A Novel Cooling Device for a Long Pulsed Nd:YAG Laser for the Treatment of Hair Removal and Vascular Lesions

Akhil Wadhera, MD,[1*] Daniel B. Eisen, MD,[1] and Vic Narurkar, MD[1,2]
[1]*Department of Dermatology, UC Davis School of Medicine, Sacramento, CA*
[2]*Bay Area Laser Institute, San Francisco, CA*

Background and Objectives: Treatment of darker skin types with shorter wavelength lasers results in higher risk of adverse events due to increased melanin absorption at those wavelengths. This was an important consideration in the development of longer wavelength lasers, which make laser removal of hair and leg telangiectasias safer in patients with darker skin. However, reduced absorption of laser energy by the target chromophores at the longer wavelengths necessitates higher treatment fluences. These higher fluences increase the chance of damage to the overlying epidermis, through which the laser energy must pass. Several cooling systems have been developed in an attempt to minimize adverse effects to the overlying tissue. We report the use of a novel cooling device on a Long Pulse (LP) 1064nm laser for optimizing epidermal safety and maximizing fluence delivery.
Study Design/Materials and Methods: Lower extremity telangiectasias, hypertrichosis and facial telangiectasias in 30 patients of skin types I to VI were treated with a LP 1064nm laser utilizing a novel cooling tip. Treatment tolerability and side effects were determined during follow up visits or phone calls. Pain during and after the procedure, erythema, bruising, crusting, pigmentary alteration and scarring were recorded.
Results: The most common side effects observed were erythema, edema and urtication. Treatment of vascular lesions was more painful than hair removal. Bruising was observed in 38% of patients treated for telangiectasias. Transient hyperpigmentation was seen in only one patient being treated for leg telangiectasias. None of the treated patients had any epidermal breakdown or scarring.
Conclusion: We describe the use of a novel contact cooling handpiece for a long pulsed Nd:YAG laser. Side effects have been minimal and the device appears to be safe and well tolerated in our study population.

INTRODUCTION

Laser hair removal and leg vein treatment for therapeutic and cosmetic purposes are fast becoming significant segments of laser practices around the world. With popularity of these procedures and the ethnic diversity of population within major metropolitan areas, laser surgeons are faced with the challenge of performing these procedures in patients of all skin types including Fitzpatrick III-VI. Laser treatment of leg veins and hair removal is based on the principle of selective photothermolysis [1]. Because of the presence of epidermal melanin, a competing chromophore, the process of hair removal and leg vein treatment is still very challenging in darker skinned patients. This not only results in reduction in the amount of energy reaching the intended targets, but also causes significant epidermal damage resulting in patient discomfort and increased likelihood of unwanted side effects such as pigmentary alteration and scarring. To overcome these challenges several strategies have been developed since the introduction of the original Ruby laser [2,3]. These include using lasers of longer wavelengths (such as the 1064 nm Nd-YAG laser) that are less avidly absorbed by melanin, use of longer pulses that allow the melanosomes of the epidermal layer to cool prior to their

destruction threshold being reached, and finally the development of efficient epidermal cooling mechanisms [4]. The above mentioned changes have resulted in making the long pulsed Nd:YAG laser with epidermal cooling as the most appropriate and safe laser to use in patients with darker skin types (Fitzpatrick skin type III-VI) [5]. One such laser recently introduced in the US market is the Mydon (Wavelight Technologies, Erlangen Germany). This paper discusses some of the advantages of a novel cooling handpiece included in the Mydon, and presents data regarding the side effect profile of this laser during the treatment of 30 patients over a period of 6 months at a University based setting.

