LASER TREATMENT OF PIGMENTED LESIONS

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In 1958, Schawlow and Townes, working with microwaves, first proposed a technique for the generation of monochromatic radiation by stimulated emission. They produced monochromatic radiation in the infrared optical region of the electromagnetic spectrum with an alkali vapor used as the active medium. Maiman, using a ruby crystal in 1960, developed stimulated emission of a red-light beam with a wavelength of 694 nm. This was the first working laser, and it is from this prototype that today’s lasers are derived. Since 1960, research and technical advances have adapted lasers to dermatology. Leon Goldman, the father of dermatologic laser surgery, published preliminary results on the effects of a ruby laser on skin diseases. Early work with the ruby laser consisted of ablation techniques. Little bleeding was noted after nonspecific damage to the superficial dermal layers, and small areas of skin could be treated with high-intensity radiation with few sequelae.

Not surprisingly, the ruby laser was found to treat pigmented lesions well owing to its ability to target melanin. Today, there are numerous lasers that can specifically target pigmented lesions, including other red light lasers (ie, alexandrite, neodymium:yttrium-aluminum-garnet [Nd:YAG]) and green light lasers (ie, 510-nm pulsed dye, 532-nm frequency-doubled Nd:YAG). The wide range of lasers that can be used to treat pigment is a result of the broad absorption spectrum of melanin. Even so, other less pigment-specific lasers have been used to treat pigmented lesions, including the CO₂ and argon lasers. The CO₂ laser exerts its effect on tissue by simple vaporization of water-containing cells. Textural skin changes and scarring may result from this nonselective destruction. A very low wattage CO₂ laser appears to reduce the risk of scarring and has been used effectively to treat superficial epidermal pigmented lesions, such as solar lentigines.

Lasers that produce pulses of light shorter than the thermal relaxation time of melanosomes are now used to selectively destroy targeted melanin. The process of removing pigmented lesions using sufficiently shorter laser pulses is called selective photothermolysis. The targeted melanosome selectively absorbs the laser light and the resultant increase in temperature induces thermal damage of
the melanosome. Because this damage occurs over a time period shorter than the melanosome’s thermal relaxation time, the absorbed energy is confined to the targeted melanin-containing melanosomes within melanocytes and keratinocytes. Selective destruction of melanosomes results without damage to surrounding tissue structures.

The pigmented skin of guinea pigs and human volunteers has been shown to respond to short laser pulses over a wide range of visible light wavelengths. Lasers that target pigment include the pulsed dye (510 nm), copper vapor (511 nm), krypton (520–530 nm), frequency-doubled Q-switched Nd:YAG (532 nm), 0-switched ruby (694 nm), 0-switched alexandrite (755 nm), and Q-switched Nd:YAG (1064 nm). All these wavelengths can effectively treat pigmented lesions without disrupting the normal surrounding tissue. Pigment-specific lasers can be divided into three categories: (1) green, (2) red, and (3) near-infrared. Green light lasers are further subdivided into both pulsed and nonpulsed systems. The red and near-infrared lasers currently available are pulsed (or Q-switched) systems. Green light lasers do not penetrate as deeply into the skin as do the red and near-infrared lasers owing to their shorter wavelengths. Green light lasers are therefore effective only in the treatment of epidermal pigmented lesions.

Figure 1. Solar lentigines prior to (A) and after (B) one treatment session with a green light pulsed laser.
GREEN LIGHT PULSED LASERS

