# Photobiomodulation of Surgical Wound Dehiscence in a Diabetic Individual by Low-Level Laser Therapy Following Median Sternotomy

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## ABSTRACT

In this single case study, we attempt to outline the possible effect of low-level laser therapy (LLLT) on delayed wound healing and pain in chronic dehiscent sternotomy of a diabetic individual. The methods that were employed to evaluate changes pre and post irradiation were wound photography, wound area measurement, pressure ulcer scale of healing (PUSH), and visual analogue scale (VAS) for pain. After irradiation, proliferation of healthy granulation tissue was observed with decrease in scores of PUSH for sternal dehiscence and VAS for bilateral shoulders and sternal dehiscence. We found that LLLT irradiation could be a novel method of treatment for chronic sternal dehiscence following coronary artery bypass grafting, as it augments wound healing with an early closure of the wound deficit. Hence, this might be translated into an early functional rehabilitation and decreased pain perception of an individual following surgical complication.

**Key words:** Low-level laser, Median sternotomy, Pain, Wound healing

## INTRODUCTION

Any disease process in general, and life-threatening ones in particular, can cause different kinds of sufferings. These sufferings particularly disrupt the quality of life of a person due to pain and reduced functional mobility which involves physical, psychological, and spiritual dimensions of an individual.[1]

Sternal wound healing complications vary from superficial skin infections to sternal instability (SI) and mediastinitis.[2] SI is defined as any abnormal motion that exists between the surgically separated sternum, either because of the bone fracture or due to disruption of wires that unite the sternum.[2] Coronary artery bypass grafting (CABG) usually encounters surgical wound dehiscence as a serious complication. Clinically, it appears as a mechanical failure of the sternum at the surgical incision due to impaired wound healing.[3] Wound breakdown is a serious complication in median sternotomy and is generally managed with surgical sutures using monofilament surgical steel, following soft tissue debridement and closed irrigation. However, this has considerably higher rates of failure.[3,4]

Moreover, psychological aspect of pain can also influence healing of chronic dehiscent wounds. Psychological symptoms [e.g., depression, anxiety, and ways of being (decreased functional ability, perceived locus of control, and self-efficacy)] affect the perception and experience of pain. Psychological factors related to pain in palliative care of chronic wounds can become an influential factor for healing by secondary or primary intention.[5]

A noninvasive treatment, which helps in wound closure by secondary intention, has been raising interest in

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medicine and related areas, is low-level laser therapy (LLLT) or simply "laser therapy." The mechanism of action of laser on wound healing is postulated as modulation of inflammation by reducing the levels of proinflammatory cytokines and increasing the levels of anti-inflammatory growth factors.[6,7]

Our objective was to observe the effect of LLLT irradiation on pain and wound healing of postoperative sternal dehiscence as a possible or an alternative therapy in chronic sternal wound management in a diabetic individual, who had undergone CABG using internal mammary artery and saphenous vein graft.

## CASE REPORT

A 48-year-old male presented with the history of coronary artery (triple vessel) disease, type 2 diabetes, hypertension, ischemic heart disease, moderate pulmonary hypertension, and moderate left ventricular systolic dysfunction. CABG was done using three grafts from the saphenous vein, the right and left internal mammary artery with a cardiopulmonary bypass of 127 min. The individual was discharged from the hospital after the 20$^{th}$ postoperative day with an ejection fraction of 39%. On 58$^{th}$ postoperative day, there was a yellowish pus discharge from the surgical wound and pain in both the shoulders. Visual analogue scale (VAS) for pain in the surgical wound and shoulders was 4 and 6, respectively. The wound was surgically explored revealing a length of 21 cm and width of 2 cm for the dehiscence. The wound was classified as stage III wound with sloughing, pressure ulcer scale of healing (PUSH) score of 13 before the commencement of laser therapy. The individual had a New York Heart Association functional classification of III during the treatment sessions.

### Investigations

Investigations before the commencement of the therapy were as follows: Hemoglobin – 8.2 g/dL, platelet count – 461 × $10^3$/μL (microliter), erythrocyte sedimentation rate – 140 mm/h; total white blood cells – 11400/μL (microliter), C-reactive protein 36 mg/L, blood urea – 65 mg%, serum creatinine – 1.1 mg/dL, serum potassium 4.5 mEq/L. The individual had a fasting glucose of 115 mg/dL. Moderate growth of gram negative pseudomonas aeruginosa was isolated from a wound swab that was found to be resistant to penicillinase, aminopenicillins, and extended-spectrum penicillin.

### Treatment

The individual was on linezolid (600 mg), antiplatelet therapy (aspirin and clopidogrel, 75 mg), atorvastatin, antiarrhythmic agents, furosemide (loop diuretics), isosorbide mononitrate (vasodilators), and beta blockers. For the management of diabetes, a combination of short acting (15 units) and intermediate acting insulin (5 units) was administered daily, during the treatment session. When no significant healing of the wound was noticed in spite of daily dressing, frequent debridement and standard medical care, on the 70$^{th}$ postoperative day (about 2 weeks after the wound dehiscence was noticed), the individual was counselled regarding the nature of treatment with LLLT. LLLT irradiations commenced on 71$^{st}$ postoperative day after the sutures were removed. The individual was evaluated for any possible absolute and relative contraindications with laser therapy at baseline. Before undergoing the irradiation with laser, a written informed consent was obtained.

