Lasers Med Sci (2007) 22: 37–41
DOI 10.1007/s10103-006-0408-8

ORIGINAL ARTICLE

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High-intensity laser for acupuncture-like stimulation

Received: 28 April 2006 / Revised: 20 July 2006 / Accepted: 4 September 2006 / Published online: 21 November 2006

Abstract The insertion of needles into specific parts of the body was shown to provide analgesic and therapeutic effects. In this study, we tested the analgesic effects of high-intensity infrared laser for acupuncture-like stimulation. Twelve adult Sprague–Dawley rats weighing 230 to 250 g were randomly assigned to laser, needle, or restraint groups. Stimulation was directed to the meridian point Taixi (KI 3) for 10 min. For laser stimulation, a pulsed Er:YAG system was used. The laser settings were adjusted to provide a focal raise in the skin temperature to about 45°C. The anti-nociceptive effect was evaluated by the tail-flick test. Both needling and laser stimulation significantly increased the tail-flick latency. Peak needling effect was observed immediately after treatment, while laser stimulation was effective both immediately and 45 min after treatment. High-intensity laser stimulation may be used alternatively or in combination with conventional acupuncture needling for pain relief.

Keywords Lasers · Acupuncture · Analgesia · Rats

Introduction

Acupuncture is one of the most widely spread components of the traditional Chinese medicine. It involves the stimulation of specific points of the body with fine needles. Such stimulation, according to traditional beliefs, would help reestablish the flow of the body's vital energy ("qi"), and by doing so, relieve pain and cure ailments. Laser acupuncture shares the same principles of the traditional acupuncture but uses low-level, non-thermal laser irradiation instead of needles [1]. Its development was probably inspired from low-level laser therapy, which is believed to stimulate wound healing and relieve pain.

Other than low-level laser irradiation, and of course the traditional mechanical stimulation of needles, many different kinds of stimulation were tried over acupuncture points. For instance, blunt pressure, heat, cold, electrical currents, and chemical agents [2–7]. Among all these forms of stimulation, heat has probably been one of the earliest, and may have even preceded that of needles [8]. From ancient textbooks, it is said that heat therapy would serve as an approach to supplement qi when it was considered depleted, while needling would drain qi when full [9]. Traditionally, heat was delivered by burning moxa wool over selected acupuncture points. Moxa is made of *Artemisia vulgaris*, an aromatic herb also known as mugwort. Moxa application can be either direct or indirect. When moxa is burned directly on the skin, two techniques may be followed: scarring and non-scarring [10]. In the scarring technique, burning moxa is placed on the acupuncture point continuously, causing a local burn with blister formation, which leads to healing with subsequent scar formation. In the non-scarring technique, the patient feels scorching heat but no blisters should be formed, and there is no scar formation. The non-scarring technique has actually a larger range of indications and is by far the most common form of heat therapy. Moxa is sometimes burned not directly on the skin, but indirectly over herbal patches, ginger slices, or mounds of salt, among others [10]. Some modern practitioners also use lamps and other heat sources instead of burning moxa.

Scientific assessment of the traditional techniques and their outcomes, particularly pain relief, has placed acupuncture among other physical therapies known clinically as counter-irritation [11, 12]. It is believed that local tissue damage from acupuncture-like stimulation would initiate a non-specific healing reaction with widespread effects throughout the body [13]. As such, twisting of connective tissues and nerve terminals with acupuncture needles [14], or extended cellular damage by the intense heat of the

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burning moxa would be essential to treatment success. Hence, traditional specialists believed that blistering the skin with the burning moxa was as important as achieving the "deqi" sensation with the needle [15], deqi being described by acupuncture patients as the sensation of radiating ache, soreness, and numbness at the needling site. However, modern treatments should be able to deliver sufficiently effective stimulation without causing serious burns or injuring the patient.

In this study, we used a high-intensity infrared laser as an alternative heat source. Our objectives were (1) to develop a safe and precise way of heat-stimulating acupuncture points and (2) to compare mechanical and thermal stimulation of an acupuncture point in producing anti-nociceptive effects.

Materials and methods

The methods described here follow the guidelines from the International Association for the Study of Pain (IASP) for the study of pain on conscious animals. The experimental protocol was reviewed and approved beforehand by the Animal Welfare Committee of Nagasaki University.

