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Infrared Light as Intervention to Improve Peripheral Sensation in an Individual Suffering from Peripheral Neuropathy: A Case Report

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Abstract:: We describe a treatment for patients suffering from peripheral neuropathy. Current treatment is focused on prevention of adverse outcomes, rather than addressing the associated circulatory and sensory deficits common to peripheral neuropathy. We describe the use of near-IR light to address the patient's sensory loss, pain and lowered function.

A 62 year old Caucasian male diagnosed as Type II diabetic was treated in this study. Using the Semmes Weinstein Monfilament Test, the Visual Analog Pain Scale and the Foot Function Index, he was found to have decreased foot sensation, pain and decreased lower extremity function. He received near-IR at 12 J/cm2 per treatment location, 3 times per week for 6 weeks. The light treatment was administered using a hand held probe over the lumbosacral spinal roots paravertebrally and on six locations on each foot. Post testing showed marked improvement in all three areas measured. These improvements were clinically significant based on the established minimally clinically important difference values for each of the three measures.

The results suggest that near-IR energy may be an effective intervention to decrease pain, improve function, and increase sensation in individuals suffering from peripheral neuropathy. Basic research suggests that near-IR may increase blood flow. This result is believed to be achieved as a result of the relationship near-IR has with nitric oxide. Additional research is needed to establish the efficacy and generalizability of this treatment for patient populations similar to the patient represented in this case report.

Key words: Near-IR, Peripheral Neuropathy, Photomodulation

1. Introduction

Peripheral nerves serve different motor, sensory, and autonomic functions [1]. Distally located neuropathic symptoms (tingling, pain, loss of protective sensation) may present when damage or injury to these peripheral nerves occurs. Individuals who experience these neuropathic symptoms as a result of peripheral nerve injury are diagnosed with a condition known as peripheral neuropathy (PN).

There are over one hundred known causes of PN; trauma, diabetes mellitus, arthritis, lupus, Lyme's disease, alcoholism, viral infections, nerve compression, exposure to poisons or medicines, and a lack of vitamin B12 or certain minerals are all precipitators of the condition [2],[3]. Often the most debilitating symptoms related to peripheral nerve

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damage are the loss of distal reflexes and a decrease in distal sensation [2].

Decreased reflex loop conduction and diminished peripheral sensation (touch, temperature, and proprioception) can result in joint deformities, ulcer formation and falls. The incidence of joint deformities (neuropathic arthropathy) in those with PN may be high as 29% [4]. These deformities and other integumentary complications result in an 8% increase in the risk of ulcer formation [5]. Decreases in reflexes and peripheral sensation contribute to an increased fall risk. MacGilchrist et al. [6] concluded that 86% of those who have frequent falls have impaired peripheral sensation. Additionally, complications associated with PN may lead to amputation. There are over 185,000 amputations in the U.S. each year, and 54% of them are the result of conditions such as PN [7].

PN affects nearly 20 million people (6% of the total population) in the U.S. with a prevalence as high as 2.4% [2],[8]. Despite these high numbers no treatment or intervention has been found to effectively address peripheral sensation loss associated with PN [9],[10],[11]. Current management of PN focuses on the identification of those at high risk of adverse events rather than the correction of the deficit. Interventions that are commonly employed include patient education, prescribing accommodative risk-reduction strategies, frequent provider visits for monitoring, and the use of orthotic devices. These interventions demonstrate sporadic success [12]. Such interventions have not been shown to improve sensation. Increase in blood flow to areas

where neuropathy exists has the greatest effect on sensation improvement [10].

Improved peripheral sensation, if it can be achieved, is expected to reduce adverse events such as joint deformities, ulcer formation, falls, and amputation. Such adverse events occur when an individual has lost the ability to sense and to respond to stimuli in a protective fashion [13].

The gold standard for objectively measuring peripheral sensation is the Semmes Weinstein Monofilament (SWM) test. In the SWM test varying thicknesses of nylon monofilaments are applied to pre-determined areas of the LE (foot). In each area the minimal thickness of the monofilament that can be sensed is recorded. The Center for Medicare and Medicaid Services (CMS) has determined that insensitivity to the 5.07 SWM gauge monofilament in at least 2 of 5 testing areas on either foot is considered to be loss of protective sensation [14]. Fifty percent of those suffering from PN do not have protective sensation [15].

