

THERMOGRAPHIC EFFECTS OF LASER THERAPY IN PATIENTS WITH CEREBRAL PALSY

Yoshimi Asagai¹, Atsuhiko Imakire², Toshio Ohshiro³,

¹Shinano Handicapped Children's Hospital Shimosuwa, Nagano, Japan

²Department of Orthopaedic Surgery, Tokyo Medical University, Shinjuku, Tokyo, Japan

³Japan Medical Laser Laboratory, Shinanomachi, Tokyo, Japan

We investigated the characteristics of low-reactive-level laser therapy (LLLT) and analyzed the effects thermographically in patients with cerebral palsy. We determined transmissivity in exposed bone specimens and in the human body using a camera with a wavelength-specific charge-coupled device. The effects of LLLT were dispersed throughout the entire body, and transmitted through bone tissue as well. At an output level of 100 mW, the laser reached a depth of about 2 cm. To study the effects on the autonomic nervous system, we treated 50 patients with cerebral palsy using the gohkoku acupuncture point (between the bases of the first and second metacarpal bones) of the left hand, and measured changes in the skin temperature of both hands. A GaALAs-diode continuous-wave laser beam with a wavelength of 810 nm and power output of 100mW was applied for 60 seconds and the skin temperature was measured with a Thermotracer TH1106 apparatus (NEC San-ei). The results were classified into 3 categories : temperature decrease, no change, and temperature increase. For evaluation of the autonomic nervous system, the laser was applied over muscles with increased muscle tone all over the body in 12 patients with cerebral palsy. Color Doppler showed an increase in blood flow in the common carotid artery in eight of the 12 patients. High speed Fourier analysis of the R-R interval in the Holter electrocardiogram showed increases in the high-frequency components originating from the parasympathetic nerves after irradiation in the same eight patients, suggesting the involvement of the autonomic nervous system in producing this change.

Key words: Laser therapy; cerebral palsy, thermographic analysis

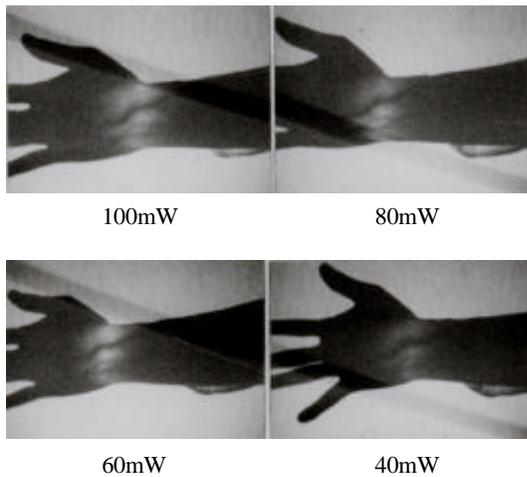
Introduction

Since 1991, we have reported that low reactive-level laser therapy (LLLT) suppresses tonic muscle spasm in patients with cerebral palsy and improves functional training (1). However, the characteristics and mechanism of action of LLLT have not been sufficiently elucidated as yet. We studied the characteristics of LLLT and its effects on the autonomic nervous system, which is considered to be one of the systems affected by LLLT.

Patients and Methods

To study the characteristics of LLLT, we examined its transmission through bleached bone specimens, using a wavelength-specific charge-coupled device camera (CCD camera). To study the effects of LLLT on the autonomic nervous system, we subsequently treated 66 patients with cerebral palsy (60 with spastic and 6 with tension athetoid cerebral palsy), whose age ranged from 10 months to 53 years (mean:10 years), with LLLT directed on the gohkoku (acupuncture point) of the left hand, to observe changes in the skin temperature of both hands. The results were compared with those obtained in 17 healthy controls, 22-

54 years of age (mean: 32 years). Room temperature was maintained at 25°C, and an 810 nm GaAIAs continuous-wave diode laser beam with a power output of 100 mW was applied over the gohkoku of the left hand for 60 seconds after an acclimatization time of 20 minutes; and skin temperature was measured using a Thermotracer TH1106 (NEC San-ei). Moreover, 18 of the subjects were exposed to laser radiation with a power output of 40 mW for 15 seconds, in order to study variations in the effect of LLLT with relation to the power output and irradiation time. The spot size at the tissue was 0.56 cm² giving power densities of 17.86 W/cm² and 7.14 W/cm² at 100 mW and 40 mW, respectively. Energy densities per point ranged from 42.8 J/cm² to 107.5 J/cm², depending on the combination of output power and irradiation time. Furthermore, to assess the effect of laser radiation on the autonomic nervous system, 12 patients were treated with the laser applied over every muscle with increased tone. In these patients, the blood flow in the common carotid artery was measured with a Doppler ultrasonography, and the RR intervals on Holter electrocardiograms were analyzed using the high-speed Fourier method.

