ORIGINAL ARTICLE

EXACT LASER FLUENCE FOR SUCCESSFUL TREATMENT OF FACE AND LEG TELANGIECTASIA

DOI: 10.36740/WLek202109215

Muna B. Mustafa[1], Wailed K. Hamoudi[1], Ghufran. S. Jaber[2], Mohammed Y. Abbas[3], Noor R. Abdulhameed[4]
[1]AL-FARABI UNIVERSITY COLLEGE, DEPARTMENT OF OPTICS TECHNIQUES, BAGHDAD, IRAQ
[2]AL-TURATH UNIVERSITY COLLAGE, DEPARTMENT OF RADIOGRAPHY TECHNIQUES, BAGHDAD, IRAQ
[3]BAGHDAD UNIVERSITY, ALKINDY COLLEGE OF MEDICINE, BAGHDAD, IRAQ
[4]CHARISMATICS LASER CENTER, BAGHDAD, IRAQ

ABSTRACT

The aim: Facial and leg telangiectasia are usual cosmetic concern for females who have different skin phototypes and ages. Until now, the various treatments for these problem have frequently failed or led to unwanted side-effects. Based on approved pre-calculated doses, the present study highlights the clinical effects and safety of treatment after using the exact laser parameters from 1064-nm Nd: YAG laser.

Materials and methods: Twenty people with facial and leg telangiectasia underwent a single laser treatment, based on pre-calculated laser parameters for each case.

Results: All subjects showed visible improvement, with 95–100% clearance of face telangiectasia directly after the first treatment, and 50–100% clearance of the lower extremity vessels after one to three days; with minimal side-effects.

Conclusions: Treatment of facial and leg telangiectasia by using true, exact, and mathematically pre-calculated parameters of long pulse 1064 nm Nd: YAG laser was an effective and safe procedure of clearing face and leg telangiectasia.

KEY WORDS: Nd: YAG laser, telangiectasia, skin absorption and scattering, laser fluence

Wiad Lek. 2021;74(9 p.II):2340-2344

INTRODUCTION

When photons strike the surface of a tissue, 4–10% of them are reflected according to the angle of incidence, and some other photons are refracted, according to the Snell's law. The affecting parameters in this interaction are those related to thermal properties of tissue, and laser parameters; such as, wave length, pulse width, focal spot size, fluence, and intensity[1, 2]. The interaction mechanisms include four main categories: thermal, photochemical, photo-ablation and photo-disruption. Our interest in this paper is the thermal interaction mechanism. Temperature is the influencing effect of every thermal laser tissue fundamental interactions[3]. It shows the extent of tissue damage depending on the values of pulse duration and deposited laser heating into the tissue. The laser energy deposition is not laser parameters issue only, but also relaying on some optical tissue parameters such as the coefficients of absorption and scattering. Moreover, the biological tissue properties are important to describe heat transfer; like specific heat capacity and thermal diffusivity[4]. In the present calculation, two important parameters related to the skin are needed: the target location (depth) and skin phototype (melanin concentration). These two parameters affect directly the application extent of Lambert law as described further [5].

THEORY

Medium absorbance is the proportion of absorbed light intensity. It is the conversation of light energy into heat in the targeted tissue. The absorbed electromagnetic radiation by a medium relies on many factors, such as electronic contact of its molecules and atoms, the wave length of light beam, thickness of the illuminated layer, in addition to other internal parameters, such as concentration of the absorbing agents and temperature[6]. To describe the effect of either concentration or thickness on absorption, we start with Beer's –Lambert's law[6]:

$$I_\chi = I_\circ \exp. (- \mu_a c \chi) \qquad (1)$$

Where;
I_χ: is the intensity at distance χ (w/cm^2)
$I_\circ$: the incident intensity (w/cm^2)
χ: radiation path thickness (mm)
μ_a: absorption co. of the ambience (cm-^{1})
c: concentration of absorption factor (mol./L)

The intensity attenuation due to scattering is depicted by a comparable relation; similar to absorption:

$$I_\chi = I_\circ \mathrm{EXP} (-\mu_\sim X) \qquad (2)$$

Where $\mu_\sim$; is the scattering coefficient

The absorption coefficient of ambience (melanin) needs to be determined precisely; a grater absorption coefficient is conjugated with blackish skin phototypes[7, 8]. The ab-

