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Graphical Informations on Low Power Laser Therapy of Pain

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Summary : The patients complained of pain due to the local ischemia were treated with Nd: YAG and diode lasers of low power. The thermograms during the therapy revealed not only the local circulatory improvement but also mild temperature elevation at the irradiated spot. Although the thermal effect was inseparable from the laser therapy, there was no heat sensation at the irradiated skin. While mechanically stimulating sensation was caused by the pulsed diode laser, IR TV camera showed wide expansion of laser beam scattering in the subcutaneous tissue and the interference fringe in the transilluminated finger with diode laser. In addition to the thermal effect, the acoustic effect of laser seems to ralate to the biostimulation. The structural water in the tissue was supposed to be the target of laser biostimulation, and a preliminary NMR experiment was performed.

Key Words : Laser, Pain, Thermography, NMR.

1. Introduction

Since low power laser therapy has been initiated by Mester in 1970's, the biostimulative effects of laser came into prominence in the medical applications of laser[1]. The acceleration of wound healing by laser therapy originally achieved by He-He laser and later the same therapeutic effects were proved by Ar, diode and CO_2 lasers[2]. Pain relief by He-He laser reported by Plog[3] was also seconded by Nd : YAG[4] and diode lasers[5]. The mechanism of the laser biostimulation is not cleared and opinions are devided on the definition of low power laser therapy[2]. The interaction of infrared laser in the biological tissue has been particularly interested, while it is drawn into the vortex of controversy, whether coherent and incoherent light lead to the same therapeutic effect[6,7].

Aside from the discussion on these problems, pain relief by laser is getting popular, because of an easy practice with small sized apparatuses and an appreciable effect without loading on the patients. Placebo effect is always involved in the laser therapy of pain, but double blind trials proved significant therapeutic results[8]. The thermographic findings during the laser therapy revealed the local circulatory improvement in the affected region associated with relief of pain[9]. Therefore the thermography is quite useful to check the practice of laser therapy of pain, but is useless to detect the beam distribution in the irradiated tissue. Although 3-D distribution of laser beam was mathematically caliculated[10] and experimentally examined[11], IR TV cam-

era revealed the profile of laser beam passing through the semitransparent material. The interaction of laser in the biological tissue was examined with NMR apparatus and the chemical shift of proton signal was recorded in the irradiated materials. These data were presented as informative findings to suppose the mechanism of laser biostimulation.

2. Materials and Methods

The patients complained of pain due to the local circulatory disturbance were selected as good candidates for the laser therapy. Most cases were treated by YAG laser stimulator (Fuji Photo-Optical Co.)[4]. It provides three optically cabled handpieces and enables the therapist to stimulate simultaneously the multiple points. Generally the laser stimulation was applied to not only the tender spots but also the distant therapeutic points from the affected region. Irradiation time and laser dose varied with case by case, but irradiation of 100 mW at the spot size of 1.5 mm in diameter for 3 minutes was set as minimum stimulus condition. The thermography was done with JTG-500M (Japan Electron Optics Laboratory) during the laser therapy and recorded in the tape. The temperature at the selected points on the thermogram was measured by the data analysis system of computer. In some cases, different types of diode stimulators were used by alone or in combination with YAG laser stimulator. The CW diode laser is 830 nm of wavelength and 10 mW of exit power. The pulsed diode laser is 904 nm of wavelength, 5—10 W of peak power, 100—200 ns of pulse width and 300—10 KHz of repetitive rate. Laser beam is focused 1 mm in diameter. The profile of laser beam expanding in a milk and the hand transilluminated by laser were pictured with IR TV camara (Hamamatsu Photonics).

Chemical shift of proton signal was recorded with FT-NMR apparatus (FX 90Q, Japan Electron Optics Laboratory), and was figured with XY-recorder. Materials were an albumen and a slug. They were put in the sample tube and irradiated with diode laser through the glass wall at the interval between pre- and post-treated recordings. As proton signals of the animals were not stable, they were traced every 30 seconds on the same recording paper shifting from top to bottom. An albumen was used as static material. The laser irradiation was performed outside the NMR apparatus and the temperature of the probe box was set to keep the room temperature. Immediately after the irradiation, the sample tube was returned to the previous position and recording was continued for 10 minutes and extended when necessary.