MATERIALS AND METHODS

This was a retrospective study of 30 patients of all skin types who reported to the dermatology clinic at UC Davis, Sacramento, CA for the laser treatment of various vascular lesions and for hair removal. For this study we used a recently FDA approved long pulsed Nd:YAG laser with a novel handpiece that provides contact cooling. The handpiece is composed of a rectangular stainless steel handpiece with rounded edges measuring 3.0 cm x 2.0 cm (Figure 1). It has an eccentric, removable, optically clear sapphire window measuring 1.2 cm in diameter. A circulating cooling liquid composed of water and ethylene glycol cools the handpiece. The handpiece is maintained at a temperature of 4^{o}C when the laser is in the standby mode, but drops to 0^{o}C when it is in ready mode. A peltier system (thermoelectric cooling) keeps the cooling-liquid cold. The laser parameters used were according to the manufacturer's recommendations and were similar to those reported in published reports of long pulsed Nd:YAG lasers. For hair removal, fluences ranged from 30 to 50 J/cm^2 with a pulse duration ranging from 15-80 ms, depending on the skin type and diameter of the hair being treated. For vascular lesions the fluences used ranged between 150 to 250 J/cm^2 with pulse durations between 20 and 65 ms. Frequency of pulses delivered ranged from 1 to 1.8 Hz.

For hair removal, patients selected were predominantly of darker skin types, Fitzpatrick III-VI. Patients who have had a recent tan (less than 6 weeks duration), pregnant, had photosensitive dermatoses, or were taking photosensitizing medications were not treated. Patients had been instructed not to use wax or pluck the hair in the areas to be treated. The area to be treated was shaved prior to the procedure and a small test area was treated. The spot size used ranged between 7 and 10 mm depending on the anatomic area being treated. A clear gel was applied to the area to help improve the cooling and mobility of the hand piece over the treatment area. Manufacturer's recommendations were used as a guide to the starting point, however both the fluence and pulse duration were adjusted until perifollicular erythema and edema was noticed. Most of our patients did not require preoperative anesthesia or post-operative analgesia. Some patients were given ice packs to be applied to the treated area for up to 15 minutes after the treatment. No patients required antiviral or antibacterial prophylaxis.

For vascular lesions, selected patients included all skin types and did not have any contraindications as listed above. The areas to be treated were covered by a clear gel and spot sizes of 1.5, 3 and 5 mm were used depending on the size and the color of the vascular lesion being treated. The maximum size of telangiectasias was limited to 3 mm. Initial fluence and pulse durations were based on manufacturer's recommendations but these parameters were adjusted by the clinician in order to achieve complete blanching of the vascular lesion. Pain reported by the patient was also used to guide the fluence and pulse duration selection. The end point for the treatment of vascular lesions was either slowing of blood flow in the targeted vessel, blanching of the vessels or perivascular purpura and urticaria. None of our patients required antiviral or antibacterial prophylaxis. Pulse stacking was avoided.

Treatment tolerability and the side effect profile of the treatments were determined either on follow-up visit or by phone. Patients were asked to rate the pain experienced during and after the treatment on a visual analog scale ranging between 1 and 10, 10 being the worst pain that they have ever experienced and 1 being no pain. Patients were also asked about the presence and duration of erythema, bruising, blistering, crusting, pigmentary alteration and scarring.

RESULTS

Table I lists the details of the patients treated for both hair removal and vascular lesions based on their skin type. Fourteen patients were treated for hair removal and 16 were treated for vascular lesions that included leg telangiectasias, facial telangiectasias and spider angiomas. In this study, 10 out of 30 or 33% were of skin type I-III and 20/30 or 67% were of skin type IV-VI. Table I also lists the mean fluence and pulse durations used for the patients of a particular skin type. In general, patients of darker skin type tolerated lower energies compared to the lighter skin types. Higher pulse durations were used in patients of darker skin types to limit epidermal damage. The mean fluences used are in line with those used previously for similar applications, especially in darker skin types.

Table II is a summary of the side effects observed in both arms of this study. The most common side effect seen in both arms was erythema. It was seen in 86% of patients undergoing hair removal and approx 100% of patients undergoing vascular lesions. Patients reported that the erythema lasted for about an hour, with longer durations observed in patients who used ice packs for cooling after the procedure. Based on the mean visual analog scores, treatment of vascular lesions appeared to be more painful than hair removal. Several patients reported the pain to be similar to that felt when struck by a rubber band, although, a few patients also reported feeling a deep uncomfortable warmth in the treated area for a few seconds after the laser treatment. For most patients the pain had resolved by the time they left the clinic and did not alter their daily activities.

