Pneumatic Skin Flattening for Reducing Pain of Laser Hair Removal: A Pilot Study

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The pneumatic skin-flattening (PSF) device applies suction to the skin immediately prior to and during laser treatment, causing skin compression, thereby reducing the pain of laser treatment. In this pilot study, I report on a paired, controlled study using a commercial alexandrite laser with and without PSF to treat the axillae of adult female volunteers. Compared with conventional laser treatment using cryogen skin cooling, PSF reduced the pain of hair removal treatment in every study participant. Future studies using larger numbers of participants and different lasers should better quantify the pain reduction afforded by PSF as compared with conventional laser treatment, as well as the potential benefits of reduced adverse effects and improved efficacy associated with PSF.

Laser hair removal works by targeting the melanin pigment in hair shafts, heating the hair using a laser pulse in the millisecond domain. The result is an inflammatory response, which signals the hair to go into a dormant phase.[1-3] The terminal hair is shed during treatment or a few days later and is replaced with a vellous hair. Cooling devices are used to protect the epidermis and reduce the pain associated with treatment.[4-9] However, the sensation of pain associated with hair removal is immediate, often limiting the maximum amount of energy a patient will tolerate during treatment or resulting in discontinuation of treatment altogether.

One possible approach to the reduction of immediate acute pain is the application of a topical anesthetic to the treated area of the skin.[10-11] The main disadvantage of such an approach is the need to apply the analgesic cream some 30 to 60 minutes prior to beginning the treatment session, causing the patient inconvenience while offering only very moderate pain relief. In addition, applying a local, topical anesthetic cream, such as lidocaine, to large skin surface areas may result in excessive systemic absorption of the anesthetic agent, resulting in systemic toxicity.[12]

This article summarizes a pilot clinical study using a new pneumatic skin-flattening (PSF) device for the reduction of pain during laser treatments and other procedures. The device utilizes a thin evacuation chamber, which generates negative pressure on the surface of the skin, resulting in elevation and very tight flattening of the skin against a transparent sapphire window (Figures 1 and 2). The compressed skin presses on tactile and pressure neural receptors in the skin, resulting in an afferent inhibition of pain transmission in the dorsal horn.[13-16] Pain reduction produced by a sensation of pressure is explained by the gate control theory of pain reduction, first suggested by Melzack and Wall in 1962.[13,14] According to the gate control theory, nerve impulses from nociceptors (pain inputs) and their sensory fibers (slower and thinner A-*delta* or C fibers) arrive at synapses in the spinal cord on their way to the brain. Larger-diameter and faster-myelinated sensory neurons (A-*alpha* and A-*beta* fibers) carrying pressure and tactile information from the surrounding skin site activate secondary

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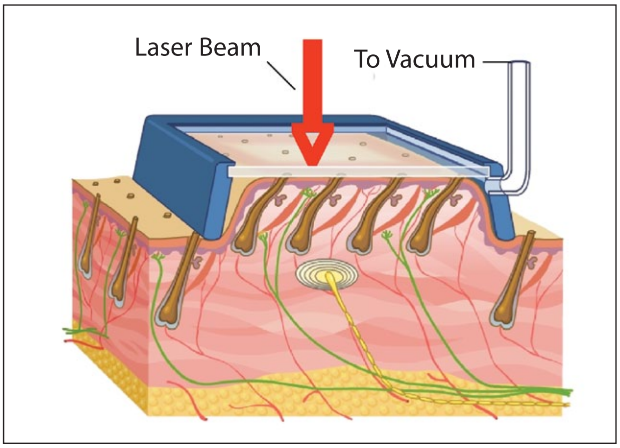

Figure 1. Schematic presentation of a pneumatic skin-flattening chamber.

