YAG (1064 nm) lasers,

Figure 5 Postinflammatory hyperpigmentation 3 months after ruby laser treatment due to failure to wear sunscreen.

Figure 6 Close-up of postinflammatory hyperpigmentation after ruby laser treatment.

as well as IPL (515 to 1200 nm) sources. These devices are most effective for hair removal because of their ability to target melanin in the hair shaft and follicle and to penetrate to the appropriate dermal depth to effect selective follicular destruction. Complications after photoepilation are influenced by skin type, body location, seasonal variations, and patient history of recent sun exposure. The extremities tend to suffer the most side effects, where as sun-protected areas, such as the axillary and inguinal regions, suffer the least. Side effects of laser-assisted hair removal are usually minor and transient (►**Figs. 5** and **6**).

The most common reactions include pain during treatment, transient erythema, and perifollicular edema; vesicle formation, pigmentary alteration, burning, and scarring have also been documented (►**Fig. 7**). Less obvious reactions include reticulate erythema and ocular complications. Most of the latter complications have occurred in individuals who are either tanned or have darker skin phototypes (IV to VI).[7,8,18] Because the 1064-nm wavelength is less efficiently absorbed by endogenous melanin, significantly fewer incidences of blistering, crusting, and dyspigmentation occur after Nd:YAG laser treatment of patients with darker or tanned skin. Complication rates will increase as skin pigment increases and as the power used increases. However, even in light-skinned individuals, with proper treatment parameters, complications and side effects can arise.[19]

Paradoxical hair growth is a possible side effect of photoepilation occurring in selected patient populations and body areas.[15] It occurs predominately on the face and neck of women of Mediterranean ancestry with darker skin phototypes. The border of the treated area and the immediately adjacent untreated skin are most commonly affected. The phenomenon has been reported when low (subthreshold) fluences are delivered to a susceptible patient, triggering hair induction rather than follicular destruction. Although laser-induced paradoxical hair growth responds well to subsequent laser treatments at moderate to high fluences, all women undergoing laser-assisted hair removal on the face or neck should be informed of the possibility of this unwanted reaction.[4]

Monopolar Radiofrequency

Radiofrequency tissue tightening is a unique nonsurgical treatment of skin laxity and tissue contour. Controlled heat modification of collagen stimulates a wound-healing

Figure 7 Postinflammatory hypopigmentation 1 week after diode treatment.

response with immediate contraction of collagen fibrils and delayed formation of new collagen.[17] The complications range from immediate transient erythema and swelling to textural changes and cutaneous depressions.[8] Late side effects such as cutaneous depressions can occur weeks or months postoperatively and result from overheating of adipose tissue and fibrous septae with monopolar radiofrequency devices (►**Fig. 8**). Caution must be used when treating over bony prominences or thin skin such as the forehead and temples; drawing skin away from bony prominences during treatment is recommended to minimize contour irregularities. Treating with lower fluences and multiple passes is advised to decrease the risk of adverse events. Mild dermal depressions often resolve spontaneously over time (►**Fig. 9**). More severe contour irregularities and scarring may improve with surgical subscision, autologous fat transfer, or cosmetic fillers (►**Fig. 10**).[17]

As with other laser and light devices, malfunctioning of the equipment may on occasion occur. The tools, including hand pieces, should be routinely evaluated and inspected for areas of damage or parts needing repair (►**Figs. 11** and **12**).

Conclusion

Although undesired, complications are a reality with clinical application of lasers, lights, and radiofrequency. Understanding the principles and mechanics of these tools can help minimize unwanted side effects, and it is imperative that all operators are aware of the spectrum of adverse effects and complication profile specific to each laser and energy source before use. Furthermore, physician and physician-extenders should only utilize these tools after they have a full understanding of possible complications and are comfortable with appropriate methods of treatment. These complications should be discussed in detail with patients, before the influences of anesthesia or numbing are introduced, and a full informed consent should be taken before the procedure. Thorough documentation of all discussion, preoperative photos, and procedure risks and benefits is essential. It is recommended to establish templates of these discussions for completion and efficiency.

Figure 9 Atrophic scar on left cheek due to Thermage over a cyst 1 year prior.

Figure 10 Thermage. Do not treat areas of acne excoriee.

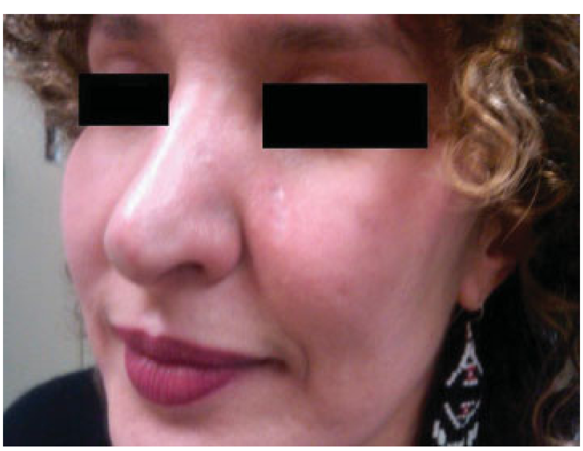

Figure 8 Thermage scar due to treatment by physician-extender over an inflamed cyst.

Figure 11 This patient developed spot blanching during treatment with a monopolar radiofrequency device.

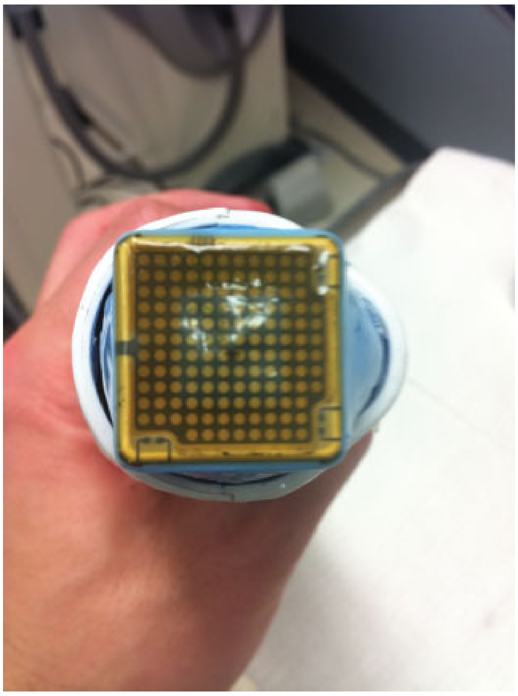

Figure 12 The tip was noted to have a black spot responsible for the dysfunction that developed midway through the treatment. The patient healed well within 2 weeks.

If the operator is unfamiliar with maintenance or specific upkeep required for these machines, individual companies should be contacted to determine a schedule of calibration and the recommended maintenance. Often the operator is familiar with settings, but not with the engineering of the laser or device. Therefore, if an error occurs, the operator may not recognize the cause such as water levels, ventilation, electrical contact, or cooling. Understanding the specific mechanics of the device—wavelength, energy source, power, common mechanical errors—greatly reduces clinical side effects.

Awareness of the varying responses, and varying risks, between skin types may spare the physician and patient unwanted side effects from these treatments, most especially patients with darker skin types. Knowing which patients are ideal for each procedure and appropriately selecting from this patient population will also significantly decrease chances of undesired side effects. In addition, consistent use of proper surgical technique with every procedure and investing the time to educate all patients of the posttreatment recovery period will ensure optimal healing conditions, and ultimately, minimize risk of complications.

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