The accuracy for output dosage of the laser machine was tested prior to irradiation using specialized photodiode equipment (dosimeter). After deciding the parameters, the individual was asked to wear wavelength-specific goggles throughout the treatment sessions to obviate any risk of accidental application into the eye. The subject was comfortably placed in a semireclining position with his back and spine well-supported. Before beginning with the irradiation, the surrounding skin surface along the surgical incision was cleaned to enhance the absorption of laser in the wound area. The frequency of the irradiation was kept to once a day for 5 days till 2 weeks.

A handheld class 4 light-emitting diodes (LEDs) (gallium aluminum arsenide) was used at a distance of 1 cm from the surgical incision. The probe was a collection of 69 such LEDs, of which 34 LEDs of 660 nm had a spectral width of 50 nm at a 50% intensity, an average power of 10 mW, a spot size of 0.2 cm$^2$ and a power density (irradiance) of 50 mW/cm$^2$. The remaining 35 LEDs were of 950 nm wavelength with a spectral width of 50 nm at 50% intensity, generating a total power of 865 mW and a frequency of 156 Hz. For the sternal wound, an energy density of 14 J/cm$^2$ was used for 700 s/session per day and for each shoulder single point was irradiated, anterolaterally with an analgesic dosage of 4 J/cm$^2$ for 240 s/session per day.

### Outcome and follow-up

The PUSH score became 12 and then 9 on the 8$^{th}$ and the 11$^{th}$ days of the irradiation, respectively. The length

of the wound remained 21 cm but the breadth decreased to 0.5 cm [Figures 1 and 2], and proliferation of healthy granulation tissue filling up the wound deficit was observed on 11th day of irradiation. The VAS score became 2 for the shoulder joints but remained 4 for the surgical incision on the 11th day of the irradiation [Figures 3 and 4, approximately 82nd day postoperatively].

## DISCUSSION

In CABG, the mechanical retraction of sternal halves in order to have an adequate view of the surgical area, causes excessive strain and compromises the anatomy of chest, back, shoulder, and neck.[2] For the concerned individual in the study, separation was observed along the entire sternum. This abnormality might have resulted in excessive sternal movement, pain in the shoulders, and difficulty in performing functional tasks. Moreover, in a review Chang, *et al*.,[5] outlined how depressions, decreased functional ability, perceived locus of control, self-efficacy, and personal trauma histories have an inextricably woven relationship with perception of pain.

We may now be able to postulate from the available evidence that interaction of physical and psychological factors can affect wound healing. Furthermore, it may also have contributed to delay in sternal wound healing. Sushma, *et al*.,[8] had reported sternal dehiscence to be a common complication among Indians, with an incidence of 4.5% post-CABG.

The combination of primary and secondary risk factors increases the chance of postoperative sternal wound complications in CABG.[2-6] In this case study, we found a number of primary risk factors contributing to dehiscence, as the individual had a history of coronary artery (triple vessel) disease with internal mammary artery grafting, prolonged duration of cardiopulmonary bypass surgery, and an increased blood loss during the surgery. In addition, individual also had type 2 diabetes mellitus, hypertension, moderate pulmonary artery hypertension, and moderate left ventricular systolic dysfunction. Personal history of chronic alcoholism, secondary risk factors like increased prothrombin time (25 s), had made

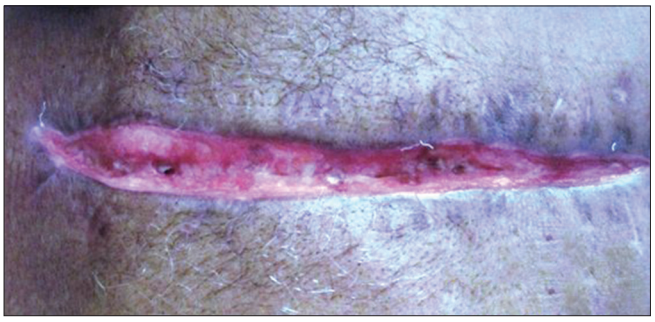

**Figure 1:** A sternal wound area of 21×2 cm seen before the commencement of laser therapy

**Figure 2:** Closure of dehiscence area with decrease in wound surface to 21×0.5 cm after irradiation with laser

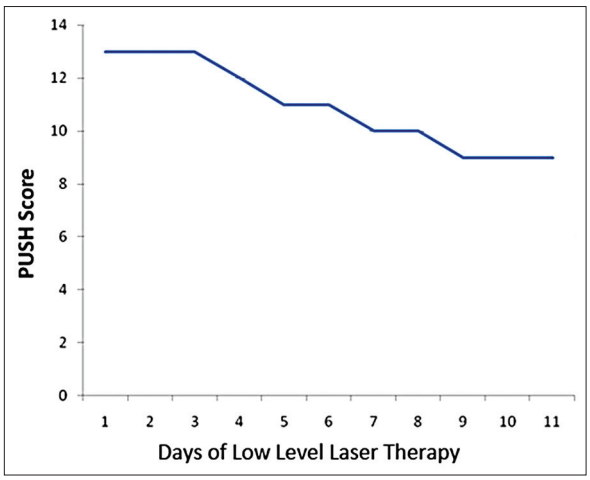


**Figure 3:** A gradual decrease in pressure ulcer scale of healing score after irradiation for 1 week, 11th day of irradiation with laser shows the lowest scores

