Update on Laser Hair Removal

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Laser hair removal (LHR) is now among the most common cosmetic laser procedures performed in the United States. Other methods of hair removal include shaving, waxing, tweezing, depilation, and electrolysis. Although both LHR and electrolysis may achieve permanent hair removal, LHR is less painful, allows for more efficient treatment of large surface areas, and is substantially less likely to scar. In addition, a recent survey found that most patients are satisfied with LHR compared with other methods of hair removal.

Photoepilation, or the removal of hair with light, may be accomplished photomechanically, photochemically, or photothermally. Photomechanical removal utilizes shock waves. Photochemical removal may use free radicals generated by the combination of a photosensitizer and light. Photothermal removal, which takes advantage of light-generated heat, is the most widely used and studied LHR method and is the focus of this article.

The first laser devices for which approval from the US Food and Drug Administration (FDA) was sought were compared with electrolysis. Despite insufficient supporting data, the efficacy of electrolysis was defined as a 30% decrease in hair regrowth 3 months after a single treatment.[1,2] In 1995, the first laser was approved for laser hair removal (LHR). It involved applying a carbon-based solution and then exposing hair to Q-switched Nd:YAG aluminum garnet laser pulses.[3] Although hair removal was achieved after only 1 treatment, further work showed full regrowth of all hair 6 months posttreatment.[4]

In 1996, Grossman et al[5] investigated the use of a normal-mode (long-pulsed) ruby laser (694 nm) for LHR. They treated 13 human subjects with fluences of 0, 30, 40, and 60 J/cm^2 for 270 milliseconds. They noted a statistically significant, fluence-dependent growth delay at 1 and 3 months for all subjects. However, a significant effect was seen only in a third of subjects treated with the highest fluence 6 months posttreatment. A small percentage of this group was found to have partial hair reduction 2 years after the study,[6] encouraging further work in LHR.

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MECHANISM OF PHOTOTHERMAL HAIR REMOVAL

Melanin is the primary absorber of light in the skin between 600 and 1100 nm.[7] Photothermal LHR destroys hair follicles by targeting this endogenous chromophore within the hair shaft, hair follicle epithelium, and heavily pigmented hair matrix.[3]

The goal in LHR is to deliver the highest fluence to the hair follicles without damaging the epidermis. To achieve this, the theory of selective photothermolysis must be applied. This landmark theory proposes that selective thermal destruction of a target will occur if enough energy is delivered at a wavelength that is well absorbed by the target within a period less than or equal to the thermal relaxation time (TRT) of the target.[8] The TRT, which is dependent on the target diameter, is defined as the time required for the target to lose 50% of its heat through diffusion. Pulse duration, or the time in which the energy is delivered, should be shorter than the target TRT and longer than the TRT of the surrounding tissue. Therefore, the ideal pulse duration ranges from 3 to 50 milliseconds between the TRT of the epidermis and hair follicle.[9]

However, LHR has also been hypothesized to damage follicular stem cells in the bulge region of the follicle.[6] These cells are generally nonpigmented and may be located a distance away from the intended pigmented targets. It has been suggested that these stem cells are destroyed by heat diffusing from the pigmented area rather than by direct heating. This theory, known as the extended theory of selective photothermolysis, proposes pulse durations longer than the TRT.[10] A recent study by Orringer et al[11] investigated whether LHR causes destruction of these stem cells. Although the study did not find immunohistochemical evidence of LHR-induced stem-cell destruction, it was limited by a small sample size and examination of tissue after only 1 laser treatment. More comprehensive studies are needed to further investigation.