The delivery of infrared light energy– a therapeutic modality – may increase peripheral circulation [16]. The FDA approved the use of this modality in 1994 [17]. Recently, the delivery of infrared light energy and similar light energy techniques has been part of ongoing research to improve peripheral sensation associated with PN [17].

Collectively, the studies related to light energies have produced varying results. In a study performed by Kochman, Carnegie and Burke [18], the application of infrared light energy produced improved peripheral sensation in 100% of the participants after 12 treatments sessions. In contrast, a study performed by Clifft, Kasser, Newton and Bush [17] produced results that showed no more improvement in peripheral sensation in those that received infrared light energy compared to a control group who received a sham (placebo) treatment.

Many of the studies exhibit large amounts of variability and lack uniformity. One design concern is the number of treatments applied. Peripheral nerves, when injured, begin the healing process almost immediately but axonal regeneration is limited to approximately 1 millimeter per day [19]. Higher numbers of treatment sessions may be needed to produce measurable changes. Lavery, Murdoch, and Williams [20] are the only researchers to study the effects of infrared light energy over a period longer than an average of 12 treatment sessions (performed 90 treatment sessions).

It is our intention to research the effects of infrared light application on diminished peripheral sensation, perceived pain and reported function in a subject suffering from PN.

2. Rationale

We chose to employ near-IR energy to treat this patient with PN because of the potential circulatory improvement that we suspected was possible. As noted by Sindrup and Jensen [10], improvement in peripheral circulation is a key factor in improved peripheral sensation. Red and near-IR energies have been shown to be absorbed by cytochrome c oxidase in the mitochondrial respiratory chain [21]. The absorption of this energy can result in the liberation of nitric oxide (NO). NO can be released from the mitochondria, vessel wall or from its attachment to hemoglobin when red and near-IR energies are applied. Liberated NO can be responsible for vasodilation and angiogenesis [21].

Given the NO related effect of near-IR energy, and in light of the need to facilitate circulation to improve sensation, we reasoned that employing near-IR in the treatment of this patient with diabetic neuropathy might enhance his peripheral circulation and lead to improved sensation and function.

3. Case Presentation

The subject (AZ) for this study is a 62 year old Caucasian male with a primary diagnosis of Type II diabetes. He is 64" in height with a BMI of 28.1 and describes his lifestyle as mostly sedentary. AZ has a past medical history of coronary artery disease (CAD), hypertension (HTN), elevated serum cholesterol, and has undergone a cholecystectomy within the last 12 months. He was diagnosed with Type II diabetes in 2005 and independently monitors blood glucose level twice daily through an Accu-Chek device.

AZ takes daily doses of the following prescribed medications to manage his health: Janumet (50mg) for controlling blood sugar levels, Lovastatin (20mg) to control his serum cholesterol levels, Meloxicam (15mg) and Aspirin (325mg) to address his occasional discomfort and lower his chances of experiencing a heart attack. He also reports taking the following over-the-counter medications on an as needed basis: Allergy Relief (10mg) and Zantac (150mg). His only known allergy is to Phenobarbabital.

AZ was recruited for our study through word of mouth. A researcher in our group informed him of our study after meeting him at the diabetes clinic where she volunteers as a physical therapist. This on campus diabetes clinic is open to university faculty, staff, and students. AZ was

referred by a family friend. It is protocol to test the peripheral sensation of each new patient to the clinic. After testing his sensation, the physical therapist concluded that he would be a good participant for our study. She supplied him all the details of our study and he agreed to participate. AZ signed a consent form prior to the initiation of this study.

The protocol for this study required the subject to participate in 18 total treatment sessions over a period of 6 weeks; specifically, the subject received infrared light energy treatment 3 times per week for 6 weeks. In each treatment session the subject received a total of 15 minutes of infrared light energy.