Experimental animals

We used male Sprague–Dawley rats weighing 230 to 250 g. The animals were acquired from Kyudo (Kumamoto, Japan) and brought into Nagasaki University's animal housing facility where the animals were allowed to acclimatize and habituate to the environment for about a week. During this period and during experimentation, the rats were kept in pairs in acrylic cages with soft bedding and food and water ad libitum. The room was temperature controlled (23±1°C) with a light/dark cycle of 12 h (lights on at 08:00). Experiments were performed during daytime hours. All animals were used only once and killed by barbiturate overdose (thiamylal sodium 160 mg/kg, i.p., Isozol, Yoshitomi, Osaka, Japan) immediately after experimentation.

Study protocol

The animals were assigned to either one of three groups: laser, needle, and restraint (n=8 in each group). All animals were subjected to 10 min of restraint in a cylindrical cage with adjustable diameter (Bowman-type restrainer). During restraint, animals in the laser group received high-intensity laser irradiation on a point equivalent to the Taixi in traditional acupuncture charts [10] (details about laser irradiation below). In the needle group, the animals received acupuncture needling on the same acupuncture point as the animals in the laser group. The acupuncture needle, a commercially available type (no. 3, Seirin, Shizuoka, Japan), was twisted half a turn back and forth once per second. Rats in the restraint group received no treatment, but had their paws randomly manipulated during restraint. The rats were submitted to the tail-flick test once before, and for several times on the 60 min after restraint.

Laser irradiation

We used a pulsed erbium YAG laser system (Dentlite, Hoya Photonics, Tokyo, Japan; wavelength 2.94 μm). The laser beam was focused by the use of a 60° contact tip, but applied at a 5-mm distance from the skin surface. Measured on thermal paper, the irradiated area had about 3 mm in diameter. The laser irradiation parameters were those necessary to increase the temperature of the skin surface to 45±1°C. These parameters were decided based on a pilot experiment where a thermocouple probe (IT-23, Physitemp Instruments, Clifton, NJ) was firmly attached to the skin in one lightly anesthetized rat (60 mg/kg i.p., Isozol, Yoshitomi Pharmaceutical, Osaka, Japan). The probe was connected to a thermometer (BAT-12, Physitemp Instruments, Clifton, NJ) for temperature reading. Then, several irradiation parameters were tested until the desired temperature was obtained. The final control panel settings were 65 mJ/pulse at 3 pulses per second.

Tail-flick test

For the tail-flick testing, the rats were placed and gently held on a testing machine (model 7360, Ugo Basile S.R.L., Comerio, Italy). This machine measures the time from the onset of a heat-stimulus directed to the rat's tail until the aversive reflex response occurs (in most instances a stereotyped flick of the tail). The result of each tail-flick testing was averaged from three consecutive trials. A 3-s interval was allowed between each trial, and each time the stimulus was directed to a different spot on the middle third of the rat's tail. To avoid excessive heating of the tail skin, a cutoff time was set at 20 s. Cutoff time was recorded on instances where no response occurred.

Data analysis

All data are displayed as the mean±SEM. Data from the three groups were compared in each time point by the non-parametric Kruskal–Wallis test. To assess the overall effect of each treatment, the data were plotted in a time course line graph, and the area under each curve (AUC) was calculated. The AUCs were also compared by the Kruskal–Wallis test. In both analyses, a $P<0.05$ was considered significant.

Results

The acupuncture point Taixi (KI 3) was transferred to the rat's anatomy, and located according to anatomical landmarks in the depression between the medial malleolus and the tendo calcaneus (Achilles' tendon). In the Sprague–Dawley rat, this is an area of hairy skin; however, the hair over the acupuncture point dried out and fell during the first seconds of laser irradiation. At the end of the 10-min laser irradiation, the skin was slightly red, but with no signs of severe burn or blister formation. Acupuncture needling was uneventful, despite the proximity to the relatively large posterior tibial artery and vein.

Before treatment, all rats showed a similar tail-flick latency of 4.9±0.2 s (Fig. 1). The tail-flick latency was longer immediately after treatment in all groups, but the mean latency in the laser and needle groups was significantly longer than in the restraint group. The average increase in response latency was about 2.2 times higher in the laser group and 2.9 times higher in the needle group than in the restraint group.