3. Results

3-1. Thermographic findings

Generally the laser therapy of pain resulted in the local circulatory increment. The demonstrative cases were selected in this paper and it goes without saying that the definite thermogrphic change did not always appear during the therapy. Transient lowering of the skin temperature was often observed after the laser stimulation, but it should be pointed out that the local circulatory increment appeared on looking the thermography carefully.

Fig. 1 is a case of the right frozen shoulder treated with YAG laser. Left picture showed smooth temperature of the back and

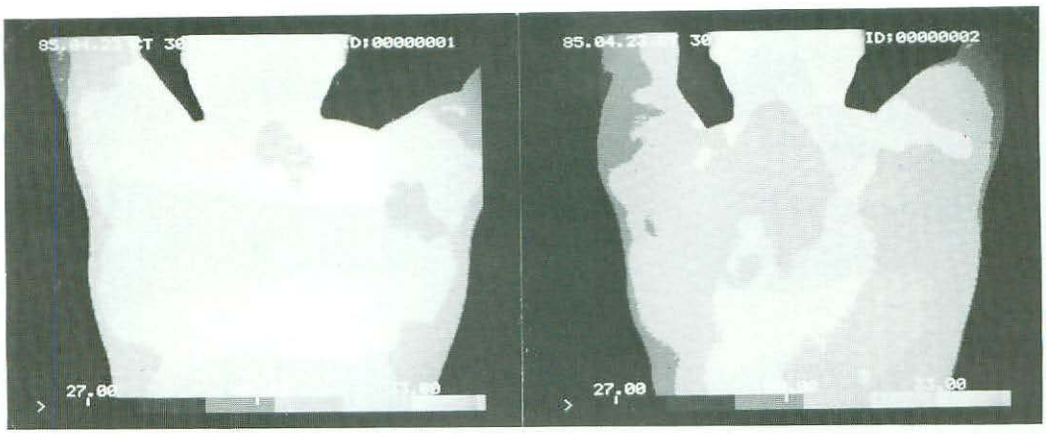

Fig. 1 Thermograms of right frozen sholder treated with YAG laser.
left : pre-treatment, right : post-treatment.

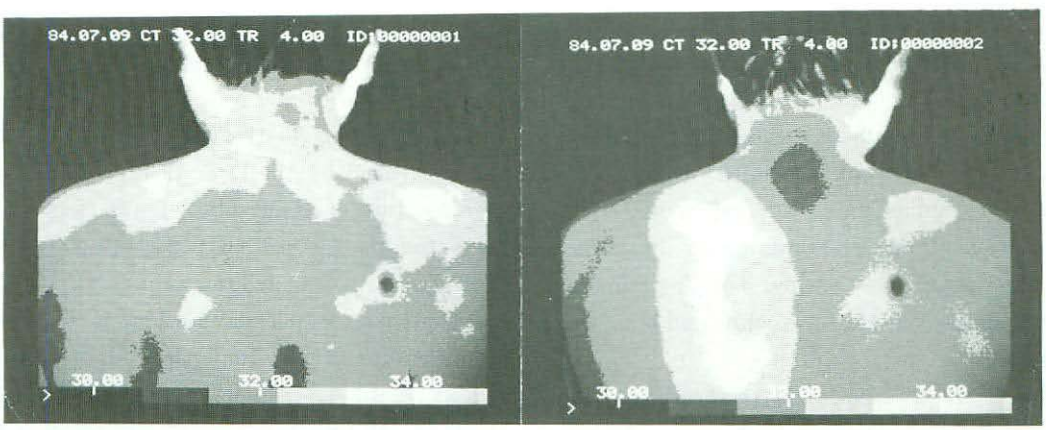

Fig. 2 Thermograms of left back pain treated with YAG laser.
left : pre-treatment, right : post-treatment.

the shoulder before the treatment. Both arms were lifted and the elevation of the right arm was disturbed due to pain and stiffness. Right picture was taken after the therapy and showed a fall of the whole temperature with a little asymmetry on both shoulders. From the therpeutic results of the muscle relaxation and the lightening of pain, it is supposed that asymmetric temperature indicates the circulatory increase to the muscles of the affected shoulder.