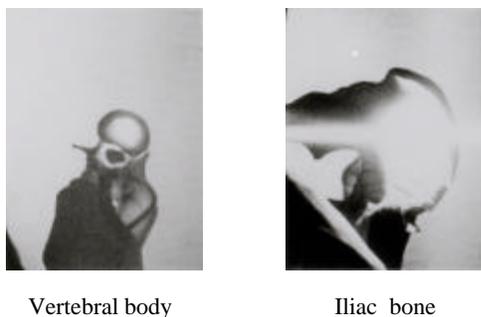


GaALAs diode laser

Fig. 1. The transmission of the beam with a power output of 40-100mW from palmar to the dorsal side of the hand was ascertained with a CCD camera.

Results

The LLLT beam clearly penetrated the target tissues to various levels and, although the depth it reached varied with the power output, the transmission of the beam with a power output of 40-100 mW from the palmar to the dorsal side of the hand was ascertained with a CCD camera (Fig. 1). The effect of the transmitted beam was then studied thermographically on the patient's hand in relation to the effect of the beam that was transmitted through the operator's hand, targeting the ghokoku point of the subject's hand. The beam was clearly transmitted through the operator's hand as seen in Figure 1, and the beam as transmitted through the operator's interdigital area (thickness of the soft tissue: 2 cm) and raised the skin temperature on the thermogram of the subject's hand. At a power output of 60 mW, the rise in temperature did not significantly vary with the wavelength of the beam; 810 nm versus 830 nm. Figure 2 shows the transmission of the beam through bleached bone specimens of the vertebrae and iliac bone at power outputs ranging from 40 to 100 mW.



GaALAs diode laser 100mW

Fig 2 Bone transmission of laser beams to the vertebral body and iliac bone with a power output of 40-100mW through bleached bone specimens was ascertained with a CCD camera.

The skin temperature of the hands of 17 normal controls and 10 patients with cerebral palsy showed a spontaneous

variation of $\pm 2^{\circ}\text{C}$. In the controls, the skin temperature varied in the $30\text{-}34^{\circ}\text{C}$ range before radiation, and within $\pm 2^{\circ}\text{C}$ after irradiation. Using variations in the temperature by 2°C or more as the criterion, the skin temperature of the hand of cerebral palsy patients was classified into 3 types: Temperature decrease, no change and temperature increase. 23 patients had no change in skin temperature, showing variations within $\pm 2^{\circ}\text{C}$; six had decreased temperature, showing falls of more than 2°C , and 36 had increased skin temperature, showing rises of more than 2°C (Fig. 3). Before irradiation the skin temperature varied between 29°C and 33°C in the no change group, and between 30°C and 34°C in the decreased temperature group; these patients had relatively mild upper limb dysfunction. In none of the patients with decreased temperature did the temperature fall below 27°C . Before irradiation the skin temperature in the increased temperature group varied between 20°C and 32°C . It was low, compared with that of patients with decreased temperature. These patients had moderate to severe upper limb dysfunction. Variations in skin temperature on the unirradiated side were similar to those on the irradiated side in all patients, regardless of the type of skin temperature. The relationship between changes in skin temperature after irradiation and the severity of upper limb dysfunction was examined in patients classified as having increased skin temperature. The more severe the upper limb dysfunction was, the lower the skin temperature before irradiation was, and the more marked the rise in skin temperature after irradiation tended to be. The interval to peak temperature tended to be longer, the more severe the upper limb dysfunction of quadriplegia was.

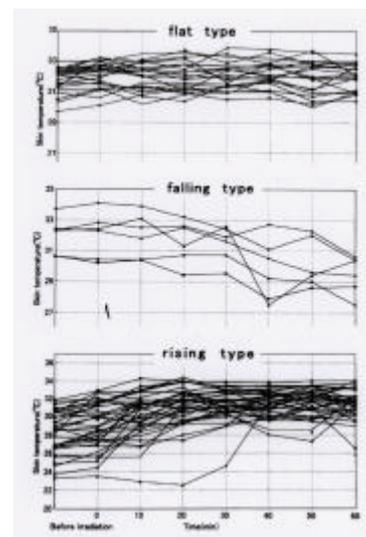


Fig 3 Time course of skin temperature after irradiation. The skin temperature of the hand of cerebral palsy patients was classified into 3 types: flat, falling and rising.

