Evaluation of a Long-Pulsed Nd:YAG Laser at Different Parameters: An Analysis of Both Fluence and Pulse Duration

ARLENE S. ROGACHEFSKY, MD,* KENNETH BECKER, MD,† GLEN WEISS, BA,‡ AND DAVID J. GOLDBERG, MD*†§

**Skin Laser & Surgery Specialists of New York and New Jersey, Hackensack, NJ, †Division of Dermatology, New Jersey Medical School, Newark, New Jersey, ‡Sackler School of Medicine, Tel Aviv, Israel, and §Department of Dermatology, Mount Sinai School of Medicine, New York, New York*

BACKGROUND. Effective hair removal continues to pose a challenge to the physician. The use of lasers represents a significant advance in epilation, but still requires further refinement. The long-pulsed Nd:YAG laser may offer advantages over other systems because of its significant depth of penetration and minimal absorption by epidermal melanin, but ideal parameters need to be determined.

OBJECTIVE. To evaluate the efficacy of a long-pulsed Nd:YAG laser system and determine the optimal parameters for hair removal.

METHODS. Twenty-two subjects were treated with a cryogen spray-cooled long-pulsed Nd:YAG laser. Four adjacent sites were assigned to each subject, where the following sets of parameters were utilized: 50 J/cm² with a 25-msec pulse duration, 60 J/cm² with a 50-msec pulse duration, 80 J/cm² with a 50-msec pulse duration, and control. Hair counts were obtained immediately, 1 week, 1 month, and 3 months after treatment, and multivariate regression analysis was used to determine the significance of hair reduction. Acute reactions and adverse events were also evaluated.

RESULTS. Treatment at all three sets of parameters resulted in significant mean hair reductions immediately, at 1 week, and at 1 month ($P < .001$). At 3 months, the higher settings of 60 J/cm² and 50 msec and 80 J/cm² and 50 msec were statistically significant for reduced mean hair counts ($P = .014$, $P = .042$, respectively), while the lowest setting at 50 J/cm² and 25 msec was not significant ($P = .079$). Patient and physician assessments suggested optimal hair reduction at the highest fluence (80 J/cm²) and longest pulse duration (50 msec). The most common acute reactions were pain during treatment, erythema, and perifollicular edema, all of which were more severe with higher fluences.

CONCLUSION. The long-pulsed Nd:YAG laser is a safe and effective method of hair removal. Increased fluence (60–80 J/cm²) and longer pulse duration (50 msec) settings were generally correlated with reduced hair counts and improved clinical outcome.

A. S. ROGACHEFSKY, MD, K. BECKER, MD, G. WEISS, BA, AND D. J. GOLDBERG, MD RECEIVED A RESEARCH GRANT AND LOAN OF THE LASER TO PERFORM THIS STUDY.

UNWANTED BODY hair is a common problem that has traditionally been dealt with in a variety of ways. Waxing, plucking, shaving, chemical depilation, and bleaching are temporary methods of epilation that are often irritating.[1–3] While electrosurgical techniques including galvanic electrolysis, thermolysis, and blend methods may provide permanent hair removal, they are time consuming, painful, have a risk of scarring, and are impractical for large areas.[4–6]

To address the inadequacies of these modalities, laser-assisted hair removal was developed. The majority of laser systems in use today employ the principle of selective thermolysis. This is the selective absorption of light of a particular wavelength by a specific substance referred to as a chromophore, in this case, melanin.[7] Selective damage also requires delivering energy in a time period equal to or less than the thermal relaxation time (TRT) of the chromophore. TRT is defined as the time needed for an object to cool after absorbing heat.[8] If heat is delivered faster than the chromophore can cool, the substance becomes hot relative to its environment and is destroyed. Conversely, if heat is delivered slower than the target can cool, heat is transferred to the surrounding environment.

Cooling of the epidermis with ice,[9] cooled gel layers,[10] cooled glass chambers,[11] actively cooled sapphire windows,[12] or pulsed cryogen sprays can minimize heat transfer to the surrounding environment. Cooling can also minimize epidermal injury from melanin absorption, which tends to occur in those of higher Fitzpatrick skin types.[13–16]

Address correspondence and reprint requests to: David Goldberg, MD, 20 Prospect Ave., Suite 702, Hackensack, NJ 07601, or e-mail: drdavidgoldberg@drdavidgoldberg.com.