Super-luminescent diodes (SLD's) were used to deliver various wavelengths of light energy. These diodes delivered infrared light in a wavelength range of 830-870nm with a dominant wavelength of 850nm (see Table 1). The light treatment was administered at 12 J/cm^2 per spot using a hand held probe over two spots on the lumbar spinal roots paravertebrally and on six locations of each foot. The locations on the feet included behind the medial and lateral malleolus in the tibial nerve distribution, the dorsal aspect of the foot over the superficial peroneal nerve distribution, the first and third metatarsal heads over the medial plantar nerve distribution, and on the fifth metatarsal head over the lateral plantar nerve distribution.

Table 1. Spectral Details of SLD Light Source.

Wavelength (nm)	Peak Wavelength (nm)	Dominant Wavelength (nm)	50% Output Low Side (nm)	50% Output High Side (nm)	Total Power Output (mW) @ 10 J/cm^2
624	640	624	620	650	
850	860	850	830	870	
624 & 850					4128

nm – nanometers
mW – milliwatts

Three outcome measures were used to evaluate the effectiveness of the treatment of interest; the Semmes Weinstein Monofilament (SWM) test, the Foot Function Index (FFI) and the Visual Analogue Scale (VAS) for pain. The research version (20 monofilament set) of the SWM test was utilized in this study as opposed to the clinical version (5 monofilament set).

Plantar sensation was tested using Semmes Weinstein Monofilaments. The test was administered to nine sites on the plantar aspect of each foot (see Figure 1) with the AZ's eyes closed. The 5.07 monofilament was held perpendicular to the skin and applied for 1-2 seconds in a three-step sequence: touch the monofilament to the skin, bend the monofilament, and then lift the monofilament from the skin. If AZ responded "yes" at the testing site, the next smaller monofilament was used until AZ did not respond. If AZ did not respond with the 5.07 monofilament, the test was repeated with the next larger monofilament. The value of the most sensitive monofilament detected at each site was documented for each foot [22].

AZ also completed the FFI, a self-administered index entailing 23 items divided into 3 sub-scales measuring the impact of foot pathology on function in terms of pain, disability, and activity restriction [23].

The VAS was administered to quantify the AZ's experienced pain. The VAS consists of a 10cm line in which one end of the line represents no pain and the opposing end represents the worst pain imaginable. AZ was asked to rate his pain by placing a mark on the line. The line was then measured with a 10 cm ruler and given a numerical value [24].

The three outcome measures were completed prior to the initial treatment, after 3 weeks of treatment, and at the end of the 6 weeks of treatment. All data collected using these outcome measures can be viewed in Figure 2.

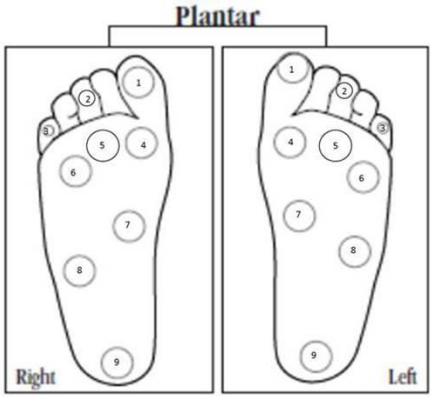

Figure 1. Sites in which sensation was tested using the Semmes Weinstein Monofilaments.

	Plantar Surface of Right Foot			Plantar Surface of Left Foot		
	Pre-Test	9 Applications	Post-Test	Pre-Test	9 Applications	Post-Test
1	5.07	4.31	**3.61	4.56	3.84	4.31
2	4.56	4.31	*4.17	4.17	3.84	4.08
3	4.56	4.08	*4.17	4.74	4.08	**3.84
4	4.31	4.08	*4.08	4.17	4.17	4.08
5	4.31	4.17	4.17	4.31	4.08	4.17
6	4.56	4.56	4.31	4.56	4.31	4.31
7	4.31	4.08	**2.83	4.17	3.84	*3.84
8	4.31	4.56	4.17	4.74	3.84	**4.08
9	4.56	4.56	4.31	4.74	4.56	**4.17

* Notes sensory improvement by 2 monofilaments
** Notes sensory improvement by more than 2 monofilaments

Foot Function Index (FFI)			Visual Analog Scale (VAS)		
Pre-Test	9 Applications	Post-Test	Pre-Test	9 Applications	Post-Test
40.6	31.8	15.9	6cm	4.3cm	0

Figure 2. Participant data obtained through the completion of the SWM test, VAS and FFI.