LASER AND LIGHT SOURCES

Dierickx and Anderson[12] proposed that permanent hair removal be defined as a significant reduction in the number of terminal hairs after a given treatment that is stable for a period longer than the complete growth cycle of hair follicles at a given body site. There are myriad choices for performing this removal today. Most devices function in the red or near-infrared wavelength, simultaneously allowing selective melanin targeting and penetration into the deep dermis. Current laser systems for LHR range in wavelength from the long-pulsed ruby (694 nm) to the long-pulsed alexandrite (755 nm) and long-pulsed diode (800 nm) to the long-pulsed Nd:YAG (1064 nm). An intense pulsed light (IPL) device that functions in the 590- to 1200-nm range has also been successfully utilized. As mentioned, although the Q-switched Nd:YAG laser has also been FDA approved for temporary LHR, it is infrequently used for this purpose in the United States.[13] However, in Asia, use of the Q-switched Nd:YAG laser is a popular form of temporary LHR.

A critical review of the literature reveals a fundamental difficulty in assessing LHR data. Unfortunately, most studies are nonrandomized. In addition, variations among studies are routinely noted because there are no standardized protocols for LHR. Differences among methods include the pretreatment preparation (eg, waxing vs shaving), the body site treated, the pulse duration, the fluence, the spot size, the number of treatments, and the time between treatments. In addition, almost all studies have limited follow-up intervals, making assessment of regrowth rates and long-term hair removal problematic. In fact, a recent evidence-based review of the LHR literature concluded that there is no evidence for complete and persistent hair removal efficacy.[14] Alexiades-Armenakas[15] suggested that there is experimental and observational evidence for LHR performance and that more randomized, controlled trials with long-term follow-up should be performed.

Long-Pulsed 694-nm Ruby Laser

The long-pulsed 694-nm ruby laser was the second FDA-approved laser for hair removal. It was first reported to cause hair follicle damage by Grossman et al[5] in 1996. Since then, varying results have been reported in the literature. Recently, the long-pulsed ruby laser has been investigated with a number of mostly nonrandomized, controlled trials.[16] Efficacy of this laser has been shown to range from 6.3% after 2 treatments of the upper lip[17] to 61% after 4 treatments of facial hair 11 months postoperatively.[18] In 1997, Dierickx and Anderson[12] reported permanent hair loss 2 years after a single treatment with the long-pulsed ruby laser, but this was observed in only 4 of 13 patients. A recent review of the literature[14] found little evidence for the effect of the long-pulsed ruby laser once nonrandomized, controlled trials were excluded. Note, however, that only 1 randomized, controlled trial has been performed so far.[17] At the present time, longer-wavelength lasers are often favored by clinicians over the long-pulsed ruby, as there is less of a chance of scarring and dyspigmentation.

Long-Pulsed 755-nm Alexandrite Laser

The long-pulsed 755-nm alexandrite laser was the third FDA-approved LHR system. The 755-nm wavelength is absorbed approximately 20% less strongly by melanin than the 694-nm wavelength of the long-pulsed ruby laser. Since dermal scattering is inversely correlated with dermal penetration, the long-pulsed alexandrite laser can penetrate deeper into the dermis. In theory, this should allow for more effective LHR, as the longer wavelength should target the deeper follicular melanocytes and cause less epidermal damage.

In 2000, Gorgu et al[18] compared the long-pulsed alexandrite laser with electrolysis for axillary hair removal in 12 patients. They found a 74% decrease in hairs 6 months after 3 treatments with the long-pulsed alexandrite laser versus a 35% decrease 6 months after 4 treatments with electrolysis. Moreover, they reported that all patients preferred laser hair removal, as it was less painful and 60% faster than electrolysis. A number of large but nonrandomized studies have evaluated the efficacy of the long-pulsed alexandrite laser. Hussain et al[19] enrolled 144 patients with Fitzpatrick skin type III, IV, or V to investigate their responses to 1, 2, or 3 treatments at 4-week intervals with fluences of 16 to 24 J/cm^2. Not surprisingly, they found that the efficacy of LHR improved as the number of treatments increased. For example, 55% hair removal was noted at 9 months after the third treatment versus 32% after a single treatment. No differences were seen among the skin types. Bouzari et al[20] confirmed these findings but also noted that an increased number of treatments was associated with increased adverse effects. The investigators defined success as greater than 50% hair removal in the absence of adverse effects.