ISSN: 1076-0512/02/$15.00/0 • Dermatol Surg 2002;28:932–936

The long-pulsed ruby,[17–23] long-pulsed alexandrite,[24–30] and long-pulsed diode lasers, intense pulsed light,[31,32] and long-pulsed Nd:YAG lasers are all accepted photothermolytic systems for hair removal.[33–39] Recent studies suggest that the longer wavelength of the Nd:YAG laser, with its decreased absorptive affinity for epidermal melanin, may provide the advantage of deeper penetration into the dermis. This enables the energy to reach the hair bulb or bulge region with the possibility of lethal follicular damage.[37,39] However, the long-pulsed Nd:YAG laser's optimal pulse width and fluence parameters used to provide deep penetration and follicular destruction still need to be better defined.

Materials and Methods

Laser

A 30 W Nd:YAG laser was used with an 8 mm handpiece, pulse durations of 25–50 msec, fluences of 50–80 J/cm², and a pulsed cryogen spray cooling system.

Patient Selection

Twenty-two patients (17 women, 5 men) with a mean age of 46 years (range 22–70 years) were enrolled. Eighteen subjects were Fitzpatrick skin type II, three subjects were Fitzpatrick skin type III, and one subject was Fitzpatrick skin type I. Treatment sites included 14 lower extremities, 5 backs, and 3 axillae.

For inclusion in this study, patients had to be between the ages of 21 and 70 years, with unwanted dark hair covering a body area of 12 cm × 2 cm. Patients were excluded for light hair, suntanned or artificially tanned skin, active localized or systemic infection, immunocompromised status, a coagulation disorder, or photosensitivity. Current use of gold therapy, chemotherapy, or anticoagulants including heavy aspirin therapy, previous laser, light, or electrolysis treatment to the proposed treatment site within 6 months, and isotretinoin use within 1 year prior to the study were also exclusion criteria.

Procedure

Patients were instructed not to shave the designated 12 cm × 2 cm study area for 1 week prior to treatment and throughout the duration of the study. This area was divided into four adjacent 3 cm × 2 cm sites (sites 1–3 and control). The control site was not treated, while the three treatment sites each received a single laser treatment. Treatment site 1 received 50 J/cm² with a 25-msec pulse duration, site 2 received 60 J/cm² with a 50-msec pulse duration, and site 3 received 80 J/cm² with a 50-msec pulse duration. These parameters were considered low, medium, and high settings, respectively. Most patients were treated with cryogen cooling. Cryogen cooling settings were set at 10 msec of precooling, 5 msec of postcooling delay, and 10–20 msec of postcooling.

One laser treatment session was performed and evaluations were undertaken before (P), immediately (IR), 1 week (1W), 1 month (1M), and 3 months (3M) after treatment. Patient discomfort during treatment was assessed on a numeric scale (0 = no pain, 1 = mild, 2 = moderate, 3 = severe, 4 = extreme). Acute reactions were observed immediately after treatment and adverse events were evaluated immediately, 1 week, 1 month, and 3 months after treatment (0 = none, 1 = trace, 2 = mild, 3 = moderate, 4 = severe). The patient and two physicians assessed hair reduction at 3 months (0 = none, 1 = fair, 2 = good, 3 = excellent).

A digital camera captured images at baseline and at all follow-up intervals. Standard photographic protocols with standardized equipment and lighting were utilized. Hair counts were undertaken from the digital images at P, IR, 1W, 1M, and 3M after treatment.

Calculations and Statistics

Because treatment areas were small, absolute hair numbers rather than the percentage of hair loss are presented in this study. Subsequently multivariate regression analysis was used to determine the significance of mean hair reduction in the treatment groups while controlling for changes over time that occurred in the control groups. A *t*-test, two samples assuming equal variances, was performed to statistically analyze the patient and physician assessments.