A maximum temperature rise of 9°C was noted in skin temperature after irradiation, but the peak temperature remained between 30 and 34°C in all the patients, which was consistent with that observed in controls (Fig. 4). To investigate the effects of output power and irradiation time, irradiation with a power output of 40 mW for 15 s was compared that with irradiation at 100 mW for 60 s in 18 patients. Of the 18 patients, seven had no change in temperature when irradiation with 40 mW, but had increased temperature after irradiation with 100 mW. Fifty-five patients were irradiated every day for 4 weeks. Compared with before irradiation, the skin temperature in 22 patients rose more than 2°C after 4 weeks. Thermographic studies in patients other than those with cerebral palsy showed that when laser radiation was applied in the acute stage of ankle sprain the high temperature of the skin and the swelling, in relation to the lesion, decreased. Thermographic studies revealed that LLLT exerts effects on blood and lymphatic fluid (Fig. 5). The response of the subjects varied depending on the condition of the irradiation side, indicating that laser irradiation contributed in the maintenance of homeostasis of the internal environment. Next, the blood flow in the common carotid artery was measured by Doppler ultrasonography before and after irradiation. The blood flow increased by an average of 0.25l/min in 8 of 12 subjects after irradiation.

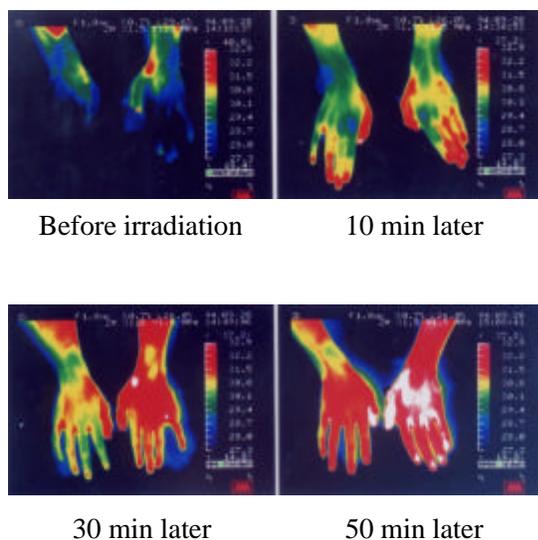
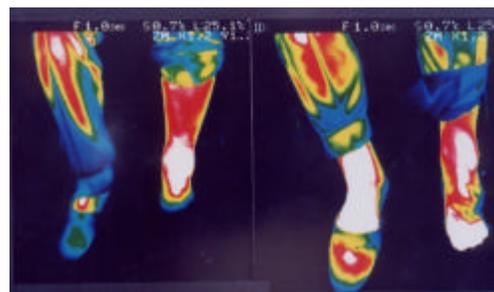


Fig 4 Rising type: a 20-year-old woman with spastic quadriplegia. A maximum rise of 9°C was noted in skin temperature after irradiation, but the peak temperature remained with 30 and 34°C in all patients

Holter electrocardiographic monitoring revealed that high-frequency wave components derived from the parasympathetic nervous system increased after irradiation in 8 of 12 subjects; that is, the LLLT exerted a systemic effect, which was considered to be mediated by the autonomic nervous system (Fig. 6).



Before irradiation 25 min later

Fig 5 The acute stage of left ankle sprain. The high temperature of the skin and swelling in relation with the lesion decreased after irradiation. The skin temperature of left foot and unirradiated side showed rises.

Discussion

The clinical application of low reactive level laser therapy (LLLT) has been a focus of attention ever since Mester used it to treat non-healing skin ulcers in 1968 and Plog used it for pain therapy in 1973. Its use in pain therapy has increased after Ohshiro developed a semiconductor laser in 1980. Walker, Harada et al., and our group have demonstrated its application for spastic paralysis (1,2,13).