Table I. Absorption coefficient of some skin components [8]

Wavelength (nm)	μ_1 (cm-^{1})	μ_2(cm-^{1})	μ_e(cm-^{1})
940	0.250	86	8.74
1064	0.250	55	5.63
1320	0.250	38	3
1450	0.250	25	2
1540	0.250	20	1

Table II. Absorption coefficients of epidermis for different laser wavelengths [8]

Skin type	Melanin pigmentation per unit volume (%)
Light skin	1.3-6.3%
moderate skin	11-16%
Dark skin	18-43%

Table III. Total attenuation factor of some tissue [10]

Tissue	λ (nm)	μ_a (cm^{-1})	$\mu_{\sim}$ (cm^{-1})	μ (cm^{-1})
Blood	665	1.3	1246	1247
Blood	685	2.65	1413	1416
Blood	960	2.84	505	508
epidermis (white)	633	2.7	187	190
epidermis(white)	700	2.7	237	240
epidermis (dark)	700	8.1	229	237
epidermis(white)	1064	3.1	130	133
epidermis(dark)	1064	7.9	122	130
dermis	1064	2.9	35	38

sorption coefficient μ_e of the epidermal layer merges both baseline skin and melanin absorption which is given by

$$\mu_e = \text{mel. \% x } \mu_1 + (1 - \text{mel \%})\ \mu_2 \qquad (3)$$

Where:

μ_e: epidermal absorption coefficient (cm-^{1})

mel %: melanosomes per unit volume

μ_1: melanin absorption coefficient (cm-^{1})

μ_2: skin baseline absorption coefficient (cm-^{1})

Table I gives data on melanosomes per unit volume for different skin types, while table II shows the absorption coefficients of the epidermis for different laser wavelengths [8].

From the above aforementioned data we have:

The absorption coefficient for the epidermal layer due to skin baseline and melanin absorptions for a darkly pigmented adult at 1064 =7.915 cm^{-1}, moderately pigmented adult = 5.6 cm^{-1}, light pigmented adult = 3.19 cm^{-1}. The factor which is related to the epidermal and dermal thickness could be taken directly from cited articles in that field[9]. Their whole attenuation coefficient is given by:

$$\mu = \mu_a + \mu_{\sim} \qquad (4)$$

In some cases, μ_a or $\mu_{\sim}$ may be negligible but it is important to recognize the existence of the two processes because the both are effective here. During the last ten years, many research have probed all types of biological tissue, and a summary of the generality of results is represented in Table III.

Heat transport is related to tissue heat conductivity; hence, heat capacity[10].

Where:

ΔT: the rise in temperature in (C°).

c: specific heat capacity = 3.6 (J/g. C°) for epidermal and 3.8 for dermal.

ρ: density = 1.2 (g/cm^{-3}) for both epidermis and dermis.

F: Fluence (J/cm^{-2}).

Thermal diffusion controls the heat flow through the tissue. For short laser pulse durations, t_p, as compared to diffusion time, t_d, there is a "thermal confinement". The diffusion time t_d is known as the thermal relaxation time and given by[4]:

$$t_d = 1/k\mu^2 \text{ [s]} \qquad (6)$$

Where: k is thermal diffusion coefficient in (m^2/s) which is related to the thermal conductivity [Watt/m K] given by:

$$k = h/cp \qquad (7)$$

Where: h- thermal conductivity; c – specific heat capacity; p-density

- For laser pulse width $T < t_d$, heat doesn't penetrate well.

-For $T > t_d$, heat diffuses to a distance greater than the optical penetration depth

The essential theory behind the use of light depends on the selective photothermolysis rule, by Anderson and Parish, 1983, which is defined as a laser damage that is restricted to a selected tissue by specific laser parameter[11].