Perifollicular erythema and edema was observed in 86% of our patients undergoing hair removal and edema and urtication was observed in 100% of our patients undergoing treatment of vascular lesions. These side effects lasted from 8- 10 hours. Seven percent of patients undergoing hair removal and 38% of patients undergoing treatment of vascular lesions reported purpura that lasted approx 2 to 14 days. One of our patients of skin type V treated for leg telangiectasias had transient hyperpigmentation that resolved within 4 weeks of treatment without the use of any depigmenting agents. None of our patients reported blistering, crusting or scarring.

DISCUSSION

Nd:YAG lasers have emerged as the most effective laser for the treatment of hair removal and leg veins in patients of darker skin types [6-10]. Although ruby and alexandrite lasers have been shown to be much more efficacious in hair removal due to better absorption by melanin their use in darker skinned patients is limited due to their side effect profile [11]. With the development of the extended theory of selective photothermolysis, lasers with pulse durations of the order of 10 - 100 ms have been developed to selectively target and destroy the regenerative component of the hair follicles that resides in the outer root sheath approx 1 mm below the epidermal surface [12]. Because the energy is delivered over large pulse durations, epidermal melanin contained within melanosomes has adequate time to cool and is not

thermally destroyed. Long pulsed Nd:YAG lasers are also useful for treatment of leg veins as the longer wavelengths allows for deeper penetration of the laser light and the larger pulse durations can be matched with the diameter and color of the leg vein being targeted [13-15].

Use of Ruby and Alexandrite lasers are associated with a fairly high risk of side effects including pigmentary alteration, blistering and scarring especially when treating patients with darker skin types. Nanni reported a side-effect rate of approx 15-35% with long pulsed alexandrite and ruby lasers in patients of skin types IV-V [16]. Lanigan performed a large prospective multi-center study for determining the side effect profiles of various hair removal lasers and found that Ruby laser resulted in 29.9% adverse effects in patients of skin type IV to VI compared to 9.4% of Nd:YAG laser [17]. In comparison to the data reported in the literature and our past experience working with other long pulsed lasers, we observed very few side effects with the Mydon. The most common side effect reported was temporary erythema that lasted few hours. Although most of our patients reported feeling some pain during the treatment, patients who had treatments with other similar devices reported that the pain was much less and the application of cold was very soothing. Also, none of our patients needed post-procedure analgesia and were able to get back to their regular daily activities right after the treatment. Perifollicular erythema and edema observed in patients being treated for hair removal and urtication of vessels seen in patients undergoing treatment of vascular lesions was a useful marker of the effectiveness of the laser. Although not reported in this paper, our preliminary data indicates that patients who had those endpoints, have better results.

Factors that affect the selection of the most appropriate device used for hair removal and treatment of vascular lesions include – clinical efficacy, side effect profile, ease and relative speed of operation. We feel that efficient epidermal cooling positively impacts most of the above-mentioned parameters. Clinical efficacy of a device can be improved by better cooling as one can deliver a higher therapeutic energy to the target chromophore, whether it is in a hair follicle or in a blood vessel. Because the epidermis is cooled, the light energy absorbed by the epidermal melanin either directly or by backscattering is not able to cause a lot of damage to the epidermis and thus the side effect profile is significantly improved. Also the treatment time can be reduced if the cooling of the epidermis can be achieved rapidly and the operator does not have to stop to cool the area prior to firing the laser beam. Anvari investigated the thermal response of in-vivo human skin to contact cooling with a sapphire window (6-12 ^{o}C); and spray cooling with a freon substitute cryogen (tetrafluoroethane) and found surface temperature reductions from 30 ^{o}C to 14-19 ^{o}C could be obtained within approximately 1 s in response to sapphire contact cooling [18]. Other studies have also shown a similar drop in epidermal temperature by using other contact cooling mechanisms [19,20].

