PHOTOTREATMENT OF RADIATION-INDUCED DERMAL INJURIES

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SUMMARY

Phototherapy develops on the experimental observation of general and considerable improvements of a lot of pathologies by the action of exposition to the optical radiation, especially visible and infrared. Recently the exposition to Polarized Polychromatic Incoherent Light Low Energy Radiation (PILER) (400 ≤ λ ≤ 2000 nm) demonstrates high biological efficacy, safety for patient and, moreover, it is low cost. This work shows first results about the phototreatment of chronic radiation-induced dermal injuries at the left hand of an orthopaedist. Irradiation dose was 40 mW/cm^2 by a source of polarized polychromatic incoherent light (Bioptron: 400 ≤ λ ≤ 2000 nm). After a year considerable improvements were observed but, in order to support this result and to avoid fresh outbreak, it is important to continue the phototreatment regularly. The AA believe this therapy has not collateral effects and it is possible a domiciliary employ.

KEY WORDS: Phototreatment, radiation, dermal injuries

INTRODUCTION

The oldest form of phototherapy, heliotherapy, was born from the observation of appreciable and vast improvements of several human pathologies thanks to exposure to solar radiation. The simple exposure to solar rays for therapeutic purposes was used by Romans, Arabs and Egyptians. However, in ancient times man certainly attributed to the sun thaumaturgical powers to the point that it was considered a divinity.

Over the centuries, scientific discoveries allowed for the putting of sunlight within a spectrum of electromagnetic radiation bands and the better understanding of physiological action mechanisms. Only during the first years of the last century did the Dane Niels Ryberg Finsen, who won the Nobel Prize in 1903, invent a machine capable of reproducing both sunlight and the optic radiation contained in it\(^a\). This machine enabled a specific use and repeated treatments in biological and medical field.

LA FOTOTERAPIA NASCE DALL’OSSERVAZIONE Sperimentale di Apprezzabili e Generalizzati Miglioramenti su Diverse Patologie Indotte a Seguito di Esposizione a Radiazioni Ottiche, in Particolare nel Visibile e nell’Infrarosso. In Tempi Relativamente Recenti l’Applicazione di Luce Incoerente Policromatica Polarizzata (PILER, Polarized Polychromatic Incoherent Low Energy Radiation) (400 ≤ λ ≤ 2000 nm) Oltre a Presentare un’ Elevata Efficacia Biologica Sì È Dimostrata di Facile Utilizzo, Senza Rischi per il Paziente e di Basso Costo. In Questo Lavoro Vengono Presentati i Risultati Preliminari del Trattamento della Radiodermite di Tipo Cronico Evolutivo Localizzata alla Mano Sinistra di un Paziente con Pregressa Attività di Medico Ortopedico. La Mano del Paziente viene Irradiata con una Sorgente di Luce Policromatica Incoerente Polarizzata (400 ≤ λ ≤ 2000 nm) (Bioptron), con Densità di Potenza di 40 mW/cm\(^2\).

Tale Tipo di Trattamento deve Protrarsi Almeno un Anno per Osservare Apprezzabili Miglioramenti e Deve Essere Mante- nuto con Costanza nel Tempo per Evitare una Ricomparsa delle Alterazioni Cutanee. In Considerazione dei Promettenti Risultati Osservati in Tempi Relativamente Brevi Rispetto alla Difficoltà di Guarigione Insita nel Tipo Stesso di Patologia, della Semplicità del Trattamento Privo di Qualunque Effetto Collaterale che lo Rende Gradito al Paziente, del Fatto non Trascurabile che l’Irraggiamento Posso Essere Effettuato anche a Domicilio o Ambulatorialmente, Riteniamo che la PILER possa Proporsi come Soluzione Validà per il Trattamento delle Patologie Cutanee in Soggetti che Svolgono Attività Interventistica con Impiego di Sorgenti di Radiazioni Ionizzanti.

Riassunto: Fototerapia, radiodermite cronica

Słowa kluczowe: Fototerapia, radioterapia, obrażenia skórne

Over the centuries, scientific discoveries allowed for the putting of sunlight within a spectrum of electromagnetic radiation bands and the better understanding of physiological action mechanisms. Only during the first years of the last century did the Dane Niels Ryberg Finsen, who won the Nobel Prize in 1903, invent a machine capable of reproducing both sunlight and the optic radiation contained in it\(^a\). This machine enabled a specific use and repeated treatments in biological and medical field.
Before understanding that the exposure to the electromagnetic radiation contained in the solar spectrum could provoke harmful effects on the human body much research had to be carried out. In fact, during the 1930s and 1940s, doctors promoted sunbathing since it were considered to give benefits to children’s health. However, a subsequent increase in skin melanoma pushed focus on the role played by ultraviolet rays on the onset of this pathology. The controlled exposure to both ultraviolet radiation and blue light was used, with satisfying results, in therapeutic treatments of psoriasis and newborn jaundice.