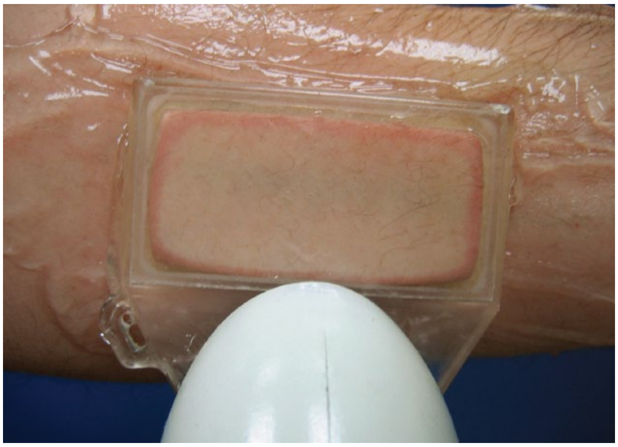

Figure 2. Skin compressed by a pneumatic skin-flattening chamber.

neurons, which secrete endogenous opioids into the pain synapse, thereby suppressing the flow of pain information to the brain (Figure 3).

Skin compression also expels blood from the treatment site, reducing the presence of hemoglobin, a competing chromophore to melanin, during laser hair removal. The elimination of hemoglobin from the light pathway reduces skin heating owing to the nontarget absorption of light, which should reduce adverse effects and improve efficacy. In this pilot study, I compare the level of pain experienced by patients during laser treatment of hair in the axillae using conventional laser treatment with dynamic skin cooling and the level of pain experienced by patients undergoing the same treatment with PSF.

MATERIALS AND METHODS

Patients

The axillae of 10 patients ranging in age from 24 to 47 years were treated, with one axilla receiving conventional laser treatment using dynamic skin cooling and the other axilla receiving conventional laser treatment using PSF without skin cooling. Both axillae were treated with the same long-pulse-duration alexandrite laser at identical fluences. Patients had Fitzpatrick skin types I through IV.

Laser and PSF

In this study, I used a 755-nm, 3-ms pulse-duration alexandrite laser, with treatment energies ranging from 14 J/cm^2 to 26 J/cm^2. An 18-mm diameter spot size was used for energies up to 20 J/cm^2 and a 15-mm-diameter spot size was used for energies greater than 20 J/cm^2. Identical laser treatment energies were used for both axillae in a given patient.

The PSF device is a 26×52-mm rectangular vacuum chamber, 7 mm in height and attached to a pump that removes air from the vacuum chamber, attaining a negative pressure of 600 millibars within less than 0.2 seconds following the placement of the chamber on the treatment site. The high vacuum ensures enhanced compression of the pressure receptors. Lask et al[16] showed that the compression level should be above 400 millibars. The vacuum chamber must be of adequate size to ensure activation of a large enough number of pressure receptors in the skin to activate gating in the dorsal horn, thereby reducing pain. The vacuum chamber is covered with a sapphire window, which can tolerate the high-energy densities generated by the laser.

Prior to placement of the chamber, a thin layer of ultrasound gel was applied to the skin to ensure lubrication and a firm seal. Three laser pulses were delivered during the 4-second suction time.

Data Collection

Pain evaluation was performed for all PSF-treated sites as well as for all control sites. Sites were randomized as to which axilla received treatment with the PSF device and which axilla received treatment using dynamic cooling. Pain evaluation was based on a modified Short-Form

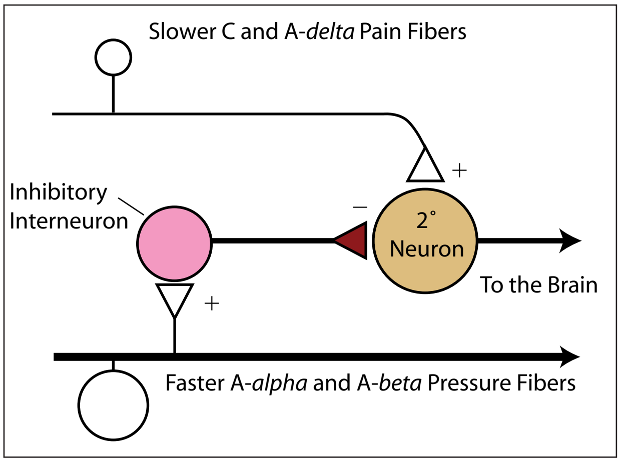

Figure 3. Operating principles of the gate control theory of pain.

