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COMPARATIVE EFFECTS OF EXPOSURE TO DIFFERENT LIGHT SOURCES (He-Ne LASER, InGaAl DIODE LASER, A SPECIFIC TYPE OF NONCOHERENT LED) ON SKIN BLOOD FLOW OF THE HEAD

by

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ABSTRACT:

Background and Objective: This study assessed the effects of optic stimuli emitted by three different light sources on head skin blood flow.

Materials and Methods: The irradiation effects of the He-Ne laser (632.8 nm, 10 mW, total energy appr. 9.4 J), the InGaAl diode laser (670 nm, 60 mW, appr. 108 J) and monochromatic light (635 nm, 112.5 mW, appr. 202.5 J) were measured using laser Doppler technology. The corresponding fluences (energy densities) varied from 0.01 J/cm^2 (He-Ne) to a range of 0.12 - 0.72 J/cm^2 (InGaAl) and 0.22 - 1.36 J/cm^2 (LED). The investigation was completed under single-blind, placebo-controlled conditions where the subjects (10 male healthy volunteers) were exposed on two occasions to the placebo (LED)-device against the laser (He-Ne or InGaAl).

Results: A short lasting vasodilation, a 54 per cent increase ($p<0.05$) in skin blood flow was seen after the InGaAl irradiation (fluences between 0.12 - 0.36 J/cm^2) whereas the non-coherent monochromatic irradiation (0.68 - 1.36 J/cm^2) used in this particular study decreased blood flow by 36 per cent ($p<0.05$). The He-Ne irradiation (0.01

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J/cm^2) had no effect. Skin temperature changes were insignificant.

Conclusions: Skin blood flow changes seemed to be related more on radiant exposures than coherency.

Key Words: Helium-Neon laser, InGaAl laser, laser-Doppler, light emitting diode, skin blood flow.

INTRODUCTION

The biomodulatory effects of low energy levels of laser irradiation have been extensively studied since the early findings of Mester and his group in Budapest (1-4). Although the He-Ne laser was originally regarded better for ulcer and wound treatment, the infrared laser radiation has been shown to be equally effective in controlled animal studies (5-7). At present the importance of coherent light is under discussion (8-11).

Recently Smith (12) proposed a new model, a combination of photochemical and photophysical events activated by visible and invisible (infrared) radiation, to explain the response in the tissues to different wavelengths of radiation. This model can explain the beneficial effects of the so called hair lasers on injured, postoperative, inflamed or infected skin areas. Rigau et al. (13) and Braverman (personal communication, Chicago 1993) have shown that both visible and infrared laser radiation increases hair growth in skin flaps in rats and rabbits.

Male pattern hair loss is often hereditary and may have an androgenic origin (14). Hair follicles are shrunk while the skin thickens, subcutaneous fat is reduced and muscle and skeletal bulk is increased. Gunn and Lee (15) propose a neuropathic mechanism through entrapment of supraorbital and sometimes occipital nerves. Low energy lasers have been used in the treatment of male pattern hair loss and Alopecia areata for over a decade (16-20). As microcirculation is often impaired in these conditions and laser radiation may improve microcirculation (21) we decided to investigate the possible effect of visible laser light and non-coherent light on skin blood flow.

Braverman et al. (7) have shown that 1.65 J/cm^2 HeNe and IR (904 nm) 8.25 J/cm^2 laser radiation given in 11 minutes did not increase subcutaneous temperature. They reported similar results in another trial extending the exposure time to 50 minutes (power density approx. 15 mW/cm^2).

The laser Doppler technique is the most reliable method for skin blood flow measurements (22-25). Although laser radiation (He-Ne 2 mW) is used to create the Doppler effect, the total irradiation dose is low (approx. 15 mJ/measuring site) and the power density approx. 30 mW/cm^2. This technique reflects the changes in the perfusion of the outer layers of skin as the major part of visible laser light is absorbed into the microcirculation of skin (the first 0.3-0.5 mm)(26).