Thanks to the research of the Hungarian Mester in 1966 in phototherapy a low power source of monochromatic coherent light (LASER) was created. This allowed deep work in the biological field with optic radiation selected in the visible or infrared, obtaining interesting cellular biochemical results.

Later, polarization was added to laser light by a Hungarian research group which showed itself to be equally effective for biological and therapeutic effects.

During relatively recent times, the experimental, but not limited to, application of incoherent polychromatic polarized light (PILER - Polarized Polychromatic Incoherent Low Energy Radiation) showed not only an equal biological efficacy which equaled that of the low power polarized laser, but showed itself to be easy to use, without risks for the patient and at low cost.

Even if interesting uses of phototherapy both LASER and PILER have been experimented in orthopedic and psychiatric fields dermatology remains the main applicable area for the treatment of some skin pathologies and ulcers.

In this work the Authors present the results obtained after the application of a protocol to treat a patient with PILER light who suffered from localized chronic and evolutionary radiodermatitis on the left hand; refractory to complete healing despite previous surgical and pharmacological treatments.

**Materials and methods**

**Radiodermatitis**

Chronic radiodermatitis is a skin disease that especially afflicts those workers who have exposed their hands to ionizing radiations released by radiodiagnostic machines.

In particular, pediatricians who held children during radiological tests or doctors specialized in trauma who treated fractures thanks to the help of X-ray radioscopy during the '50s and '60s have been stricken.

Currently, the disease is found with ever lower incidence due to better knowledge about protection and the use of equipment with better systems of radiation protection.

The etiology of chronic radiodermatitis has several competing factors: the type of equipment and radiation used, the length of exposure, the geometry and distribution of the radioactive beam, the number of exposures, etc.

The hands constitute the selective localization of chronic radiodermatitis, in particular the left hand in traumatology because of the position assumed during manipulation.

The fingers most affected were, in general, the index, middle and ring on the dorsal and medial faces.

The treatment of radiodermatitis, which can be classified into chronic simple, evolutionary and cancerized, is intended to control the disease and requires a complex therapeutic approach, almost always directed towards interventions, be they surgical, radiation-based, or lymphatic, without definitive results. It is difficult to have a spontaneous remission in any of the three chronic phases.

The type of radiodermatitis which was the object of the present study was of the evolutionary, with dead tissue, bleeding ulcers, painful movement and contact with chemical agents, even those of normal daily use.

**Clinical history of the patient**

The patient, a trauma surgeon, had the greatest exposure to X-rays in a period that ranged from 1958 to 1968, after a latency period of three years, lesions began to appear on the left hand, initially on the back of the index finger, corresponding to the second and third finger bones and, successively, on the medial face of the index and middle fingers, with the emergence of onychodystrophy on the index finger to the middle of the ring finger.

The skin degeneration caused significant functional impairment, as to prevent the closure of the fist due to stiffness and the phalanx of the left index finger. Once ulcerations began, induced as a result of simple subliminal trauma or the use of soaps and other inevitably aggressive substances, given the...
surgical activities of the subject, necessitated the transplant of autologous skin cells; the new skin did not show any signs, and a histological examination resulted in the diagnosis of chronic radiodermatitis without neoplastic degeneration.

Despite the success of the transplant, after about a year, a partial erosion of transplanted skin began, with the appearance of ulcerative lesions and bleeding in the dorsal region of the middle finger (Fig. 1) and partial invasion of the dorsal and medial region of the index finger in correspondence to the second phalanx (Fig 2).

All topical pharmacological treatments did not prevent new ulcerations: the inevitable result was the impossibility of the patient to continue in his professional activities.

**Time and place of irradiation**

The radiation was done for 6 minutes on the back of the left hand, for three minutes on the right side of the left index finger and for another 3 minutes on the right side of the left middle finger. Care was taken that the distance from the skin from the lens of the lamp was 15 cm.

Before the irradiation proceeded, as according to the instructions from Bioptron to moisten the surface for radiation with a spray containing water mixed with oxygen supplied by Bioptron was done. Doses were given once a day for two days a week for the first two months, and thereafter once a week for about a year. The patient did not take any other pharmacological or topical treatment during the course of the phototherapy.

**Application of the DASH questionnaire**

For the purposes of an objective assessment, before, during and after the treatment, the Italian version of DASH (Disability of the Arm, Shoulder and Hand) questionnaire was given to the patient\(^{16}\).