More demonstrative thermograms were shown in Fig. 2. This is a case of the left back pain caused by the muscle strain behind the left scapula. YAG laser therapy was applied to the distant acupuncture points and

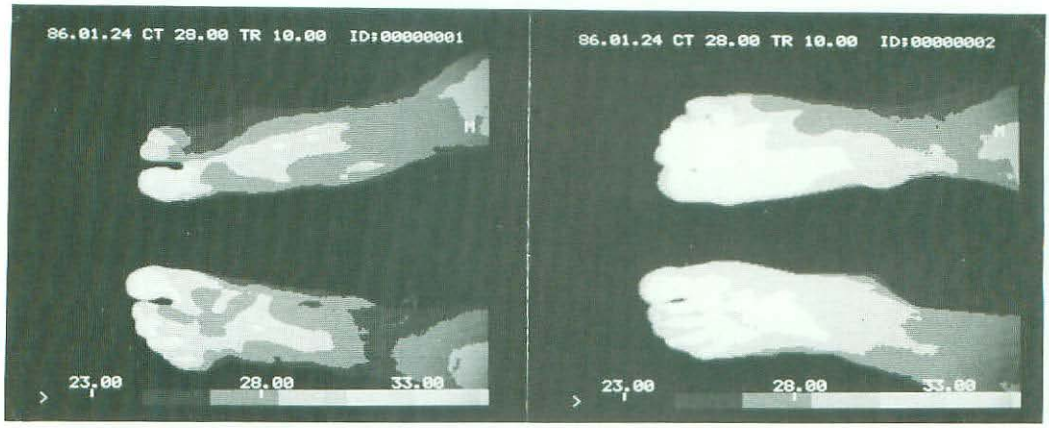

Fig. 3 Thermograms of dysesthesia of right fifth toe treated with diode laser. left : pre-treatment, right : post-treatment.

then laser irradation was concentrated to the painful region for 15 minutes. Right picture of the post-treatment revealed remarkable circulatory increment extending in the wide area surrounding the irradiated spots. Heat production at the irradiated spots disappeared soon after the therapy, but the circulatory increment lasted for a while and pain was relieved.

Fig. 3 is a case of dysesthesia on the right fifth toe with low back pain. The circulatory disturbance was obvious on the lateral side of the right foot in the left picture. Pulsed diode laser therapy was performed on the lumbar region and resulted in increased circulation of the feet, particularly on the affected side. On the next day YAG laser therapy resulted in the similar thermographic findings. Lumbago was relieved within a few days, but dysesthesia remained. Treatments were repeated over a month and dysesthesia disappeared three months later.

Figs. 4 and 5 are a case of Raynaud's disease. Recordings were done under different room temperature. At the temperature of about 18℃ (Fig.4) the vascular response was easily evoked by the laser therapy. While the temperature of about 14℃ (Fig.5) was so severe for the patient that the release of the peripheral vasoconstriction reluctantly appeared by the prolonged irradiation. In Fig.4 the temperature of the fingertips was represented at A to E points. Irradiation of YAG laser of 150 mW for 3 minutes resulted in the temperature elevation of about 3℃, while there was a little change of temperature in the non-irradiated fingertips. The local temperature at the irradiated sopt is depending on the laser energy dose, but it is hard to recognize the thermal effect as heat sensation. It is intersting that pulsed diode laser sometimes causes a mechanically stimulating sensation on the irradiated point, even though the average power is less than 1 mW.