These lasers produce energy with pulses shorter than the thermal relaxation time of melanosomes. Examples of these lasers are the flashlamp-pumped pulsed dye and frequency-doubled Q-switched Nd:YAG lasers. The flashlamp-pumped pulsed dye laser produces a 510-nm wavelength and 300-ns pulse of energy whereas the frequency-doubled Q-switched Nd:YAG laser produces a 532-nm wavelength and 5- to 10-ns pulse of energy. Both lasers produce excellent results when used to treat epidermal pigmented lesions such as solar lentigines and ephelides. Because the green wavelength of these lasers is also well absorbed by oxyhemoglobin, purpura formation may occur following laser irradiation. The purpura resolves in 1 to 2 weeks after treatment, with resolution or lightening of the clinical lesion in 4 to 8 weeks. Occasionally, purpura leads to postinflammatory hyperpigmentation. It should be noted that these lasers produce a variable response in epidermal pigmented lesions such as cafe-au-lait macules, Becker's nevi, and epidermal melanoma. Because of the variability in clinical response, testing the treatment areas of the respective lesion may be prudent prior to engaging in a full treatment. Even when cafe-au-lait macules and Becker's nevi show resolution after treatment, recurrences have been reported. Recurrences may occur because of the impact of these lasers on melanosomes, with little effect on the pigment-producing melanocytes. Careful sun protection may retard, but will not prevent, recurrence. Because melasma occurs secondary to a combination of genetic, sun-induced, and hormonal factors, successful laser treatment is the exception rather than the rule in this condition. The green pulsed lasers, because of their short wavelengths, do not penetrate very deeply into the dermis and are thus ineffective for treating dermal pigmented lesions (Figs. 1 and 2).

GREEN LIGHT NONPULSED (QUASICONTINUOUS WAVE) LASERS

Nonpulsed, quasi-continuous wave green light lasers such as the copper vapor (511 nm) or krypton (520-530 nm) lasers share some characteristics with the aforementioned pulsed lasers. Because the thermal relaxation time of the melanosome is exceeded using these lasers, however, they do not produce the same consistent clinical results. Although epidermal pigmented lesions may be cleared successfully with the copper vapor and krypton lasers, more treatment sessions are usually necessary to achieve lesional clearance. There is also a theoretically higher incidence of scarring when using these systems (Fig. 3).

RED LIGHT PULSED LASERS

The two currently available red light pulsed lasers are the Q-switched ruby and Q-

Figure 2. A, Cafe-au-lait macule prior to treatment with a green light pulsed laser. B, Early recurrence of cafe-au-lait macule observed 18 months after last laser treatment.
switched alexandrite lasers. The Q-switched ruby laser emits a 694-nm beam with a 20- to 50-ns pulse duration. The Q-switched alexandrite laser emits a 755-nm wavelength with a pulse duration of 50 to 100 ns. The longer wavelengths of these lasers allow deeper penetration into the dermis. Their mechanism of action on melanin-containing melanosomes and melanocytes involves selective photothermolysis, photoacoustical mechanical disruption, and chemical alteration of the target tissue. Photoacoustic mechanical disruption is caused by rapid thermal tissue expansion, creating pressure waves that fragment pigment particles in the dermis. Within the dermis, absorption of the laser energy by melanin-rich stage III and IV melanosomes causes selective pigment destruction. These lasers can also be used to treat epidermal pigmented lesions without purpura formation owing to the relative lack of hemoglobin absorption at these wavelengths (Figs. 4 and 5). The major benefit of the red light systems over green light lasers is their efficacy in the treatment of dermal pigmented lesions such as congenital nevi and nevi of Ota. Although these lasers are uniformly successful in the treatment of nevus of Ota, the response to laser treatment of congenital nevi is more variable. In both clinical entities, the lasers appear to destroy some but not all of the involved melanocytes. Darker congenital nevi in younger patients appear to show the best response; however, pigment recurrence is common. Nevii of Ota are typically very responsive to laser treatment, with rare to no
Figure 4. Solar lentigo prior to (A) and after (B) treatment with a red light pulsed laser.
recurrences seen (Figs. 6 and 7). The responses of dermal melasma are quite variable, with repigmentation or pigmentary worsening a common occurrence.

Recently, long-pulsed ruby lasers (300-700 µs pulses) have been shown to be effective in the treatment of Q-switched ruby laserresistant congenital nevi. These lasers may also be of use in laser-assisted hair removal (see the article by Dr. Wheeland elsewhere in this issue).