Our study focuses on the use of a LP 1064 nm laser with a novel integrated cooling device that has been recently approved for use in the US (Mydon, Long pulsed 1064 nm Nd:YAG laser, Wavelight Technologies, Erlangen, Germany). This device provides pre-, parallel and post-cooling of the treated area via an integrated water-cooled handpiece. Because of the excellent thermal conductivities and specific heats of stainless steel and sapphire used in the construction of the handpiece, thermal equilibrium can be reached between the skin and the handpiece fairly rapidly. The area of the hand piece from the ring edge of the metal plate to the center of the aiming beam helps to pre-cool the treated area, the clear sapphire window under the laser beam allows parallel cooling, and the area of the handpiece from the aiming beam to the metal edge of the handpiece provides extended post-cooling of the treated area. As the operator traces a blood vessel or treats the hair in an area, pre-, parallel and post- cooling occur simultaneously, allowing the operator to rapidly treat the area with much less discomfort for

the patient. The use of a topical gel helps in dissipating the heat and allows smooth gliding movement of the handpiece over the treated area.

Although there are other LP 1064 systems approved by the US FDA that provide pre-, parallel and post-cooling, this handpiece offers 2 significant advantages. Firstly, the handpiece has a longer stainless steel plate that provides an extended post-cooling period. The second advantage that this handpiece offers is the ability to remove the sapphire window when treating fine telangiectasias. Removing the sapphire window improves the visibility of the operator and avoids application of pressure that may blanch the vessel and remove the chromophore being targeted. To our knowledge no other long pulsed Nd:YAG system has this flexibility.

Because of the limited duration of follow-up, we have decided not to report the efficacy data in this paper. However, our preliminary efficacy data (Figs. 2 and 3) is very encouraging and we are currently conducting a multi-center IRB approved study to evaluate the efficacy of this laser for the above-mentioned applications.

CONCLUSION

Long pulsed Nd:YAG lasers with epidermal cooling should be the treatment of choice for the treatment of telangiectasias and hair removal in patients of Fitzpatrick skin type IV-VI. Efficient epidermal cooling plays a significant role in improving the tolerability of the long pulsed Nd:YAG laser. The cooling mechanism included in the Mydon is unique, and when used for hair removal and treatment of facial and leg telangiectasias in our study, it appears safe and well tolerated.

REFERENCES

1. Anderson RR, Parrish JA. Selective photothermolysis: precise microsurgery by selective absorption of pulsed radiation. Science, 220: 524-7.

2. Grossman MC, Dierickx C, Farinelli W, Flotte T, Anderson RR. Damage to hair follicles by normal-mode ruby laser pulses. J Am Acad Dermatol, 35: 889-94.

3. Dierickx CC, Grossman MC, Farinelli WA, Anderson RR. Permanent hair removal by normal-mode ruby laser. Arch Dermatol, 134: 837-42.

4. Nelson JS, Majaron B, Kelly KM. Active skin cooling in conjunction with laser dermatologic surgery. Semin Cutan Med Surg, 19: 253-66.

5. Battle EF Jr, Hobbs LM. Laser-assisted hair removal for darker skin types. Dermatol Ther, 17: 177-83.

6. Battle EF Jr, Hobbs LM. Laser therapy on darker ethnic skin. Dermatol Clin, 21: 713-23.

7. Goldberg DJ, Silapunt S. Hair removal using a long-pulsed Nd:YAG Laser: comparison at fluences of 50, 80, and 100 J/cm. Dermatol Surg, 27: 434-6.

8. Goldberg DJ, Silapunt S. Histologic evaluation of a millisecond Nd:YAG laser for hair removal. Lasers Surg Med, 28:159-61.

9. Cannarozzo G, Bonan P, Campolmi P. Epilation with Nd:YAG laser: a brief analysis of the technical application methods, results and pre- and post-treatment procedures. J Cosmet Laser Ther, 5: 189-91.

10. Goh CL. Comparative study on a single treatment response to long pulse Nd:YAG lasers and intense pulse light therapy for hair removal on skin type IV to VI--is longer wavelengths lasers preferred over shorter wavelengths lights for assisted hair removal. J Dermatolog Treat, 14: 243-7.