More or less the laesr therapy increases the peripheral circulation, but the therapeu-

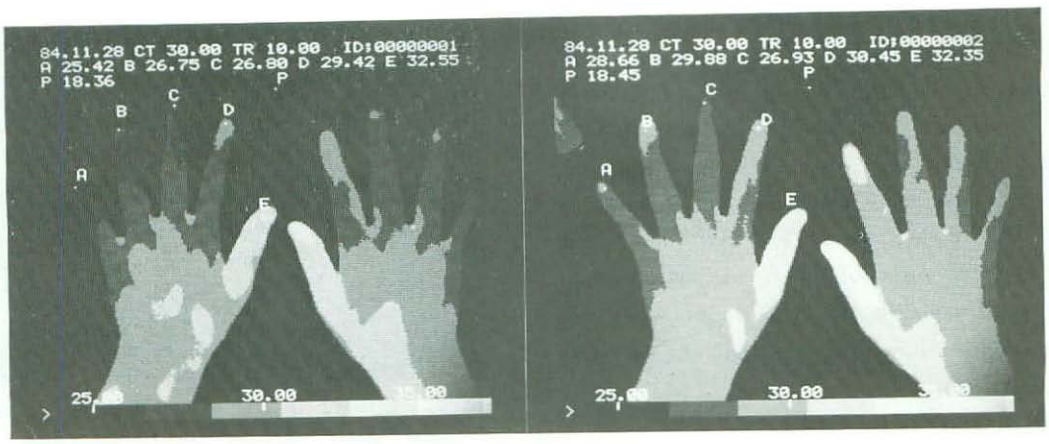

Fig. 4

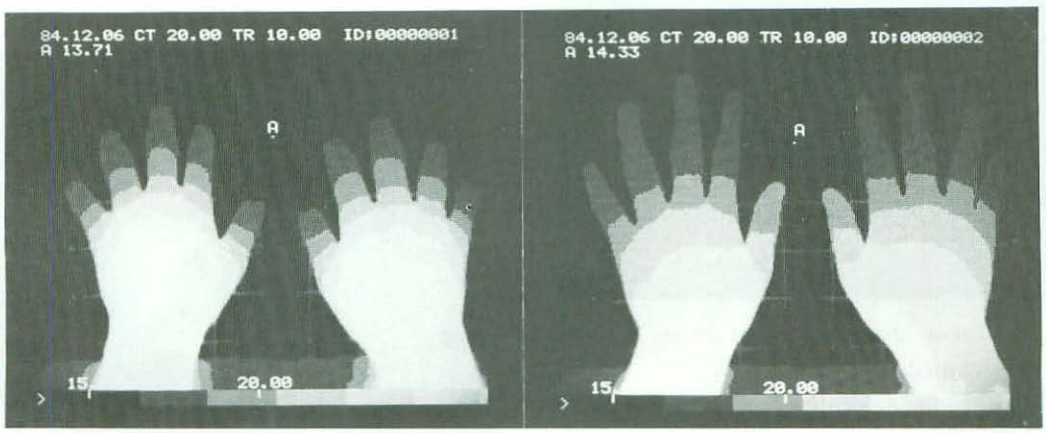

Fig. 5

Fig.4 & 5 Thermograms of Raynaud's disease treated with YAG and diode lasers at different room temperature.
left : pre-treatment, right : post-treatment.

tic effect lasts only a few hours. Such temporary effect is the object of critisism. In this case of Raynaud's disease, the therapeutic effect was getting enhanced and her chilled hands exposed to cold recovered sooner than former days. Forty treatments were repeated over three months and terminated in the early spring. Of course it should be considered the influence of the climatic circumstances, the symptoms were reduced in the following winter without treatment. Such delayed therapeutic effects were observed in many chronic cases.

3-2. Laser beams in the tissue

Fig. 6 is a profile of diode laser beam irradiated to a milk. Picture was taken with IR TV camera and the energy distribution was color-displayed with Photoncounting Image Acquisition System (Hamamatsu Photonics). CW diode laser of 1.2 mW (left) and pulsed diode laser of 10 W at peak power, 100 ns of pulse width, 5 KHz of repetitive rate (right) showed similar pattern of energy distribution.