Table IV. Treatment parameters

case	age	Treated area	Skin color	Spot diameter mm	Fluence J/cm²	Pulse duration ms	Temp after cooling °C
1	48	nose	5	5	110	25	4
2	45	nose	5	5	115	25	4
3	48	cheek	5	5	110	25	3
4	45	Leg	2	5	150	20	10
5	45	Leg	2	5	140	20	7
6	45	leg	2	5	140 150	20 30	7
7	28	cheek	3	5 3	150 170	30 15	8
8	47	Cheek	2	3	190	15	8
9	48	cheek	3	5	120	30	8
10	35	Cheek	3	3	180	25	13
11	33	Cheek	3	5	150	30	12
12	42	leg	2	5	160	15	18
13	44	cheek	2	5	140	20	9
14	28	Cheek	4	3	140 180	25 20	10
15	29	Cheek	4	3	140 180	25 20	3
16	39	Below jaw	4	3	180	20	3
17	42	nose	5	3	150	20	3
18	44	cheek	5	5	145 115	20 30	3
19	37	cheek	3	3	115 120	20 25	4
20	37	chin	4	3	180	20	6

THE AIM

Based on approved pre-calculated doses, the present study highlights the clinical effects and safety of treatment after using the exact laser parameters from 1064-nm Nd: YAG laser.

MATERIALS AND METHODS

Twenty women with different skin phototypes (I–V), and age 20-50 years with leg and facial enlarged veins, were treated with pulsed Nd: YAG The Elite+™ Aesthetic laser system; operating at 1064nm. The treatment parameters were varied for each case; depending on the size of veins being treated, as presented in table IV. The subjects were examined after each treatment at different follow-up times after last treatment. The skin phototype was determined for each case by DESS skin phototype analyzer (model GB531). In addition; the skin temperature was measured before and during the treatment, using Ingco laser thermometer.

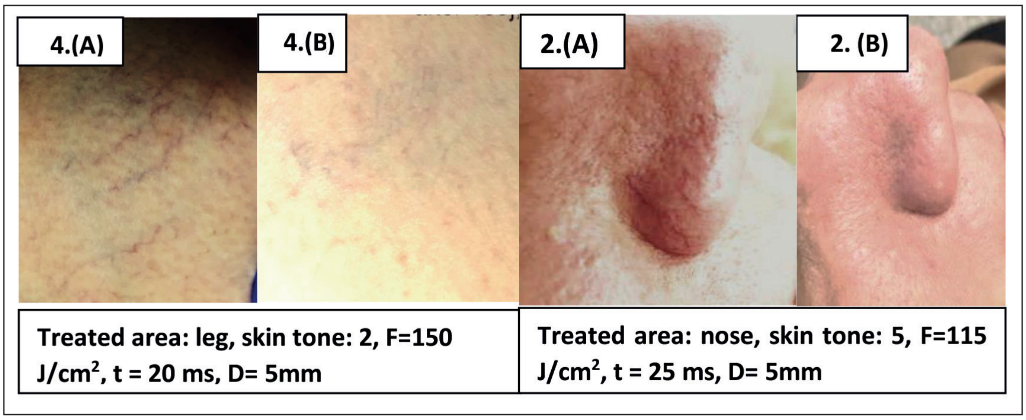
RESULTS AND DISCUSSION

In the present work, 4% 5% and 7% reflection losses were assumed respectively for dark, moderate and light skin photo-types. The laser beam losses by epidermis attenuation factors were calculated from equation 1; after taking into account the melanin pigment percentage, the corresponding total scattering and absorption attenuation factor and the dermal thickness in the treated area. This provided the precise laser fluence reaching the dermal layer. The exact temperature rise was therefore found for each 0.1 mm of the dermal layer thickness after applying equation (6) for the absorbed fluence with dermal thickness to which the laser beam has reached. Table V shows the gradual drop in temperatures through the dermal layers; which were minimal for the Nd: YAG laser.

The advantages that fundamental frequency Nd: YAG laser offers, compared to other lasers include: deeper penetration and minimal melanin absorption without harming the superficial epidermal layer when using efficient cooling. The rise in epidermal temperature is very limited for light skin photo-type and becomes more serious for darker skin photo-type; as shown in table V. This can be ascribed to the variation in the absorption coefficient values between different skin tones which impose a maximum limit on the penetrating laser fluence value in each case[12]. A comparison between results for dark skin (skin-tone 5) subject 2 and light skin (skin-tone 2) subject 4 shows clearly the

Table V. The rise in temperature within the skin layer (with slandered deviation value)