Eremia et al[21] did a retrospective chart review and interview of 89 patients 15 months posttreatment with the long-pulsed alexandrite laser. Mean hair removal was 74% after 5.6 treatment sessions in various body areas. Investigators found that patients with Fitzpatrick skin type I consistently had a better response than others in all sites except for the trunk. This was closely correlated with patients with Fitzpatrick skin type I tolerating higher fluences. Lloyd and Mirkov[22] found a 78% removal of bikini hair 1 year after 5 treatments with the long-pulsed alexandrite laser at 3-week intervals. In addition, 2 small studies[23,24] compared the long-term results of LHR with the long-pulsed alexandrite with the results of LHR with the long-pulsed diode. They found similar efficacy up to 1 year after 3 to 4 treatments with the long-pulsed alexandrite laser versus 3 to 4 treatments with the long-pulsed diode laser.

Recently, Touma and Rohrer[25] reported a patient with persistent 70% hair removal 5 years after a single treatment with a 3-millisecond alexandrite laser. This is a rare but interesting single-case report.

Long-Pulsed 810-nm Diode Laser

The longer wavelength of the 810-nm diode laser also has the advantage of reduced scatter, allowing for deeper dermal penetration and, in darker-skinned patients, the advantage of increased epidermal protection. Several studies have evaluated its efficacy compared with shaving, the long-pulsed alexandrite laser, the long-pulsed Nd:YAG laser, and noncoherent light. It has generally performed favorably in all of these comparisons. Baugh et al[26] showed that the efficacy of diode LHR, as with other lasers, is fluence dependent. Lou et al[27] evaluated the long-term results of the diode laser in patients with Fitzpatrick skin types I and II. Although the results were favorable, a large number of subjects dropped out of the study and a large between-group variation in protocol occurred. As mentioned, 2 small studies compared the long-pulsed alexandrite and long-pulsed diode lasers for hair removal and found similarly favorable results at up to 1 year.[23,24] One study found slightly more pain, blistering, and hyperpigmentation with the diode laser than with the long-pulsed alexandrite, however.[23]

Long-Pulsed 1064-nm Nd:YAG Laser

Although the 1064-nm wavelength of the long-pulsed Nd:YAG laser allows for deeper penetration than the long-pulsed ruby, alexandrite, and diode lasers, it is not as readily absorbed by the target chromophore melanin. Although it is therefore much safer for patients with darker skin, it is also limited by reduced efficacy. To improve efficacy, higher fluences are used, which are accompanied by an increased risk of epidermal damage and pain.

Tanzi and Alster[28] studied the effect of the long-pulsed Nd:YAG laser on patients of differing skin types and found that LHR was more effective on the body than the face, with a mean hair removal of 48% to 53% on the body and 41% to 46% on the face. Despite the small sample size, the investigators found patients of differing skin types to have similar results. The long-pulsed Nd:YAG laser has been evaluated in patients with darker skin, with good results. In 2001, Alster et al[29] treated 20 patients with Fitzpatrick skin type IV, V, or VI and found 70% to 90% hair removal 12 months after 3 treatments. Adverse effects were minimal and temporary. Histologic sections showed selective follicular injury.

Bouzari et al[30] compared the 3 most popular laser systems in 2004. The long-pulsed Nd:YAG, long-pulsed diode, and long-pulsed alexandrite lasers were evaluated in a retrospective study of 75 patients. These investigators also did not find a difference in efficacy or adverse effects based on skin type. The long-pulsed alexandrite and long-pulsed diode lasers showed similar efficacy and were both more efficacious than the long-pulsed Nd:YAG laser. The investigators found a positive correlation between the number of treatments and hair removal, as with other studies.