The laser devices used in this study emitted in the visible

light range (632.8 - 670 nm). Both lasers are in common use to improve hair growth. The placebo device was provided with LEDs (Light Emitting Diodes) emitting at the same wavelength range (635 nm).

Purpose of the study.

The purpose of this study was to investigate the possible changes of head skin blood flow during and immediately after optic stimuli emitted by three different light sources, two of them used routinely in the treatment of male pattern hair loss and to improve hair growth in alopecia areata.

MATERIAL AND METHODS

Ten otherwise healthy male volunteers suffering from male pattern hair loss participated in the study. Their mean age was 35±8.5 years (24 - 43 yrs). All restrained from smoking or drinking coffee/tea or other caffeine containing drinks in the morning of the study. All subjects were normotensive and were not on any medication.

Study design.

All experiments were done between 08.00 and 12.00 in the morning. All subjects were unaware of the sequence of the lasers used. All devices emitted in the same visible red range (632.8 to 670 nm). Laser treatments and measurements were done by separate people.

The study protocol.

Experiment 1

1) 30 min rest at an easy chair
2) perfusion and temperature measurement
3) 30 min placebo laser treatment
4) perfusion and temperature measurement
5) 30 min rest
6) perfusion and temperature measurement
7) 30 min active Diode laser treatment
8) perfusion and temperature measurement
9) 30 min rest
10) perfusion measurement

Minimum interval between the Experiments 1 and 2 was 48 hours.

Experiment 2

1) to 10) as above, but with another active (He-Ne) laser at step 7).

Environmental factors

All experiments were done in the same room with stable temperature (22-23 in centigrades) and no mechanical ventilation (Fig. 1A). The inside hood air temperature was measured at the end of every treatment with an electric thermometer. Variation remained between 27.7±0.3 and 28.7±0.5 (Table 1).

Table 1.

Inside hood air temperature after the treatment

Placebo 1	Diode laser	Placebo 2	He-Ne laser
28.4 ± 0.3	28.7 ± 0.5	27.9 ± 0.3	27.7 ± 0.3

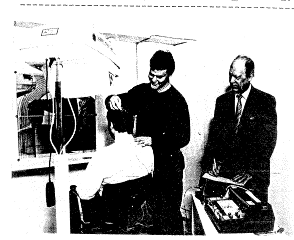


Fig. 1A. Blood flow measurement with a PeriFlux PF3 monitor and a PF309 probe before irradiation. The hood equipped with either laser diodes or LEDs (Placebo) on the left upper corner. The inside hood air temperature was measured between the scalp and the hood at the end of irradiation.

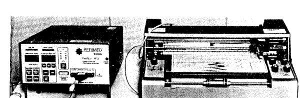


Fig. 1B. Laser Doppler equipment used in the study.

Flow measurement

Skin blood flow was measured using the laser Doppler technique. In this technique, a narrow beam of monochromatic light generated by a low power laser is carried by an optical fibre probe to the tissue being studied. The light is diffusely scattered and partly absorbed within the illuminated tissue volume. Light hitting moving cells will undergo a slight Doppler shift (change in wavelength) but light hitting static structures remains unchanged. The magnitude and frequency distribution of the Doppler shift are directly related to the number and velocity of cells, but virtually unrelated to the direction in which they move. The measurement probe incorporates two additional optical fibres which pick up and carry part of the illuminating beam backscattered from the tissue to photodetectors where it is converted into electronic signals. The Doppler shifted components are extracted from the laser noise and other interfering frequencies. The background noise is thus effectively suppressed to produce a cell-motion correlated signal called the flux. The flux is defined as: Perfusion or Blood Cell Flux = Number of blood cells moving in the measured volume x Mean velocity of these cells. Perfusion or flux measured by PeriFlux represents the bloodcell transport through the microvascular network from the arterial to the venous side. It is integrated over the entire measured volume - in normal skin a hemisphere with a radius of about 1 mm. Thus the units used in the measurement are arbitrary and reflect relative changes in the perfusion or flux. Further details of this method can be found elsewhere (22-23).