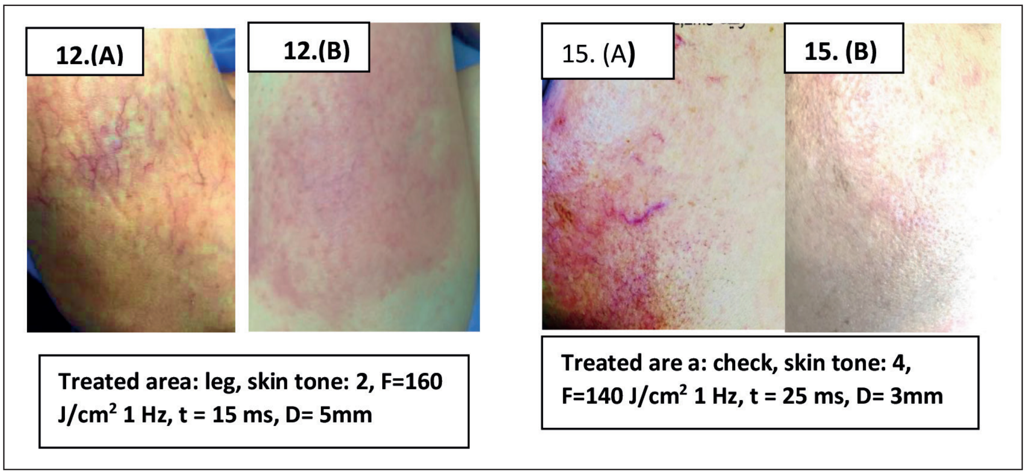
Subject no.	Epidermis cooling degree in C°	Rise in temperature in C °			
		Epidermis ± 31.079836	of dermis ± 3.146139	0.2 of dermis ±2.151523	0.3 of dermis ±1.471344
1	4	99.625392	46.55889	43.53696	41.47037
2	4	115.40669	46.86136	43.7438	41.61183
3	4	109.36856	46.55889	43.53696	41.47037
4	10	51.871799	52.82955	47.82521	44.40295
5	10	48.880346	51.77424	47.10353	43.90942
6	10	51.871799	52.82955	47.82521	44.40295
7	0	118.99668	51.57112	46.96462	43.81442
8	3	78.667108	53.28537	48.13693	44.61612
9	3	52.631858	47.28549	44.03385	41.81018
10	0	127.5259	52.42824	47.55078	44.21527
11	0	107.93825	49.85687	45.79232	43.01273
12	5	57.863252	53.88485	48.5469	44.89648
13	5	56.750195	49.38683	45.47088	42.79291
14	5	97.357708	49.38683	45.47088	42.79291
15	0	97.357708	49.38683	45.47088	42.79291
16	0	93.827397	57.65481	51.12503	46.65956
17	0	149.61743	49.86264	45.79626	43.01542
18	0	143.21311	49.60036	45.6169	42.89276
19	0	80.508117	47.1749	43.95822	41.75846
20	0	100.5754	56.60821	50.4093	46.1701



Treated area: leg, skin tone: 2, F=150 J/cm^2, t = 20 ms, D= 5mm

Treated area: nose, skin tone: 5, F=115 J/cm^2, t = 25 ms, D= 5mm

Fig. 1. Treatment results after using the pre-calculated laser parameters for vascular vein treatment of subjects: 2, 4, (A) before treatment and (B) after laser curing



Treated area: leg, skin tone: 2, F=160 J/cm^2 1 Hz, t = 15 ms, D= 5mm

Treated are a: check, skin tone: 4, F=140 J/cm^2 1 Hz, t = 25 ms, D= 3mm

Fig. 2. Non-purpuric full recovery laser treatment result images for laser-treated subjects 12, 15; using the preceded calculation of the required treating temperature.

serious problems associated with darker skin. With the use of a low laser fluence for the second subjects, the temperature rise was still higher even at lower (4°C) skin cooling. In the case of 10°C cooling, for subject 4 the use of higher laser fluence produced a lower rise in temperature[13]. This is attributed to the difference in absorption coefficient for different skin photo-types; figure (1).

After the consideration of skin-tone and temperature rise, a set of parameters were calculated to treat 17 cases. These calculations revealed the accurate temperatures required through the skin layer; table (IV). All subjects with facial and leg vein treatment showed excellent outcomes with 95–100% clearance as shown in figure (2); with very mild burn sensation. No scarring, textural, purpura, or pigmentary changes were noted. No subject had to interrupt her social life because of the treatment results. The preceded calculation of temperature rise, the use of exact laser fluences relative to these temperatures, and the sufficient cooling employed, helped in achieving final positive results in one session. This agrees exactly with the statement of Cannarozzo, Giovanni in the Atlas of Lasers and Lights in Dermatology book [14].