In the following 60 min of tail-flick testing, the average response latency remained higher in the needle group than in the restraint group, but without reaching statistical significance. However, in the laser group, another increase in the tail-flick latency was observed at 55 min (45 min after treatment). At 55 min, the tail-flick latency was significantly longer in the laser group than in the needle group or the restraint group (P=0.0011). The laser group had therefore two periods of anti-nociceptive action, one immediate, and another 45 min after treatment.

Comparing the area under the treatment curves in Fig. 2, we observed that both laser and needle groups had a significantly greater effect than the restraint group in increasing the tail-flick latency (Fig. 2). The AUC for the total 70-min observation period was 40.6% greater in the laser group and 26.6% greater in the needle group than in the restraint group. The laser treatment was more effective than the needle treatment in increasing the overall tail-flick latency, but the difference was not statistically significant.

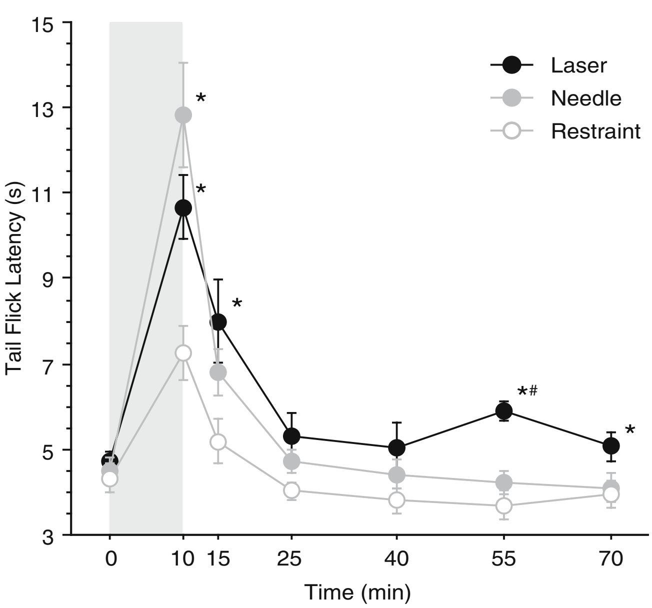

Fig. 1 Time course of anti-nociceptive effects measured by the response latency in the tail-flick test. The *shaded area* represents the treatment period. Treatment with high-intensity laser produced two distinct periods with increased response latency compared to needle or restraint only. *P<0.05 against the control (restraint group), and #P<0.05 against the needle group in the Kruskal–Wallis test

Discussion

In this study, we used an infrared laser as a heat source to stimulate acupuncture points. Infrared lasers, such as the CO_2 and the Neodymium YAG lasers, are often used for the neurophysiological evaluation of pain. In such studies, the painful sensation caused by the high-intensity heat of the laser beam is estimated by electroencephalography, and recorded responses are called laser-evoked potentials [16–19]. Presently, the kind of stimulation provided by these lasers is considered the closest one can get to the ideal painful stimulus, in that it is controllable, safe and reproducible [17]. It is also nociceptive-specific provided that only the laser beam, but not the tip of the laser device, touches the surface of the skin. In pain tests, very intense stimulation is applied with brief duration (few milliseconds) [19]. For the purpose of this study, however, a milder stimulation was used for a prolonged time (10 min). In addition, in this study a contact tip was used to focus the beam and reduce the irradiated area. However, although the beam diameter was estimated at 3 mm, because the laser beam was directed to the acupuncture point manually, the total irradiated surface was a circular area of about 5 mm in diameter. This form of irradiation was preferred over tight fixation, for the small movement of the irradiated surface may help minimize receptor fatigue and reduce habituation [19]. Applied to the very delicate skin of the albino rat, this stimulation produced erythema and charring of the hair on the irradiated area. The same stimulation, when applied to the experimenter's skin, resulted in mild erythema, which resolved in a few days.