4. Discussion

There was marked improvement in each of the three outcome measures. AZ had an overall decrease in his VAS score of 6cm, a decrease in his FFI score by 24.7% and an improved sensation in all 9 planter locations on both feet. Each of these improvements was considered clinically significant based on the established minimally clinically important difference (MCID) values for each measure. The MCID for the VAS score is 1.4cm, the FFI is 7 percentage points [25,26]. AZ had an increase in the VAS measure by 4.28 times the MCID value and improved in the FFI by 3.53 times its MCID. The VAS and FFI are intended to objectify the experience of pain and the effect that lower extremity function has common life activities. The improvements in the outcome measures at the conclusion of the 18 interventions sessions suggest that AZ obtained pain relief and improved function in his lower extremities.

AZ's sensation improved by at least one monofilament size in all 9 plantar areas tested on both feet. Several plantar testing sites improved by 2 monofilament sizes, while a few sites improved by more than 2 (see Figure 2). The force that is required to bend the monofilament

strand is listed in Figure 3. Improved sensory ability may serve to help AZ avoid future foot conditions such as ulcer formations, joint deformities and even amputation.

We entertain the possibility that the improvements documented may be as a result of Nitric Oxide (NO) stimulation. NO is a free radical whose production can be stimulated by the application of near-IR energy. The production of NO is expected to lead to a cascade of events on the cellular level. The result of these events is smooth muscle relaxation within vessels. As these vessels relax they dilate (vasodilation) thus increasing blood profusion and allowing greater nutrient and oxygen delivery in the affected areas [27]. NO also acts as a neurotransmitter and can influence neurotransmission [28].

Physical activity is one possible mechanism through with stretching of vessel walls occurs. AZ described his life as mostly sedentary, reporting that he rarely engaged in any physical activities outside of what his occupation required of them. During the course of the study AZ was required to meet in our research facility three times per week for a total of 6 weeks. To meet this requirement, to attend each treatment session he had to drive to our location, park and walk to and from our research facility. The addition of these tasks to AZ's normal daily activities would have increased his physical activity levels. The increase in physical activity may have stimulated the production of NO through the stretching of vessel walls and the improvement that we have documented could be related to the cascading effects of this molecule brought on by increased physical activity.

Current research suggests a relationship between infrared light energy and NO. NO is bound to hemoglobin. It has been suggested that NO can be released from its bond with hemoglobin through intense illumination [28]. If released in this manner, NO would have the same effects on vessels and neurotransmission as those seen as a result of stretching the vessel walls. It has been proposed that the delivery of infrared light energy provides the illumination necessary to dissociate NO from hemoglobin, facilitate vasodilation and improve neurotransmission [29],[30].

We have documented improvement in all three outcome measures used in our study after the delivery of infrared light energy. We have not identified a definite mechanism or explanation for the improvement of the AZ's condition, but we suggest that liberation/formation of NO may play a role. Further clinical research must be done to determine the linkage between the bench research supporting the near-IR and circulation/neurotransmission connection and the patient-related physiological and functional outcomes that might reasonably be expected.

5. Conclusion

The results of this study suggest that infrared light energy may be an effective intervention to decrease pain, improve function, and increase sensation in an individual suffering from peripheral neuropathy. We have found some limited evidence to suggest that the delivery of infrared light energy could be a plausible treatment for those suffering from impaired sensation. The mechanism for this potential outcome is not addressed in this data collection. Basic research does suggest that this intervention may increase blood flow leading to improved sensation. It is believed that this is achieved as a result of the infrared light's relationship with NO. Additional research, including randomized controlled trials, is needed to establish the efficacy and generalizability of this treatment for patient populations similar to the patient represented in this case report.

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