Results

Prior to treatment there was no significant difference in mean hair counts between the control and treatment sites. Immediately after treatment there was a statistically significant regression-adjusted mean absolute hair reduction of 8.5, 11, and 12 hairs in treatment sites 1–3, respectively (all $P < .001$). At 1 week, the three treatment sites had mean absolute hair reductions of 6.3 ($P < .001$), 9.0 ($P = .001$), and 10 ($P < .001$), respectively. At 1 month, the treatment sites had mean absolute hair reductions of 12, 14, and 15 (all $P < .001$), respectively. At 3 months (Figures 1–3), mean absolute hair reductions were statistically significant at site 2 (7.7 hairs,

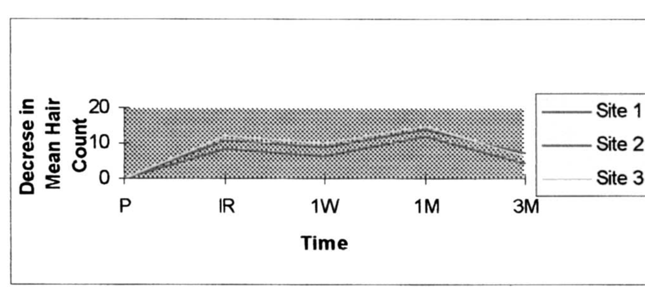

Figure 1. Regression-adjusted changes in mean hair counts over time after one treatment with the cryogen-cooled long-pulsed Nd:YAG laser.

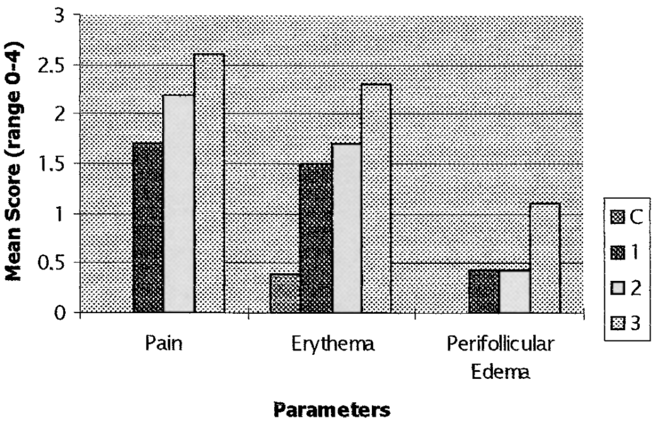

Figure 2. Control and three treatment sites before treatment. Site 1 parameters were 50 J/cm^2, 25 msec; site 2 parameters were 60 J/cm^2, 50 msec; site 3 parameters were 80 J/cm^2, 50 msec. C represents the untreated control site.

P = .014) and site 3 (6.6 hairs, P = .042), but not at site 1 (4.7 hairs, P = .079).

There was a peak in mean hair reduction at 1 month after treatment for all three treatment sites (Figure 1). For the control sites immediately after treatment, at 1 week, 1 month, and 3 months after treatment, there was no decrease in mean absolute hair counts. The evaluating physicians judged improvement at 3 months to be between none and fair for the first two sites, and between fair and good for the third treatment site. There was no statistically significant difference between the patient and physician assessments at 3 months.

All patients reported some discomfort during treatment that increased with higher settings (increased fluence and longer pulse duration). On average, pain was rated as moderate. Other acute reactions that increased with higher parameters included erythema, perifollicular edema, edema, and hair singeing (Figure 4). Immediate purpura, bleeding, blistering, crusting, or pigmentary changes were not observed. Patients were also assessed for adverse reactions at 1 week, 1 month, and 3 months after treatment. At 3 months, the only side effects observed, hyperpigmentation (n = 2) and erythema (n = 2), occurred in a subgroup of patients who had been treated without cryogen spray.

Discussion

Effective laser-assisted hair removal depends on the principles of selective thermolysis and thermal relaxation time. There is a complex interaction between the selective absorption of light of a particular wavelength by the absorbing chromophore and the subsequent distribution of that energy. Laser-emitted wavelength, fluence, pulse duration, and epidermal cooling are all relevant parameters in this interplay. Ideal parameters have yet to be optimized.