**Results**

The first functional and skin improvements were seen by the patient two months after the application of PILER, so he decided not to undergo another intervention such as a skin transplant, as had been proposed after the reappearance of injuries and to continue, instead, with radiation.

The skin improvements, slow but steady, were such that, at a distance of about one year, a clear improvement in the skin of the fingers with the disappearance of ulcers and bleeding, almost a complete collapse of dead tissue, restructuring of the smooth, rosy skin, and an improvement in onychodystrophy has been observed (Fig. 3).

The objective evaluation of the functional improvements was supported by the results of the scores of responses to the patient DASH questionnaire administered at different times during treatment as evidenced by the graph attached (Fig. 4).

Indeed, the pain at movement and bending of the fingers is progressively decreasing with a comparative improvement in the quality of life of the patient.
The cell is surrounded by an external plasma membrane made of a layer of lipids and protein molecules which act in the mediation and regulation of the exchange with the external environment between the cell and the surrounding tissue. The state of the health of the cell depends, therefore, on the correction function of the mediator of its membrane. A disturbance in this function, which occurs when the polar extremities and lipid membrane are no longer aligned properly, leads to a malfunction of membrane channels, of the lipids and their receptors responsible for supplying the cell with energy and nutrients. This malfunction, in turn, influences the activity of the respiratory chain of the cell with a consequent reduction in the amount of ATP needed to stimulate chemical processes.

Exciting a solution of biomolecules with polarized light, coherent or incoherent, operate in such a way that among all the dipole chromophores linked to biomolecules present select those whose component parallel to the plane of polarization of light is greater. Consequently, through chromophores, energy consumption, in the visible and/or in the infrared, is transferred to the constituents of tissues and various metabolic processes and functions. In this way, the enzymes and their receptors can resume their metabolic activity, the mitochondria produce new ATP: the cell is reactivated and its potential restored to the levels of a healthy cell. The information stored in the DNA is again accessible and regenerative processes are revived.

Numerous studies have demonstrated how the cellular rebalancing of the portion of the skin with lesions becomes healthy through the endogenous restoration capacity from the migration of macrophages which assist the granulocytes in their phagocytical activities, allowing the elimination of waste and bacteria and releasing messenger substances; those substances, in turn, control the proliferation and function of various cells such as connective tissue (fibroblasts), skin (keratinocytes) and vascular cells (endothelial cells).

In addition, the macrophages secrete cellular growth hormones particularly active in healing process such as bFGF (Fibroblastic Growth Factor), EGF (Epidermal Growth Factor) and the TNF-alpha (Tumor Necrosis Factor alpha). The growth hormones, in turn, stimulate cell proliferation of fibroblasts and epithelial cells, and ensure the formation of new vessels. The metabolic improvement demonstrated, even in distant locations from where the polarized light was shone, can therefore be attributed to the involvement of growth agents across the system of circulation.

The healing lesions, thanks to the reactivation of blood circulation and lymphatic drainage, encourage the downsizing of the edema and an enhanced immune response. Overall, one gets an improvement of physiological processes relating to the granulation phase of reepithelialization of the skin.

In view of the above AA. consider that the healing of the patient’s skin lesions, that from the
initial state, involved the skin and the underlying dermis, are attributable to the ability of PILER to reach the germinal layer and stimulate activity damaged by ionizing radiation through the humoral mechanisms and energy above\(^8\,^{23}\).

The AA., in addition, through the development of DASH questionnaires on three different stages of treatment (initial, intermediate and final) were able to highlight a marked improvement in functionality of the patient’s hand (Fig. 5), certainly correlate to an improvement in the underlying physiology of the skin areas concerned.

Although the energy density of the source PILER (Bioptron) and 2.4 J/cm\(^2\), is a low energy density compared to other treatments carried out by other AA.\(^6\,^{11}\,^{12}\,^{20}\) has, however, proved largely to possess the same, intense effects of biostimulation, obtained with the laser at low power, against many intracellular biological processes, but without having the risk, invasiveness, need to adopt the related safety standards, in addition to a larger area of application, greater ease of use and displacement which allows use of outpatient and at home.

The greater acceptance by the patient to undergo PILER therapy for the lack of side effects and invasiveness compared to traditional therapies for radiodermatitis cannot be overlooked.

The AA must stress that this type of treatment with PILER must be consistently maintained over time in order to avoid a recurrence of skin alterations.

Conclusions

In view of the above and the net improvements achieved in a relatively short time in respect to the difficulty of healing inherent in the same type of pathology the AA considers that PILER can act as a viable option for the treatment of skin diseases in people who engage in interventional activities using sources of ionizing radiation\(^9\).

Bibliografia

1) Bioptron light Therapy, Bioptron AG, Munchaltorf, 1997, 55.


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