Noncoherent 590- to 1200-nm IPL

IPL devices deliver noncoherent, multiwavelength (nonlaser) light from 500 to 1200 nm. Filters may be used to eliminate shorter wavelengths and focus the range of output to avoid damaging the epidermal pigment. Because of this filtration, assessing efficacy with these devices is difficult. Results vary greatly, as parameters, including the wavelength, are not standardized. Some studies have compared treatment with IPL with that of lasers, including the long-pulsed Nd:YAG,[31] long-pulsed ruby,[32] and long-pulsed alexandrite.[33] IPL performed favorably in all of the studies but had a greater adverse-effect profile except when compared with the long-pulsed alexandrite laser.

PRECAUTIONS AND ADVERSE EFFECTS

Although LHR is generally safe, as with all procedures, adverse effects may occur. Most adverse effects result from epidermal injury caused by unwanted energy absorption in superficial bystander melanin. Therefore, patients with tanned or darker skin undergoing LHR with shorter-wavelength lasers have the highest rates of adverse effects; a patient with Fitzpatrick skin type VI undergoing LHR with the long-pulsed 694-nm ruby laser is at greatest risk. Although a patient with Fitzpatrick skin type I who is treated with the long-pulsed Nd:YAG is least likely to experience adverse effects, one must also balance reduced risk with decreased melanin absorption at this wavelength, which will decrease efficacy. It is for this reason that the workhorses of LHR are the long-pulsed alexandrite and long-pulsed diode lasers, which afford selective absorption by melanin with relatively deep dermal penetration.

Adverse effects of LHR may include erythema, blistering, hypopigmentation or hyperpigmentation, crusting, purpura, pain, scarring, atrophy, paradoxical hypertrichosis, leukotrichosis, persistent heat sensation, reticulate erythema, leukotrichia, cold urticaria, or thrombophlebitis. Perifollicular erythema and edema, which usually clear within 1 to 4 hours posttreatment, should not be regarded as adverse effects, as they are necessary end points in all LHR procedures. Although there are many possible adverse effects, fortunately most are temporary and may be avoided with careful attention to laser parameters. Fluences must be uptitrated carefully while ensuring sufficient pulse duration to avoid epidermal damage. In addition, cooling of the epidermis may minimize heat transfer to surrounding structures and protect the epidermis from injury, especially in patients with darker skin.[34,35]

More recently described adverse effects of LHR include paradoxical hypertrichosis and reticulate erythema. Paradoxical hypertrichosis is the increase in terminal hairs at sites adjacent to or treated with LHR. This is a rare (0.6%–4%) but troubling adverse effect for patients. It has been reported posttreatment with the long-pulsed alexandrite laser,[33,36,37] long-pulsed diode laser,[38] and IPL.[39] Although a small number of cases have been reported, the data thus far suggest that patients with dark hair and Fitzpatrick skin type III, IV, or V may be at increased risk for developing this adverse effect. In a recent article reporting paradoxical hypertrichosis, Kontoes et al[40] identified 30 of 750 patients in Greece who developed this adverse effect. The investigators noted that hair induction began months after the first treatment and was most common on the face and neck areas. They suggested treating the new hairs with LHR at higher fluences and with longer-wavelength devices and reported favorable treatment results with this method.[36,40]

In 2004, Lapidoth et al[41] reported a case series of 10 patients who developed reticulate erythema following diode-assisted LHR. They noted that patients received cumulative laser treatments with increasing fluences and that 6 of 10 patients had a history of chilblain. Lim and Lanigan[42] suggested that this phenomenon may reflect vascular damage after hemoglobin absorption by deeper-penetrating wavelengths and reported on a patient developing this adverse effect posttreatment with the deep-penetrating, long-pulsed Nd:YAG laser.

CONCLUSIONS

LHR is among the most established uses of light in clinical dermatology. Recent advances have expanded options to treat a broad spectrum of skin types, although treating patients with white or red hair remains poorly effective. Further studies in this area and in LHR in general will ideally elucidate best practices and, it is hoped, even reveal continued efficacy with the current modalities.

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