CONCLUSIONS

The present exact fluence calculation is an equitable presentation of the selective photothermolysis operation in Nd: YAG laser treatment of varicose vein. Also, the calculations are a useful tool to precisely determine the parameters that control photo-thermal effect in the treatment of veins by the (1064nm) Nd: YAG laser. In the current study, the clinical data and associated calculations can be used as a reference for safe varicose laser treatment to ensure satisfaction and gratification of patients and to flourish the business of laser aesthetic applications in dermatology. It should be mentioned that this is the first attempt to adopt scientific way for deciding the exact laser fluence values needed for treating enlarged veins, rather than trial-and-error method, mostly used by dermatologists. The present study will help improve the treatment results of laser aesthetic applications, in general, and avoid unpleasant side effects.

REFERENCES

1. A. Major et al., "Nd: YAG 1064 nm laser in the treatment of facial and leg telangiectasias," Journal of the European Academy of Dermatology and Venereology, 2001;15(6):559-565.
2. A. Bashkatov, E. Genina, V. Kochubey, and V. Tuchin, "Optical properties of human skin, subcutaneous and mucous tissues in the wavelength range from 400 to 2000 nm," Journal of Physics D: Applied Physics, 2005;38915:2543.
3. S. H. Choi, "Fast and robust extraction of optical and morphological properties of human skin using a hybrid stochastic–deterministic algorithm: Monte-Carlo simulation study," Lasers in Medical Science, 2010;25(5):733-741.
4. T. Lister, P. A. Wright, and P. H. Chappell, "Optical properties of human skin," Journal of biomedical optics, 2012;17(9):090901.
5. E. V. Ross and N. Uebelhoer, Laser-tissue interactions, in Lasers in dermatology and medicine: Springer, 2011, pp. 1-23.
6. R. Steiner, "Laser-tissue interactions," in Laser and IPL technology in dermatology and aesthetic medicine: Springer, 2011, pp. 23-36.
7. V. V. Tuchin, "Tissue optics," 2015: Society of Photo-Optical Instrumentation Engineers (SPIE).
8. W. Hamoudi, "Laser-Human Skin Interaction: Analytical Study and Optimization of Present Non-Ablative Laser Resurfacing," Iraqi Journal of Applied Physics, 2008;4(3):5-11.
9. K. RoBERTSoN and J. L. Rees, "Variation in epidermal morphology in human skin at different body sites as measured by reflectance confocal microscopy," Acta dermato-venereologica, 2010;90(4):368-373.
10. M. H. Niemz, Laser-tissue interactions. Springer, 2007.
11. A. Fratila, G. Gauglitz, A. Strohbücker, and D. Radu, " Selektive Photothermolyse der Besenreiser und retikulären Varizen mit dem langgepulsten Nd: YAG Laser," Phlebologie, 2019.
12. P. L. Bencini, A. Tourlaki, V. De Giorgi, and M. Galimberti, "Laser use for cutaneous vascular alterations of cosmetic interest," Dermatologic therapy, 2012;25(4):340-351.
13. Z. Asiran Serdar and N. Fisek Izci, "The evaluation of long–pulsed Nd: YAG laser efficacy and side effects in the treatment of cutaneous vessels on the face and legs," Journal of cosmetic dermatology, 2019.
14. G. Cannarozzo, S. P. Nisticò, K. Nouri, and M. Sannino, "Lasers for the Treatment of Vascular Lesions (Visible and Near Infrared): Vascular Tissue," in Atlas of Lasers and Lights in Dermatology: Springer, 2020, pp. 17-24.

Contributionship:

Muna B. Mustafa [A,B,F]
Wailed K. Hamoudi [B,D,C,F]
Ghufran. S. Jaber [B,D,E]
Mohammed Y. Abbas [B,E]
Noor R. Abdulhameed [B,E]

Conflict of interest:

The Authors declare no conflict of interest.

CORRESPONDING AUTHOR

Wailed K. Hamoudi
Department of Optics Techniques,
Al-Farabi University College, Baghdad, Iraq
e-mail: wjuaini2007@yahoo.com

Received: 25.06.2021
Accepted: 31.08.2021

A – Work concept and design, **B** – Data collection and analysis, **C** – Responsibility for statistical analysis, **D** – Writing the article, **E** – Critical review, **F** – Final approval of the article