Our data and physician and patient assessments demonstrated a trend toward increased hair reduction with higher fluences (60–80 J/cm^2) and longer pulse widths (50 msec). At these higher parameters there is also greater patient discomfort and more risk for adverse effects. It should be noted, however, that patients did not use any form of anesthetic on the treatment area. Epidermal cooling is an essential component of laser-assisted hair removal. There is substantial benefit from pre- and postlaser cooling in preventing adverse effects, as evidenced by the subgroup of patients who were treated without cryogen spray.

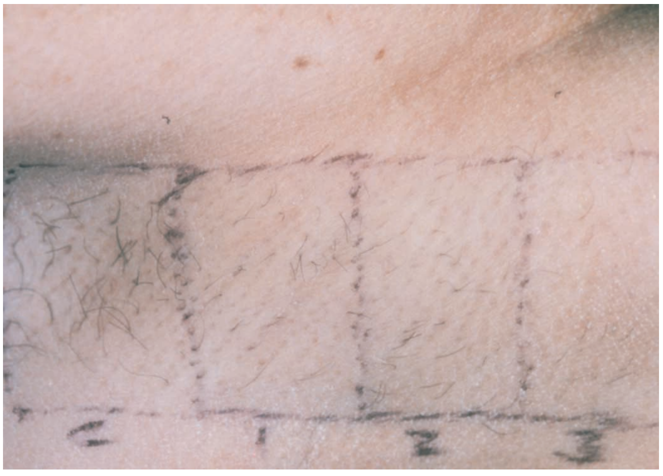

Figure 3. Control and three treatment sites 3 months after treatment. Note that the greatest improvement was at 60–80 J/cm^2 and 50 msec.

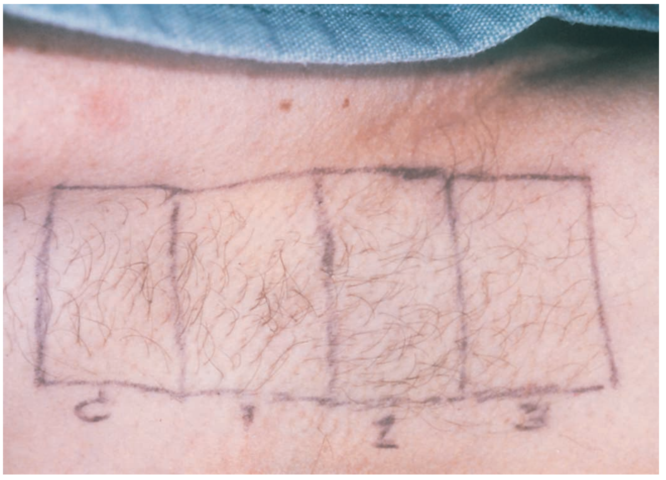

Figure 4. Acute reactions in the control and three treatment groups immediately after laser treatment.

A peak in mean hair reduction occurred 1 month after treatment; between 1 month and 3 months, hair reduction decreased (Figure 1). This is consistent with what has been seen in other laser hair removal studies.[40–42] Multiple sessions at such higher fluences and longer pulse durations may be required for longer-term hair removal.

Conclusion

Optimal hair reduction with the cryogen spray-cooled long-pulsed Nd:YAG laser was achieved at higher fluences (60–80 J/cm^2) and longer pulse durations (50 msec). These high settings are safe and effective when appropriate cooling is provided. Multiple sessions at these parameters should be studied in the future and evaluated for long-term hair removal.

