Adverse Effects of Q-Switched Laser Treatment of Tattoos

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Anton M. Holzer, MD, Susan Burgin, MD, and Vicki V. Levine, MD, have indicated no significant interest with commercial supporters.

Case Report

A 26-year-old woman presented for consultation regarding laser removal of a professional tattoo. There had been no prior attempts at tattoo removal. Physical examination revealed a black tattoo in the form of a dragon on the mid-lower back (Figure 1). Initially, the patient underwent a test treatment on the lower portion of the tattoo. The Q-switched ruby laser (QSRL) was used at a fluence of 4.0 J/cm^2 and a spot size of 6.5 mm.

After the first treatment session, the patient reported development of asymptomatic blistering confined to the tattoo pigment. This recurred after the next treatment session. On examination, vesicles were observed in the precise distribution of the tattoo pigment (Figure 2). With topical wound care, the vesicles resolved without any permanent sequelae.

Comment

The method of quality switching or giant pulse formation was described by McClung and Hellwarth in 1962.[1] Initially, the Q-switched (QS) laser was thought to pose a greater risk of tissue injury and dispersion than its continuous wave (CW) counterpart due to the higher power of its pulses.[2] Because QS lasers adhere to the theory of selective photothermolysis, however, this did not prove to be the case. In 1983, Reid and colleagues[3] reported the successful use of a QS laser for tattoo removal, and although the QSRL did not become commercially available for several years, the theoretical and practical basis for the use of QS lasers was firmly in place. In the ensuing two decades, QS ruby (694 nm), alexandrite (755 nm), and neodymium:yttrium-aluminum-garnet (Nd:YAG; 532 and 1,064 nm) lasers have been successfully employed for the eradication of a wide variety of both professional and amateur tattoos.[4]

Adverse Effects

Although the basis for the use of QS lasers is the relative safety of ultrashort pulse durations, adverse effects have been reported with their use. An immediate adverse effect is a sharp needlelike pricking sensation, but pain can be satisfactorily controlled with topical or injected anesthetics.[5] Other side effects associated with these lasers include thermally induced epidermal and dermal changes, pigmentary alteration, and the possible effects of laser-released antigens and other chemical compounds.

Thermally Induced Damage and Inflammatory Changes

This case report details blistering after laser tattoo removal, a known possible complication of QS laser therapy. Data on the frequency of blistering after QS laser treatment are scarce: Werner and workers[6]

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Figure 1. Pretreatment tattoo.

Figure 2. Posttreatment tattoo: vesicles in distribution of tattoo pigment.

report that 7.5% of patients experienced blistering after treatment of tattoos with the frequency-doubled QS Nd:YAG (532 nm), 5.4% after QSRL, and 1.1% after QS Nd:YAG (1,064 nm). Histologic findings in QSRL-treated guinea pig skin, include epidermal damage and subepidermal bulla formation. The epidermal damage is dependent on the degree of pigmentation of the epidermis and consists of vacuolization of pigment-containing melanocytes and keratinocytes.[7] These findings are mirrored in QSRL-treated tattoos in human skin, and blistering was occasionally seen at fluences of 3 to 4 J/cm^2.[8] Vascular injury is also often seen in treated tattoos, evidenced by petechiae or even frank hemorrhage. This is due to the fact that hemoglobin does absorb some energy at all of these wavelengths.

Clinically apparent inflammation is another reported, though transient, side effect of QS laser therapy. Erythema and edema are commonly observed. An alarming inflammatory sequela is detailed in one case report of a forearm compartment syndrome after QS Nd:YAG laser treatment of a decorative tattoo.[9] Contributory factors in this case were the location of the tattoo (distal forearm) together with its size (it occupied around a third of the forearm circumference) and the fact that the number of passes with the QS Nd:YAG laser exceeded the recommended guidelines. Although the Koebner phenomenon has been reported with long-pulse laser therapy,[10] it has not been reported after QS laser treatment.

Scarring is less frequent with QS lasers than with their CW predecessors; however, both atrophic and hypertrophic scar formation have been reported.[8,11] Scarring may be more common following treatment of "double tattoos"—tattoos placed over preexisting tattoos. Two patients with double tattoos developed hemorrhagic bullae with subsequent atrophic and hypertrophic scarring after one treatment with QS ruby and alexandrite lasers.[12] The high intensity of pigment in the double tattoos presumably leads to greater energy absorption and heat production with consequent dermal damage. Use of lower fluences to treat these patients may therefore be prudent.