NEAR-INFRARED PULSED LASERS

The Q-switched Nd:YAG laser produces a 1064-nm wavelength beam with a pulse duration of 10 ns. Despite less absorption of this wavelength by melanin compared with the green and red light lasers, its advantage lies in its ability to penetrate more deeply in the skin. In addition, it may prove to be more useful in the treatment of lesions in individuals with darker skin tones. Like the Q-switched ruby and alexandrite lasers, the Q-switched Nd:YAG laser is highly effective in clearing of nevus of Ota. When used in combination with a carbon-containing topical suspension, the Nd:YAG laser may also effectively remove unwanted hair (Fig. 8). Because carbon-coated hair, rather than the melanin of pigmented hairs, is the absorbing chromophore, both pigmented and nonpigmented hairs may be treated (see the article by Wheeland).

LASER TREATMENT PROTOCOL

Green Light Lasers

_Pulsed Dye (510 nm) Laser_

Treatments are usually initiated at 2.0 to 3.0 J/cm² using nonoverlapping 5-mm laser spots. An immediate ash-white tissue response should occur. Repeat treatments are delivered at 6- to 8-week intervals. Solar lentigines typically require one to two laser treatments, whereas cafe-au-lait macules may require 2 to 12 treatment sessions.

Frequency-Doubled Nd: YAG (532 nm) Laser

Solar lentigines and cafe-au-lait macules are typically treated at fluences of 2.0 to 2.5 J/cm² using 1- to 3-mm spots at 10 Hz. Like the pulsed dye laser, only a couple of laser sessions are needed to treat lentigines. The response of cafe-au-lait macules is variable.

Quasi-Continuous Wave Copper Vapor (511 nm) and Krypton (520-530 nm) Lasers

The copper vapor laser is used at 0.16 to 0.25 W using a 150-µm spot at 0.2-second intervals. The krypton laser is operated at 700 mW with a 0.2-second pulse and 1-mm spot. These lasers can be used to treat solar lentigines, but their use in cafe-au-lait macules has
Figure 6. Nevus of Ota prior to (A) and after (B) treatment with a red light pulsed laser.
Figure 7. Congenital pigmented nevus prior to (A) and after (B) several treatment sessions with the Q-switched ruby laser.
commonly led to textural changes following treatment.

**Red and Infrared Light Lasers**

**Q-Switched Ruby Laser (694 nm)**

Fluences of 5.0 to 6.0 J/cm² are used to treat epidermal and dermal pigmented lesions. One or two treatments effectively clear lentigines whereas cafe-au-lait macules and nevi of Ota require four or more treatments at bimonthly intervals. Significant lightening of infraorbital hyperpigmentation can be achieved within two laser sessions.

**Q-Switched Alexandrite Laser (755 nm)**

Fluences of 6.0 to 7.0 J/cm² are used to treat nevi of Ota, melanocytic nevi, and infraorbital hyperpigmentation. Treatment sessions are scheduled at 6- to 8-week intervals with an average of five treatments required to effect clearance of nevus of Ota. Three treatments produce significant clearing of melanocytic nevi, whereas two sessions can significantly lighten infraorbital hyperpigmentation.

**Q-Switched Nd: YAG Laser (1064 nm)**

Energy densities averaging 8.0 J/cm² using a 3-mm spot size are required to treat nevus of Ota. Similar parameters are used to treat benign melanocytic nevi; however, lower fluences are used for infraorbital hyperpigmentation.

**SUMMARY**

Several pigment-specific lasers can effectively treat epidermal and dermal pigmented...
lesions without complications using the basic principles of selective photothermolysis. Although such pigmented lesions as solar lentigines and nevi of Ota are relatively easy to treat using pigment-specific laser technology, cafe-au-lait macules and melasma show variable responses to treatment. New, longpulsed pigment-specific lasers may prove to further enhance the clinical results obtained in resistant pigmented lesions and other conditions.

References


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