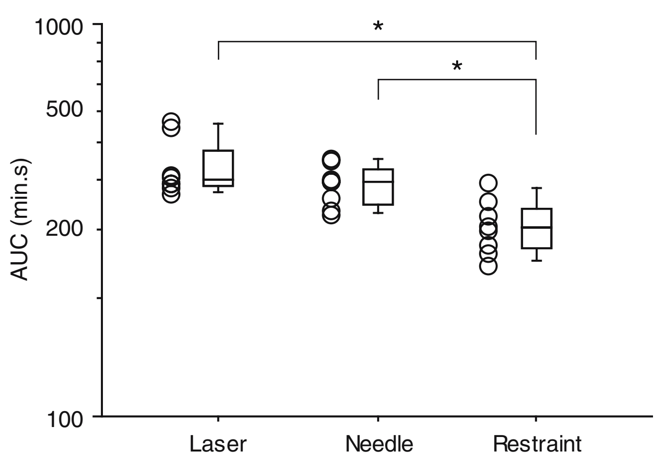

Fig. 2 Area under the curve (AUC) comparison between treatment groups. Either treatments with laser or needle held similar results regarding anti-nociceptive action. Both treatments were more effective than restraint only. *Box plot* shows the median values, the 25th and 75th percentiles (*box edges*), and the 10th and 90th percentiles (*whiskers*). *Circles* indicate individual data points. *P<0.05 in the Kruskal–Wallis test

At present, only low-intensity lasers are used in laser acupuncture [1]. Numerous positive applications for this kind of therapy have appeared. These include chronic hiccups (concomitant with needles and blunt pressure) [20], neurogenic pruritus [21], obesity (in combination with a low-calorie diet) [22], urinary incontinence [23], and postoperative nausea and vomiting [24]. Low-intensity lasers have the clear advantages of producing no skin trauma or pain; however, it is not clear if the stimulation of acupuncture points with low-intensity laser brings any pain relief [1]. One preliminary report indicates that non-thermal irradiation of an acupuncture point may have analgesic effects in rats [25]. On the other hand, it was long known that heterotopic painful thermal stimulation produces anti-nociceptive effects in both laboratory animals and humans [11, 26–28]. In normal human subjects, conditioning thermal stimulation above 44°C provides analgesic effects that last for several minutes after the stimulation is discontinued [27]. Likewise, the increase in tail-flick latency (i.e. increased tolerance to the noxious stimulus) observed in this study was possibly a result of the activation of endogenous anti-nociceptive systems produced by noxious stimulation. In addition, we may speculate that the second increase in the tail-flick latency observed 45 min after the high-intensity laser irradiation was an indirect effect caused by local inflammatory reaction. In the light of recent evidence [25], however, we cannot completely discard a possible non-thermal effect of the laser on the irradiated tissue in producing analgesia as well.

It is well-known that stress has analgesic effects on laboratory animals, a phenomenon called stress-induced analgesia, or SIA [29]. The restraint necessary for the laser and needle treatments certainly worked as a stressor, and for this reason an increase in the tail-flick latency was also observed in the restraint-only group. It is also worth mentioning that the stress response may have influenced the laser and needle treatments; nevertheless, the comparisons between different treatment groups are still valid because all animals in this study were subjected to the same stressors.

The acupuncture point used in this study is the one called Taixi, the third point in the kidney channel [10]. It is a relatively shallow acupuncture point located on the medial aspect of the foot. Its innervation is attributed to the medial crural cutaneous nerve, on the course of the tibial nerve. This point was selected because, among other indications, stimulation of the Taixi is used for the treatment of pain in the lower back. It is also a point where heat therapy is applicable [10]. Our results suggest that stimulation of the Taixi with high-intensity laser irradiation may produce anti-nociceptive effects; however, we may not indicate high-intensity laser irradiation as a replacement for the traditional heat therapy with burning moxa because some of the effects of the therapy with moxa may be attributed not only to the heat, but also to the contact with the herb itself or its burning smoke. Nevertheless, in this study, heat therapy with laser was as effective as needle therapy in producing anti-nociceptive effects; as such, heat therapy may be preferable, for heat stimulation (by high-intensity laser irradiation or other) is still less invasive than the mechanical stimulation of needles or other forms of stimulation used on acupuncture points. It is conceivable that both laser and needle treatments could have had an even greater effect if applied concomitantly; however, further studies are required to test whether these effects can actually be summated or not.

Acknowledgements This study was presented in part at the 11th World Congress on Pain (Sydney, Australia), 2005. It was supported by a grant-in-aid for Scientific Research from JSPS (No. P05242). KMS is a JSPS postdoctoral fellow.

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