Our equipment consisted of a PeriFlux PF3 perfusion monitor and a PF309 probe (PERIMED AB, Box 564, S-175 26 Järfälla, Sweden)(Fig. 1B). Specification of equipment:
Laser classification: Class 2 (FDA 21 CFR 1040-10/11).
Laser: 2 mW He-Ne laser of 632.8 nm wavelength. No other radiation present.
Radiation from probe tip: <1 mW.
Measured volume: At normal skin: hemisphere of approx. 1 mm radius.
Doppler shift frequency: 20 Hz to 30 kHz.
Flux time constants: 0.02, 0.2, 3 s

Blood flow measurement was done at 4 sites on the scalp skin as shown in Fig. 2 before, immediately after and 30 minutes after irradiation (see study protocol).

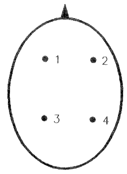


Fig. 2. Measuring points on the scalp (sites 1-4).

Temperature measurement

Skin temperature

Skin temperature was measured at sites 1 and 3 (Fig. 2) immediately before and after laser treatment with an electric thermometer with a thermistor in contact with skin, response time 5 s (Ellab, Denmark).

Inside hood air temperature

Inside hood air temperature was measured at the end of treatment with the device described above.

Laser devices

Helium-Neon laser, Boston hairtreatment laser (Laser Trigologico, AT/HeNe/10, Boston Elettrodomestici SRL, Via Tiziano 9, I-20145 Milan, Italy)
Optical output: 10 mW divided into 166 fibres with an energy loss of appr. 48%.
Output power/fibre tip: appr. 0.03 mW
Wavelength: 632.8 nm
Total energy in 30 minutes (at tube): appr. 18 J
Total energy in 30 minutes (at fibre tips): appr. 9.4 J
Total energy in 30 minutes (at fibre tip): appr. 0.06 J
Calculated energy density: appr. 0.01 J/cm²/30 min
Distance from the fibre tip to the skin: appr. 4 cm
Divergence of the beam: appr. 40 degrees

Diode (InGaAl) laser, Laser Hair Care 3000 (Laser Science AB, P.O.Box 2209, S-103 15 Stockholm, Sweden)(Fig. 3-4).
Optical output: 15 x 4 mW = 60 mW
Wavelength: 670 nm
Total energy in 30 minutes: 108 J
Energy/diode in 30 minutes: appr. 7.2 J
Max. theoretical energy density: appr. 1.09 J/cm²/30 min
Calculated energy density at the inner circle in front: 0.72 J/cm²/30min
Calculated energy density at the inner circle at rear: 0.36 J/cm²/30 min
Calculated energy density at the outer circle in front: 0.24 J/cm²/30 min
Calculated energy density at the outer circle at rear: 0.12 J/cm²/30 min
Distance from the diode to the skin: appr. 4 cm
Divergence of the beam: 40 degrees

Placebo Laser, Laser Hair Care 3000 provided with 15 x 7.5 mW LEDs (Sharp Electronics Corporation, U.S.A.).
Optical output: 112.5 mW
Wavelength: 635 nm
Total energy in 30 minutes: 202.5 J
Energy/diode in 30 minutes: appr. 13.5 J
Max. theoretical energy density: appr. 2.05 J/cm²/30 min
Calculated energy density at the inner circle in front: 1.36 J/cm²/30 min
Calculated energy density at the inner circle at rear: 0.68 J/cm²/30 min
Calculated energy density at the outer circle in front: 0.43 J/cm²/30 min

Calculated energy density at the outer circle at rear: 0.22 J/cm²/30 min
Distance from the diode to the skin: appr. 4 cm
Divergence of the beam: appr. 40 degrees

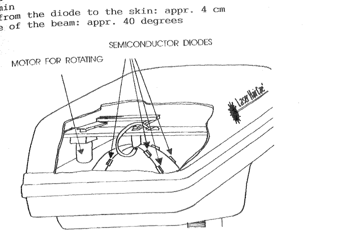


Fig. 3. Construction of the diode laser (Laser Hair Care 3000).