References

1. Marchell NL, Alster TS. Evaluation of temporary and permanent hair removal methods. J Aesthetic Cosmet Dermatol Surg 1999;1: 3–12.
2. Wagner RF Jr. Physical methods for the management of hirsutism. Cutis 1990;45:319–21, 325–6.
3. Olsen EA. Methods of hair removal. J Am Acad Dermatol 1999; 40:199–202.
4. Wagner RF, Tomich JM, Grande DJ. Electrolysis and thermolysis for permanent hair removal. J Am Acad Dermatol 1985;12:441–9.
5. Hobbs ER, Ratz JL, James B. Electrosurgical epilation. Dermatol Clin 1985;75:437–44.
6. Richards RN, Meharg GE. Electrolysis: observations from 13 years and 140,000 hours of experience. J Am Acad Dermatol 1995;33:662–6.
7. Anderson RR, Parrish JA. Selective photothermolysis: precise microsurgery by selective absorption of pulsed radiation. Science 1983;220:524–7.
8. van Gemert MJC, Welch AJ. Time constants in thermal laser medicine. Lasers Surg Med 1989;9:405–21.
9. Gilchrest BA, Rosen S, Noe JM. Chilling port wine stains improves the response to argon laser therapy. Plast Reconstr Surg 1982;69:278–83.
10. Lask G, Elman M, Slatkine M, Waldman A, Rozenberg Z. Laser-assisted hair removal by selective photothermolysis. Dermatol Surg 1997;23:737–9.
11. Chess C, Chess Q. Cool laser optics treatment of large telangiectasia of the lower extremities. J Dermatol Surg Oncol 1993;19:74–80.
12. Zenzie H, Erofeev A, Smirnov M, Dierickx C, Anderson R, Altshuler G. Contact cooling of the skin. SPIE Proc 1999;22:19–23.
13. Anvari B, Tanenbaum BS, Milner TE, Kimel S, Svaasand LO, Nelson JS. A theoretical study of the thermal response of skin to cryogen spray cooling and pulsed laser irradiation: implications for treatment of port wine stain birthmarks. Phys Med Biol 1995;40: 1451–65.
14. Anvari B, Milner TE, Tanenbaum BS, Kimel S, Svaasand LO, Nelson JS. Dynamic epidermal cooling in conjunction with laser treatment of port-wine stains: theoretical and preliminary clinical evaluations. Lasers Med Surg 1995;10:105–12.
15. Nelson JS, Milner TE, Anvari B, et al. Dynamic epidermal cooling during pulsed laser treatment of port-wine stain. A new methodology with preliminary clinical evaluation. Arch Dermatol 1995;131: 695–700.
16. Nelson JS, Milner TE, Anvari B, Tanenbaum BS, Svaasand LO, Kimel S. Dynamic epidermal cooling in conjunction with laser-induced photothermolysis of port wine stain blood vessels. Lasers Surg Med 1996;19:224–9.
17. Polderman MC, Pavel S, le Cessle S, Grevelink JM, van Leeuwen RL. Efficacy, tolerability, and safety of a long-pulsed ruby laser in the removal of unwanted hair. Dermatol Surg 2000;26:240–43.
18. Wimmershoff MB, Scherer K, Lorenz S, Landthaler M, Hohenleutner U. Hair removal using a 5-msec long-pulsed ruby laser. Dermatol Surg 2000;26:205–10.
19. Solomon MP. Hair removal using the long-pulsed ruby laser. Ann Plast Surg 1998;41:1–6.
20. Williams R, Havoonjian H, Isagholian F, Menaker G, Moy R. A clinical study of hair removal using the long-pulsed ruby laser. Dermatol Surg 1998;24:837–42.
21. Dierickcx CC, Grossman MC, Farinelli WA, Anderson RR. Permanent hair removal by normal-mode ruby laser. Arch Dermatol 1998; 134:837–42.
22. Grossman MC, Dierickx C, Farinelli W, Flotte T, Anderson RR. Damage to hair follicles by normal-mode ruby laser pulses. J Am Acad Dermatol 1996;35:889–94.
23. Sommer S, Render C, Burd R, Sheehan-Dare R. Ruby laser treatment for hirsutism: clinical response and patient tolerance. Br J Dermatol 1998;138:1009–14.
24. Raulin C, Greve B. Temporary hair loss using the long-pulsed alexandrite laser at 20 milliseconds. Eur J Dermatol 2000;10:103–6.
25. Lloyd JR, Mirkov M. Long-term evaluation of the long-pulsed alexandrite laser for the removal of bikini hair at shortened treatment intervals. Dermatol Surg 2000;26:633–7.