Undesired Pigmentary Alterations

QS lasers may be associated with hyper-, hypo-, and rarely depigmentation. Although pigmentary alteration is usually transient, it can be permanent.[13] Hypopigmentation is more common when the wavelength of the laser is well absorbed by melanin-laden melanocytes. The QS Nd:YAG (532-nm) laser usually causes a short-lived hypopigmentation in all skin types, either due to the minimal depth of penetration of this wavelength (therefore preserving follicular melanocytes)[4] or due to the reduced fluences used compared to other laser wavelengths. Longer lasting hypopigmentation is more commonly seen with the QSRL than the QS Nd:YAG (1,064 nm).[11] In a comparison of QS alexandrite, Nd:YAG (1064-nm), and ruby lasers in the treatment of blue-black tattoos, hypopigmentation occurred most frequently with the ruby laser (38%) followed by the QS alexandrite (2%). No hypopigmentation was seen after QS Nd:YAG (1,064 nm) treatment. In two separate studies with the QS alexandrite laser, Alster[14,15] found no permanent hypopigmentation when amateur, professional, and traumatic tattoos were treated. The QSRL has the highest incidence of hypopigmentation because melanin absorbs more energy at this wavelength. The QS alexandrite has a lower risk of hypopigmentation due to its slightly longer wavelength, which has less melanin absorption and deeper tissue penetration, as well as its lower peak power seen with the longer pulse width (compared to the QSRL). The difference in beam profile between the QSRL and the QS alexandrite may also account for the higher incidence of ruby laser–induced hypopigmentation. The QSRL beam has a Gaussian distribution with higher energies in the center. The beam profile of the QS alexandrite is dependent upon the delivery system. An articulated arm produces a Gaussian beam, whereas a fiber will produce a more flat-topped beam. At 1,064 nm, the QS Nd:YAG laser has the longest and most deeply penetrating wavelength, with the least risk of pigmentary alteration. Thus the QS Nd:YAG (1,064 nm) is the safest choice for laser tattoo removal in darker skin types.[16] Recently the excimer laser has been shown to improve post–QS laser-induced hypopigmentation.[17] Since this effect is only transient, continued treatment is needed to maintain the improvement.

The side effect of depigmentation occurs more rarely than that of hypopigmentation after QS laser therapy.[18] Depigmentation as a desired end point after QS laser therapy was reported in a patient with vitiligo universalis. Here melanocyte destruction in pigmented patches was accomplished after QSRL treatment at high fluences.[19]

Generally, the incidence of hyperpigmentation is related to skin type. Patients with Fitzpatrick skin type III or greater are most likely to develop postinflammatory hyperpigmentation. Although use of the QS Nd:YAG laser is preferable, temporary hyperpigmentation is still common.[4] The use of topical hydroquinones and sunscreens in the treatment of hyperpigmentation is helpful.

Paradoxical darkening of tattoo ink may occur following treatment with QS lasers.[20,21] In one study, the tattoo darkening developed immediately after laser impact in most pigments and was not obscured by the whitening caused by the laser.[22] This phenomenon is seen most commonly in the red-, white-, brown-, and flesh-colored inks that are used in cosmetic tattoos such as for lipliners, eyeliners, and eyebrows. It has been noted that white, brown, and flesh colors undergo darkening more commonly than red.[18] It is thought that QS laser treatment generates reduction of the pigments, from rust-colored ferric to black ferrous oxide, or white titanium^{4+} to blue titanium^{3+} dioxide. Paradoxical darkening has been treated successfully with the pulsed carbon dioxide laser,[18] a QS laser from a class different than the one originally employed (alexandrite and Nd:YAG for ruby-darkened pigment)[23] and even with the very same laser that darkened the tattoo in the first place (ruby for ruby).[24] Because it may not be possible to remove this darkened pigment, it may be judicious to perform a test treatment in these tattoos. A case of tattoo brightening has been reported—color change from brown to bright orange to yellow—in inks of unknown composition. This is theorized to result either from the sequential removal of differently pigmented chromophores or from a previously undescribed chemical reaction.[25]

Effects of Laser-Released Antigens, Toxins, or Carcinogens

Both immediate (Type I)[26] and delayed (Type IV)[27] hypersensitivity reactions after tattoo removal with QS lasers have been reported. The first published report describes two patients who developed systemic delayed reactions after laser therapy. One patient developed a localized and generalized pruritic eruption 2 to 3 weeks after QSRL and QS Nd:YAG treatment. A skin biopsy revealed a spongiotic dermatitis. The second patient developed a generalized urticarial eruption approximately 1 week after her sixth treatment with the aforementioned lasers. Prior treatments had been uneventful.[25] In 2002, England and colleagues[26] described a patient who developed an urticarial eruption within 30 minutes of tattoo treatment with the QS Nd:YAG laser (at 1,064–532 nm). Prophylactic treatment with oral corticosteroids and antihistamines may prevent similar reactions after subsequent treatment sessions.[24]

A quantitative chemical analysis of tattoo pigments was undertaken in an effort to provide guidance as to antigenicity and treatment resistance of standard inks employed by professional tattoo artists;[28] this has been heralded as an important first step toward the elimination of ink-specific adverse effects of tattooing and laser removal such as paradoxical darkening and hypersensitivity reactions.[29]

Treatment of traumatic tattoos with QS lasers may result in combustion. A case of QS laser ignition of a traumatic tattoo from firework debris has been reported.[30]

A worrisome adverse effect of laser tattoo removal is the possibility of toxicity or carcinogenesis from laser-cleaved pigments. Recent evidence has revealed that the high laser intensities of QS lasers can cleave azo pigment compounds to form toxic and carcinogenic decomposition products such as 2-methyl-5 nitroaniline, 2-5-dichloraniline, and 4-nitrotoluene.[31] Further study may be necessary to determine whether tattoo laser treatment generates sufficient doses of these compounds to present cause for concern.

In summary, we report a case of blistering after QS laser treatment. Even when blistering does develop, there is usually no adverse effect on healing. Although laser tattoo removal is generally a safe procedure, side effects as have been enumerated above occur infrequently.

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