McGill Pain Questionnaire, a commonly used tool to measure pain.[13-16] Patients graded pain according to a 10-point scale, with a score of 0 to 1 corresponding to barely feeling the treatment pulses, a score of 2 to 3 corresponding to feeling the treatment pulses but with little or no pain, a score of 4 to 5 corresponding to feeling mild and tolerable pain; a score of 6 to 7 corresponding to feeling acute but still tolerable pain, and a score of 8 to 10 corresponding to feeling intolerable pain.

RESULTS

Patients

The 10 patients ranged in age from 19 to 47 years (average age, 34 years). Fitzpatrick skin types ranged from I to IV, with 4 patients having skin type I, 4 patients having skin type II, 1 patient having skin type III, and 1 patient having skin type IV.

Laser Treatment

Laser fluences ranged from 14 to 26 J/cm^2 (average, 21 J/cm^2). Energies up to 20 J/cm^2 were delivered using an 18-mm-diameter spot, and fluences greater than 20 J/cm^2 were delivered with a 15-mm-diameter spot.

Pain of Treatment

The mean pain score for the axillae receiving laser treatment using PSF without any cooling was 1.5, with a range of 0 to 5. For these axillae, 3 patients reported a pain score of 0, four reported a pain score of 1, one reported a pain score of 2, one reported a pain score of 4, and one reported a pain score of 5.

In contrast, the average pain score for the axillae treated with dynamic cooling using a cryogen spray was 5.7 with a range of 3 to 8. For these axillae, one patient reported a pain score of 3, one reported a pain score of 4, two reported a pain score of 5, three reported a pain score of 6, two reported a pain score of 7, and one reported the highest pain score of 8.

DISCUSSION

In this pilot study, the PSF device reduced the pain associated with laser hair removal in a statistically significant manner. Every patient rated the axilla treated with the PSF device to be less painful than the axilla treated with the dynamic cooling device. The average reduction in the pain score was 4.2 points on a 10-point scale. Paired *t* test analysis showed the pain reduction afforded by PSF to be statistically significant at the $P<.001$ level.

Lask et al[16] reported substantial pain reduction when 500 mm Hg of negative pressure was applied with the PSF when using intense pulsed light, an 810-nm diode laser, and a 755-nm alexandrite laser to achieve hair removal. These authors also demonstrated decreased posttreatment erythema when using PSF and reported that PSF, in comparison with conventional treatment, resulted in equivalent or greater hair removal.

The decrease in pain following laser treatment using PSF is thought to result from the overall reduction in pain sensation (the gate control theory) caused by the pressure sensation produced by the PSF device and possibly from the decrease in erythema that occurs with skin compression.[16] The reduction of blood in the compressed skin as a competing chromophore to melanin may also be a significant factor in reducing pain. The contribution to pain reduction provided by compressing the skin and reducing hemoglobin absorption is supported by a decrease in posttreatment erythema, demonstrating a decrease in the overall inflammatory response in skin treated with the PSF device. The fact that other similar methods of pain reduction work, such as devices that use vibration to "compete" with pain and thereby reduce the sensation of pain felt during a procedure,[15] speaks to the ability of pressure, as explained by the gate control theory, to have an effect on cutaneous pain sensation. The relative contribution of pressure or compression of cutaneous blood vessels can be studied by comparing wavelengths that are strongly absorbed by hemoglobin with those that are not when using PSF in association with laser treatments.

The current study demonstrates that PSF used in conjunction with the long-pulse-duration alexandrite laser reduces the pain associated with laser treatment. Others have suggested that PSF reduces posttreatment erythema and may improve the efficacy of laser hair removal treatments.[16] Future studies to quantify posttreatment erythema and compare the degree of hair reduction with and without PSF should further delineate the role for PSF in laser treatment and its mechanisms of action. This device is currently being investigated for its ability to reduce pain associated with other laser treatments, including the treatment of pigmented lesions, vascular lesions, and tattoos.

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