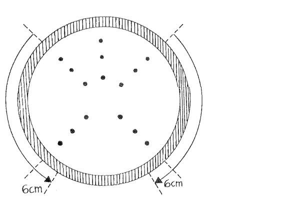


Fig. 4. Diode placement in Laser Hair Care 3000.

The properties of different lasers used in this study are shown in Table 2.

Table 2.
Laser devices.

	mW	nm	J	J/cm²/30 min
He-Ne laser	10	632.8	18	0.01
Diode laser (InGaAl)	60	670	108	0.12-0.72
Placebo laser (LED)	112.5	635	202.5	0.22-1.36

Statistics

Statistical analyses were made by the Student's two-tailed t-test for paired observations and group comparison (SAS analysis software package). Differences were considered significant at $P<0.05$.

RESULTS

Temperature

Hood temperature. The differences of the inside hood temperatures were insignificant (Table 1).

Skin temperature. The average skin temperatures before and immediately after irradiation are shown in Table 3. No significant changes were recorded in any treatment group and the mean temperatures of these groups at sites 1 and 3 did not differ from each other ($P>0.05$).

Table 3.
Average skin temperatures. Sites 1 and 3.

	Site 1		Site 3	
	Before	After	Before	After
Placebo 1	35.2±0.4	35.7±0.4	35.5±0.9	35.9±0.6
Diode laser	35.3±0.6	35.9±0.4	35.6±0.6	36.0±0.3
Placebo 2	34.4±1.3	35.0±1.2	34.7±1.4	35.1±1.1
HeNe-laser	34.9±0.9	34.9±1.2	34.9±1.2	35.2±1.1

Skin blood flow

In the first experiment LED (Placebo 1)(635 nm, 112.5 mW, 0.68-1.36 J/cm²) induced a clear vasoconstriction (Figure 5) at 30 min after treatment ($t=2.060$, $P<0.05$), whereas InGaAl diode laser produced a transient vasodilation and increased blood flow immediately after laser irradiation ($t=2.404$, $P<0.05$)(Table 4a). This effect was over at 30 min after irradiation (Figure 5). These changes were greatest at sites 3 and 4 where the calculated laser fluences were around 0.36 J/cm² (Tables 5a, 6a).

Table 4 a.

Average skin blood flow. Sites 1 - 4 combined (N=40).

	Placebo 1	Diode laser
Before	13.21 ± 12.49	8.36 ± 8.53
After	10.58 ± 10.06	12.91 ± 8.39 *
30 min after	8.28 ± 8.58 *	9.45 ± 7.06

* = $P < 0.05$

Table 4 b.

Average skin blood flow. Sites 1 - 4 combined (N=40).

	Placebo 2	He-Ne laser
Before	3.31 ± 3.25	3.25 ± 4.16
After	2.74 ± 3.13	2.89 ± 3.23
30 min after	3.25 ± 4.16	2.33 ± 2.77

Table 5 a.

Average skin blood flow. Sites 1 + 2 (N=20).

	Placebo 1	Diode laser
Before	17.00 ± 14.74	10.92 ± 10.37
After	14.85 ± 11.74	12.75 ± 5.59
30 min after	10.85 ± 10.42	12.25 ± 7.87

In the second experiment neither LED (Placebo 2) nor He-Ne laser (0.01 J/cm²) could induce any significant change in skin blood flow (Tables 4b, 5b, 6b).

Table 5 b.

Average skin blood flow. Sites 1 + 2 (N=20).

	Placebo 2	He-Ne laser
Before	4.44 ± 3.56	4.12 ± 4.59
After	4.15 ± 3.75	4.05 ± 3.61
30 min after	4.12 ± 4.59	3.40 ± 3.29

Table 6 a.

Average skin blood flow. Sites 3 + 4 (N=20).

	Placebo 1	Diode laser
Before	9.42 ± 8.12	5.80 ± 4.98
After	6.31 ± 5.28	13.07 ± 10.46 *
30 min after	5.70 ± 5.05	6.55 ± 4.49

* = $P < 0.05$

Table 6 b.

Average skin blood flow. Sites 3 + 4 (N=20).