26. McDaniel DH, Lord J, Ash K, Newman J, Zukowski M. Laser hair removal: a review and report on the use of long-pulsed alexandrite laser for hair reduction of the upper lip, leg, back, and bikini region. Dermatol Surg 1999;25:425–30.
27. Nanni CA, Alster TS. Long-pulsed alexandrite laser-assisted hair removal at 5, 10, and 20 millisecond pulse durations. Lasers Surg Med 1999;24:332–7.
28. McDaniel D, Ash K, Lord J, Newman J, Zukowski M. The long-pulsed alexandrite laser: a preliminary report on hair removal of the upper lip, leg, back and bikini region. Lasers Surg Med 1998; 10(suppl):39.
29. Narukar V, Miller HM, Seltzer R. The safety and efficacy of the long pulse alexandrite laser for hair removal in various skin types. Lasers Surg Med 1998;10(suppl):189.
30. Finkel B, Eliezri YD, Waldman A, Slatkine M. Pulsed alexandrite laser technology for noninvasive hair removal. J Clin Laser Med Surg 1997;15:225–9.
31. Dierickx CC. Hair removal by lasers and intense pulsed light sources. Semin Cutan Med Surg 2000;19:267–75.
32. Weiss RA, Weiss MA, Marwaha S, Harrington AC. Hair removal with a non-coherent filtered flashlamp intense pulsed light source. Lasers Surg Med 1999;24:128–32.
33. Gold MH, Bell MW, Foster TD, Street S. Long-term epilation using the EpiLight broad band, intense pulsed light hair removal system. Dermatol Surg 1997;23:909–13.
34. Goldberg DJ, Silapunt S. Hair removal using a long-pulsed Nd: YAG laser: comparison at fluences of 50, 80, and 100 J/cm^2. Dermatol Surg 2001;27:434–6.
35. Goldberg DJ, Samady JA. Evaluation of a long-pulsed Q-switched Nd:YAG laser for hair removal. Dermatol Surg 2000;26:109–13.
36. Goldberg DJ, Silapunt S. Histologic evaluation of a millisecond Nd:YAG laser for hair removal. Lasers Surg Med 2001;28:159–61.
37. Littler CM. Hair removal using an Nd:YAG laser system. Dermatol Clin 1999;17:401–30.
38. Kilmer SL, Chotzen VA, Calkin J, Silva S, McClaren M. Laser hair removal with the long-pulsed 1064 nm Coolglide laser system. Lasers Surg Med 2000;12(suppl):21.
39. Bencini PL, Luci A, Galimberti M, Ferranti G. Long-term epilation with long-pulsed neodymium:YAG laser. Dermatol Surg 1999;25: 175–8.
40. Goldberg DJ. Laser hair removal. In: Goldberg DJ, ed. Laser hair removal. London: Dunitz, 2000.
41. Alster TS, Bryan H, Williams CM. Long-pulsed Nd:YAG laser assisted hair removal in pigmented skin: a clinical and histologic evaluation. Arch Dermatol 2001;137:885–9.
42. Nanni CA, Alster TS. Optimizing treatment parameters for hair removal using a topical carbon-based solution and 1064nm Q-switched neodymium:YAG laser energy. Arch Dermatol 1997;133:1546–9.

Commentary

This study supports the fact that hair reduction can be achieved with long-pulsed Nd:YAG laser irradiation. However, it fails to show what it concludes: a trend toward increased hair reduction with the use of higher fluences and longer pulse durations. Only the former assertion (higher fluence yielding better hair removal) was demonstrated, which is in concert with the findings of others.[27,41,42] Thus, while one of the study's objectives was to determine the optimal parameters for hair removal, it falls short of accomplishing this goal, based in large part on the fact that independent adjustments of fluence and pulse duration were not made. In addition, it is difficult to reach valid conclusions regarding treatment efficacy based on a single treatment session with limited posttreatment follow-up, particularly since it is known that several laser sessions are generally necessary to effect long-term hair removal (more than 6–12 months). There is no question that the authors' scientific objectives were worthy, but further investigation is needed in order to define the best treatment protocol for laser-assisted hair removal.

TINA ALSTER, MD
Washington, DC