Laser energy has various physical properties of light, such as reflection, refraction, transmission, absorption, and scattering. Specific advantages of laser energy are its monochromaticity, high directionality, temporal or spatial coherence (successive waves and particles with a fixed wavelength and phase), giving excellent high photon densities in the target tissue. Furthermore, low incident levels of LLLT energy are not easily absorbed by water and hemoglobin in red blood cells in dermal and subdermal tissues in the wavelength range of between 790 and 940 nm. However, several aspects of LLLT have not been elucidated, e.g., depth of penetration into tissues, scattering, absorption and transmission in the deep areas of the tissue, and its transmission through bone.

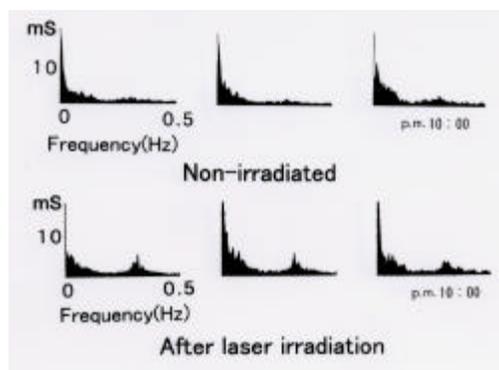


Fig 6 Holter electrocardiographic monitoring. High-frequency wave components derived from the parasympathetic nerve system increased after irradiation.

We have studied the transmission of laser light through bone using a CCD camera, bleached bone specimens and the human body. HeNe laser energy (632.8 nm, 5 mW) was not transmitted, whereas transmission through bone by GaALAs semiconductor laser (40, 60, 80, 100 mW) was observed, even when reflection of the laser energy was taken into consideration.

Concerning the depth of penetration into tissue, it was confirmed that the light was transmitted in the hand and hand joints (about 3 cm thick), although it was also scattered and absorbed. Transmission of the light was studied by thermography since thermography has been used to evaluate the effects of LLLT (4). Laser energy transmitted through the finger (2 cm thick soft tissue) at a wavelength of 810 nm and 100 mW for one minute could increase the skin temperature of the subject's hand.

Concerning the skin temperature of the hand before and after irradiation with LLLT, the skin temperature rose in patients with a low skin temperature before irradiation and the peak temperature was 31-34°C, indicating it was almost equal to normal skin temperature before irradiation. A thermography study in non-cerebral paralysis cases confirmed that the high temperature range of the skin in the sprain region was lowered by laser irradiation during the acute phase of the ankle sprain. LLLT can also possibly act in maintaining the homeostasis of the internal environment of the tissue (Fig. 5).

We investigated the differences using two irradiation conditions, 40 mW for 15 s and 100 mW for 60 s, using thermography, and found that skin temperature rose in patients whose temperatures did not vary when the lower power was used. There were also subjects in whom no differences were seen between these radiation conditions.

Waker (2) and Harada et al (3) suggested the mechanism of action of low reactive level laser in spastic paralysis was an efferent inhibitory action and an effect on the autonomic nerve function, respectively. In a thermographic study, we reported the effects on improvement of blood flow through the autonomic nerve and the spinal reflex pathway (1). The present study also suggests that the effect on the autonomic nerve function is an important factor in the action mechanism in the inhibition of muscle tone. However, the action mechanism has not been sufficiently elucidated, and systemic and local actions not mediated by the autonomic nerves have been suggested. Future studies

should clarify these suggested mechanisms of action.

Conclusions

The effects of low reactive-level laser therapy were dispersed throughout the entire body, transmitted possibly via bone tissue in addition to blood and lymphatic fluids. At an output power of 100 mW for 1 minute, the skin temperature of the subject's hand increased due to irradiation with laser energy giving a penetration depth of 2 cm through soft tissue. Changes in the surface temperature of both hands after laser irradiation over the ghokoku were studied. The skin temperature rose by a maximum of 9°C after irradiation over the ghokoku. However, the peak temperature was consistent with that observed in controls. The results of Doppler ultrasonography and high-speed Fourier analysis of the RR interval on the EKG, in addition to the thermography, revealed that low reactive-level laser therapy exerts an effect on the autonomic nervous system.

Address for Correspondence

Yoshimi Asagai MD
Director, Shinano Handicapped Children`s Hospital
6525-1 Shimosuwa
Suwagun, Nagano
Japan 393-0093
Tel: +81-266 -27 -8414
Fax : +81- 266 -27- 7936
Email: Asagai@poplar.ocn.ne.jp

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