11. Galadari I. Comparative evaluation of different hair removal lasers in skin types IV, V, and VI. Int J Dermatol, 42: 68-70.

12. Altshuler GB, Anderson RR, Manstein D, Zenzie HH, Smirnov MZ. Extended theory of selective photothermolysis. Lasers Surg Med, 29: 416-32.

13. Groot D, Rao J, Johnston P, Nakatsui T. Algorithm for using a long-pulsed Nd:YAG laser in the treatment of deep cutaneous vascular lesions. Dermatol Surg, 29: 35-42.

14. Ross EV, Domankevitz Y. Laser treatment of leg veins: Physical mechanisms and theoretical considerations. Lasers Surg Med, 36: 105-16.

15. Sadick NS, Weiss RA, Goldman MP. Advances in laser surgery for leg veins: bimodal wavelength approach to lower extremity vessels, new cooling techniques, and longer pulse durations. Dermatol Surg, 28: 16-20.

16. Nanni CA, Alster TS. Laser-assisted hair removal: side effects of Q-switched Nd:YAG, long-pulsed ruby, and alexandrite lasers. J Am Acad Dermatol, 41: 165-71.

17. Lanigan SW. Incidence of side effects after laser hair removal. J Am Acad Dermatol, 49: 882-6.

18. Anvari B, Milner TE, Tanenbaum BS, Nelson JS. A comparative study of human skin thermal response to sapphire contact and cryogen spray cooling. IEEE Trans Biomed Eng, 45: 934-41.

19. Raulin C, Greve B, Hammes S. Cold air in laser therapy: first experiences with a new cooling system. Lasers Surg Med, 27: 404-10.

20. Hohenleutner U, Walther T, Wenig M, Baumler W, Landthaler M. Leg telangiectasia treatment with a 1.5 ms pulsed dye laser, ice cube cooling of the skin and 595 vs 600 nm: preliminary results. Lasers Surg Med, 23: 72-8.

TABLES:

Table 1: Patient and treatment details

	Hair Removal			**Vascular**		
Skin type	**No. of patients (%)**	**Mean Fluence (J/cm2)**	**Mean PD (ms)**	**No. of patients (%)**	**Mean Fluence (J/cm2)**	**Mean PD (ms)**
Type I	0 (0%)	-	-	-	-	-
Type II	1 (7%)	40	15	5 (31%)	226	25
Type III	1 (7%)	45	30	3 (19%)	195	35
Type IV	4 (29%)	36	42	3 (19%)	206	35
Type V	5 (36%)	44	64	3 (19%)	180	60
Type VI	3 (21%)	30	80	2 (12%)	170	40
Total	14			16		

Table 2: Incidence of side effects after laser treatment

Side Effect Profile (%)	**Hair Removal**	**Vascular**	**Duration of side effects**
Erythema	12/14 (86%)	16/16 (100%)	60 mins
Pain (Mean)	3.93*	4.38*	1-2 mins
Edema/Urtication	12/14 (86%)	16/16 (100%)	8-10 hours
Bruising	1/14 (7%)	6/16 (38%)	2 -7 days
Blistering	0/14 (0%)	0/16 (0%)	-
Pigment alteration			
Hyper-pigmentation	0/14 (0%)	1/16 (6%)	4 weeks
Hypo-pigmentation	0/14 (0%)	0/16 (0%)	-
Scarring	0/14 (0%)	0/16 (0%)	-

* - Scores based on a Visual Analog Score between 1 and 10, 1 being no pain and 10 being the worst pain the patient has ever experienced.