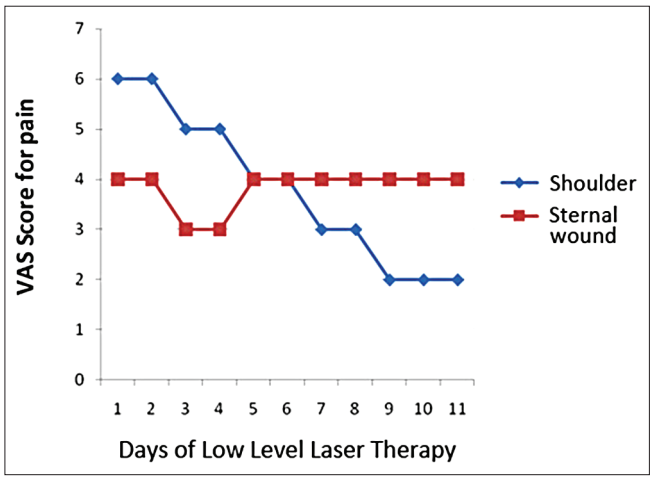


**Figure 4:** Blue and red lines represent shoulder and sternal visual analogue scale, respectively. VAS for shoulder pain declined to a score of 2 on 11th day of irradiation with laser

the situation more complicated, possibly increasing the likelihood of morbidity during the healing process, resulting in dehiscence.

Delayed wound healing is a complex situation, and irradiation with laser therapy involves stimulation of certain growth factors and cytokines that orchestrate various stages of wound healing, resulting in an accelerated resurfacing of wounds (re-epithelization), and filling up of the wound area by granulation tissue.[7] In the present case study, LLLT facilitated wound closure by photobiomodulation. LEDs were used that are postulated to generate both red and infrared laser radiations causing reduction in inflammation, increase blood flow to the tissues leading to the proliferation of endothelial cells thereby increasing the formation of new blood capillaries within the damaged tissues.[7,9]

The concept of physical rehabilitation is gaining increasing attention in palliative care individuals. The goal of rehabilitation in the palliative care patient is to eliminate or reduce disability by optimizing functional status, physical independence, and quality of life through appropriate treatment.[10] The use of rehabilitation in palliative care should be individualized and account for the overall life expectancy and the individual's desire to actively participate in therapy. While rehabilitation is widely clinically accepted as an adjuvant therapy in any kind of pain management, physical therapists are usually limited to the use of thermal therapy (heat, cold, and ultrasound), transcutaneous electrical nerve stimulation for the management of surgical pain.[10] While the concept of LLLT irradiation is a novel technique which can play a pivotal role in the management of pain and closure of chronic nonhealing ulcers. Thereby, leading to an early functional mobilization and hence promoting overall well-being of an individual.

Though in LLLT, a significant difference exists between lasers and LEDs in the way light energy is delivered (optical power output), LEDs provide a gentler delivery of the same wavelength of light compared to other lasers. The LED also has an advantage of different wavelengths being combined together to ensue delayed wound healing.[11] However, efficacy of LED in wound healing can be undermined as LED has increased light transmission to the target tissue when the LED is in contact with the skin that might be questionable in individuals with chronic wounds. Another concern with LED is that the absolute transmission depth of irradiation cannot be determined. Moreover, very precise adjustments of irradiation parameters to human physical characteristics are required prior to therapy for optimal beam delivery to the target tissue for attaining maximum physiological effects.[12]

However, in a systematic review by Peplow, *et al.*, the authors posit LLLT irradiation to regulate the formation of nitric oxide synthase leading to increased production of nitric oxide – which is known for its anti-inflammatory, antithrombotic effects in wound healing.[5] We found that LLLT application also produced analgesia for the bilateral shoulders, as is also claimed by Peplow *et al.*, in a review.[5] A possible mechanism for it could be increased blood flow after irradiation leading to resolution of inflammatory response in the shoulder joints.

## CONCLUSION

Laser therapy induces biomodulation of dehiscence sternal wound following median sternotomy in CABG. Laser therapy may be heralded as a potential new method for noninvasive, effective, and safe wound care in postoperative dehiscent wound. Analgesic effect of laser therapy may be incorporated for early rehabilitation for painful shoulders following mechanical failure of sternum postoperatively in CABG. This can contribute to early functional rehabilitation of an individual thereby promoting improved quality of life in individuals postoperatively.

Though, we have outlined the merits of LLLT in this single case study, a more rigorously controlled study design using LLLT is required to provide conclusive evidence for a potentially important role of LLLT in sternal wound healing.

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