Fig. 6 Laser energy distribution in a milk.
left : CW diode laser of 1.2 mW,
right : pulsed diode laser of 10 W of peak power, 100 ns of pulse width, 5 KHz of repetitive rate.

The increment of repetitive rate of the pulsed diode laser showed the similar pattern to the increment of the average power. Fig.7 is the results of various repetitive rates of 2, 4, 6 and 8 KHz, while the power was kept constant.

Fig. 8 is the hands transilluminated with YAG laser of 100 mW on the right side and CW diode laser of 10 mW on the left side. The expansion of both penetrating beams was wide and exceeded the common expectations.

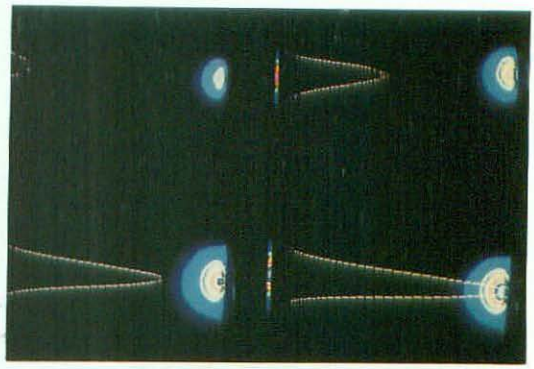

Fig. 7 Energy distribution of pulsed diode laser with various repetitive rates of 2, 4, 6 and 8 KHz.

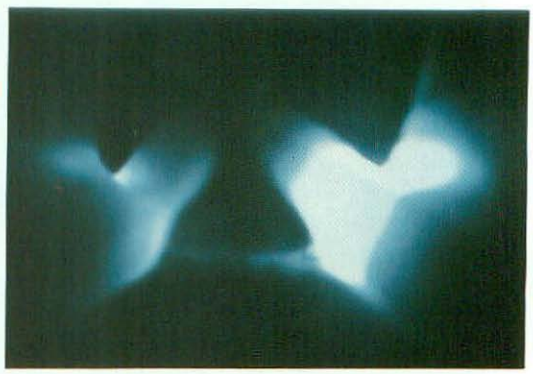

Fig. 8 Transilluminated hands with YAG laser of 100 mW (right) and CW diode laser of 10 mW (left).

Fig. 9 is the index finger transilluminated with CW diode laser of 1 mW The laser irradiated from the opposite side passed through the soft tissue and showed the interference fringe. The similar picture was recorded by pulsed diode laser, but the interference fringe did not appear by LED.

3-3. NMR studies

Fig.10 is NMR record (^{1}H 89,6 MHz) of a slug irradiated with pulsed diode laser of

Fig. 9 Interference fringe appeared in the transilluminated index finger with CW diode lasry of 1 mW.

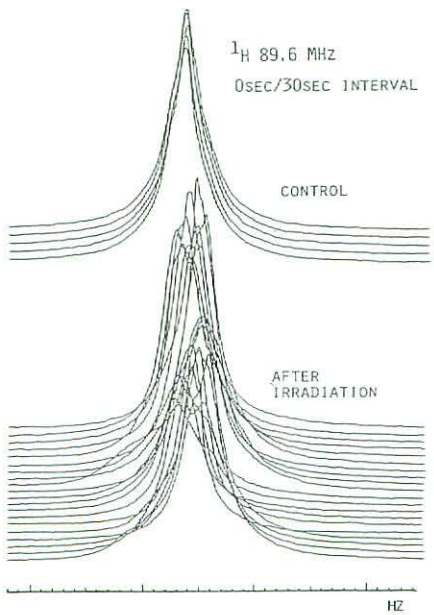

Fig.10 NMR signals recorded from a slug showed chemical shift by laser irradiation.