	Placebo 2	He-Ne laser
Before	2.18 ± 2.43	2.38 ± 3.47
After	1.32 ± 1.24	1.72 ± 2.52
30 min after	2.38 ± 3.47	1.26 ± 1.50

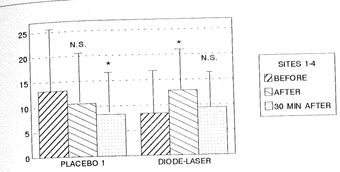
DISCUSSION

Although laser Doppler technology is generally regarded a reliable and valid method to estimate changes in skin blood flow the maintenance of stable recording was not always easy and the arbitrary units of the measuring scale made the comparison of different experiments difficult. In the first series of experiments the initial values (Placebo 1) were markedly higher than later during the experiment (e.g. Placebo 1/Diode-laser t=2.206, p<0.05). As the purpose of this study was to investigate the possible changes of head skin blood flow using three types of monochromatic light sources, the experiment was constructed to check the commercially used He-Ne- and diode-lasers against a placebo device (non-coherent, visible, monochromatic LED). All three devices emitted in the same orange-red wavelength band (633-670 nm) and the distance of the light sources (diodes or fibre tips) to the scalp skin was about 4 cm. The main differences were in the optic power, irradiance and fluence (radiant exposure).

The optic power was weakest in the He-Ne laser (total 10 mW, at fibre tips 0.03 mW), six times higher in InGaAl-laser (total 60 mW, each diode 4 mW), and once more doubled in LED (total 112.5 mW, each diode 7.5 mW). The calculated irradiance (power/unit area) was in the same order: 0.005 mW/cm², 0.6 mW/cm² and 1.06 mW/cm². Total emission during 30 min treatment varied correspondingly from 9.4 J (He-Ne) to 108 J (InGaAl) and 202 J (LED).

The results show that the radiant exposures of 0.01 J/cm² (He-Ne) did not induce any change in skin temperature or blood flow.

AVERAGE SKIN BLOOD FLOW
(N=40)



* = p<0.05; N.S.= not significant

Fig. 5. Average skin blood flow changes (± S.D.) after Placebo 1 and Diode Laser irradiation (sites 1 - 4 combined).

Interestingly, the higher irradiance and radiant exposure of the noncoherent LED-light (Placebo 1)(0.68-1.36 J/cm²) induced a clear vasoconstriction which was overcome by a diode laser emitting less than one third of that dose (0.12-0.36 J/cm²). This vasodilation was short lasting and not present in the second measurement 30 minutes later. Lowe and coworkers (27) recently reported on laser mediated reduction in skin temperature most likely due to a concomitant reduction in skin blood flow as measured with the laser Doppler technique. They postulated that such effects may be dose dependant as the response was seen in the 1.5 J/cm² laser group but not in the 9.0 J/cm² laser group. This correlates nicely with the flow measurements in our series but not with the skin temperatures where no significant changes were recorded. Our results are in accordance with those presented by Braverman et al. (7). They could not show temperature changes with radiant exposures of 1.65 J/cm² (He-Ne) or 8.25 J/cm². Similar changes from vasoconstriction to vasodilation related to the intensity of stimulation are seen during and after transcutaneous electric nerve stimulation (TENS) and with acupuncture needling (28, 29).

It is difficult to interpret the clinical importance of our findings on hair growth and it is a subject of another study. In this study we have shown that radiant exposures between 0.12 J/cm² and 1.36 J/cm² may affect scalp skin blood flow.

CONCLUSIONS

This study indicates that the visible red monochromatic laser light (670 nm) induces a temporary increase in skin blood flow with radiant exposures between 0.12 and 0.36 J/cm². Non-coherent,

visible red monochromatic irradiation (635 nm) from light-emitting diodes (Sharp Electronics Corporation, U.S.A.) with fluences between 0.68-1.36 J/cm² induced vasoconstriction lasting at least 30 minutes after irradiation. Radiant exposure of 0.01 J/cm² (He-Ne) had no effect. Skin blood flow changes in this study seemed to be related more on radiant exposures than coherency.

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