Figures:

Fig. 1. Cooling tip of Mydon (Long pulsed Nd:YAG, Wavelight Technologies, Erlangen, Germany)

A B

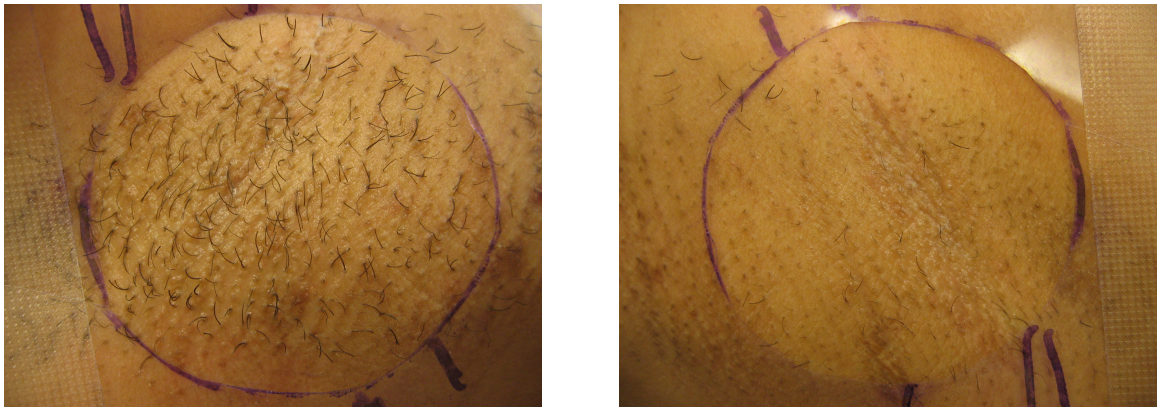
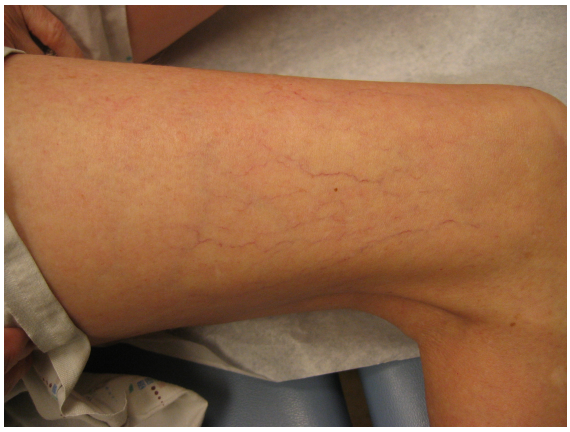


Fig. 2. Axillary Hair Removal in patient with Fitzpatrick Skin type V; A – Untreated side, B – Treated side with (one month follow-up after two trmts.)

A



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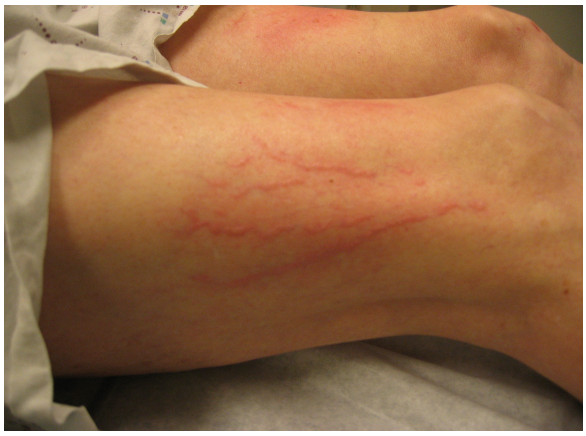

C

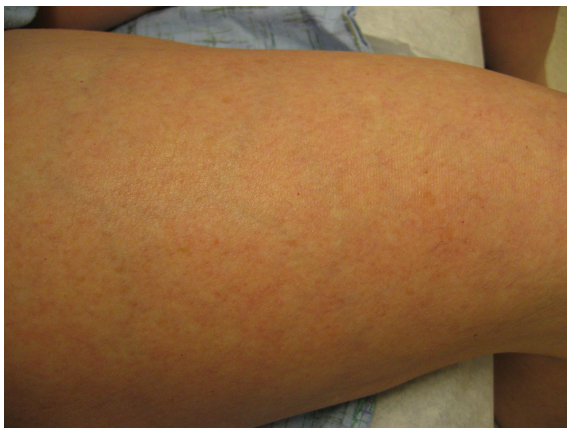

Fig. 3. Leg vein treatment in patient of Skin type II; A - Pre-treatment, B - Immediately post-treatment, C - Six months after only 1 treatment