3.5 W at peak power, 1200 Hz of repetitive rate, 200 ns of pulse width, for 3 minutes. The upper five traces were recorded before irradiation. After irradiation the proton signals shifted to left and right a few Hz and then the signals were deformed. The latter change seemed to indicate the movement of the animals.

An albumen was used as a static material. As shown in the upper recordings of Fig. 11, the proton signals were stable before irradiation. The signals shifted to left and right after the irradiation and returned stable 30 minutes later. The results observed in the preliminary experiment suggested a possible influence of laser on water molecules.

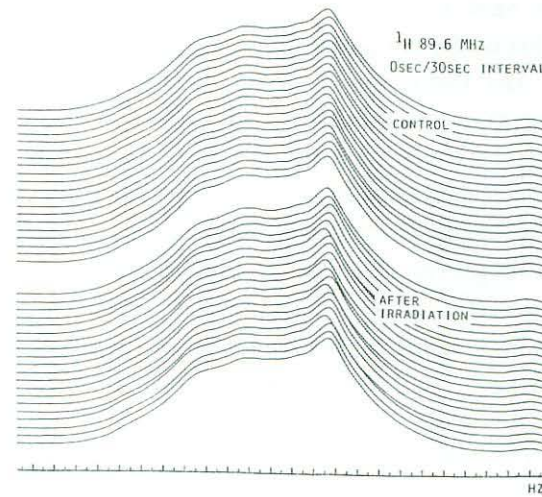

Fig.11 NMR signals recorded from an albumen showed chemical shift by laser irradiation.

4. Discussion

Laser vaporization and coagulation are the representative thermal applications of high

power laser. While low power laser therapy is applied for the biostimulation, which is regarded due to the non-thermal effect of laser. It is not always true. For example, diode laser of 10 mW inceases the skin temperature up to about 0.5℃ by continuous irradiation for 3 minutes. The average power of pulsed diode laser is less than a milliwatt, although the peak power is beyond a watt. YAG laser of 200 mW is hard to be accepted as low power laser, however the temperature elevation at the skin irradiated with YAG laser of 200 mW for 3 minutes is within several degrees centigrade and there is no heat sensation. On the other hand, pulsed diode laser sometimes causes mechanically stimulating sensation at the irradited point. Clear definition of low power laser therapy is hard to be established by the classification of the exit power[2].

The thermographic studies during the laser tharapy offered us a lot of infomations related to not only the vascular response but also the local thermal effect at the irradiated spot. The understandable thermographic findings are presented in this paper and it must be noted that these demonstrative data were recorded by the chance of the selected patients and the intensive laser therapy. Additionally it is emphasized that the vascular response is remakable in the affected rigion and not in the normal tissue.

Comparative studies with different lasers on the same patient revealed interesting facts. In addition to mechanically stimulatng sensation by pulsed diode laser, the interference fringe in the irradiated tissue suggests the acoustic effect of laser besides the thermal effect. Pauling suggested the block of the ion transportation by the hydrate of the anesthetics[12]. Based upon his hypothesis, NMR experiment was desinged to examine the influence of laser on the structural water in the tissue. Regretably the NMR experiment is preliminary and further experiment is planing to prove the speculation that the influence of laser on water molecules may pull trigger of the biostimulation.

5. References

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痛みの低出力レーザー治療に関する画像情報

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要旨：局所循環障害が関与していると診断した痛みを訴える患者に Nd：YAG または半導体レーザー治療を行ない，サーモグラムを検討した．サーモグラムはレーザー治療による局所循環の改善を示すのみならず，レーザー照射局部の軽微な皮膚温上昇を示した．しかし照射局所に熱感を生ずることはない．ただしパルスレーザーでは機械的刺激感覚を生ずることがある．赤外線ＴＶカメラで皮下組織でのレーザーの広がりを観察すると，予想以上に拡散範囲が広く，しかも干渉縞が認められた．レーザーの生体刺激には熱作用とともに光子による振動作用が働くものと思われる．そのターゲットは生体の構造水であろうと想定し，ＮＭＲ装置で予備実験を試みたところ，プロトン信号のゆらぎを記録した．