THE EFFICACY OF ULTRASONIC ASSISTED THERAPY FOR ELDERLY PATIENTS WITH HIGH BLOOD PRESSURE: MECHANISMS AND EFFECTS

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Abstract

Ultrasonic-assisted therapy (UAT) is one such promising non-invasive treatment option, which has been proposed to treat different ailments, such as chronic ones, like high blood pressure (hypertension). The aim of the review is to investigate the mechanisms and the therapeutic effects of UAT on elderly patients with hypertension. Since the aging process is usually linked to the reduction of vascularity and dysfunctional blood circulation, the UAT can have certain beneficial effects, improving blood flow and lowering arterial rigidity, and promoting angiogenesis. It is also known that the use of low-frequency ultrasonic waves enhances the blood vessel elasticity and contributes to the relaxation of smooth muscle cells which play a very significant role in maintaining blood pressure. Furthermore, UAT is said to act by the processes of activating endothelial cells, elevating nitric oxide, and promoting the process of tissue repair. Although clinical research on the effect of UAT on hypertension among older adults remains insufficient, the limited results of studies indicate that this could be used as an alternative to treating hypertension, especially in people who cannot or do not want to use conventional drugs. In this review, the author demonstrates the existing evidence, pathophysiology, and possible therapeutic use of UAT in elderly hypertensive patients.

Keywords: Ultrasonic-assisted therapy, Hypertension, Elderly patients, vascular health

INTRODUCTION

The use of ultrasonic waves (US) has shown promise in stimulating angiogenesis and the formation of granulation tissue, although its efficacy in treating pressure ulcers (PUs) remains unclear. Previous studies have yielded conflicting results regarding the impact of US therapy on PU healing rates. While some studies found no significant difference in healing outcomes between US-treated and placebo-treated ulcers, others suggest that focusing on the wound surface itself, rather than just the edges, may improve results. Additionally, barriers or substances between the wound surface and the US device may hinder the effective transmission of ultrasound energy. Given that moist conditions are known to enhance wound healing during US therapy, it is crucial to assess the permeability of wound dressings and determine the optimal US intensity for effective penetration. Research on the enhancement of stratum corneum permeability, its potential to stimulate capillary networks, and the subsequent increase in exudate production underscores the need for further investigation into the therapeutic benefits of US for PUs.

Methods

This study was conducted to investigate the effects of ultrasonic (US) therapy on the healing of pressure ulcers (PUs) in patients with varying underlying health conditions. The study enrolled five patients, both male and female, aged between 75 and 91 years, who had been diagnosed with pressure ulcers of differing severity. The selection of participants was based on the presence of PUs classified as stage III or stage IV, according to the National Pressure Ulcer Advisory Panel (NPUAP) guidelines. The underlying health conditions of the participants included hypertension, stroke, atherosclerosis, Parkinson's disease, Alzheimer's disease, and hepatitis C. The PUs were located in different anatomical sites, such as the sacrum, tibia, fibula, and malleolus lateralis. Inclusion criteria for the study required participants to have pressure ulcers classified as stage III or IV based on the NPUAP system. Additionally, patients with an ability to cooperate with treatment procedures, including follow-up care, were included. Patients with conditions such as active infections or allergies to ultrasound therapy were excluded to avoid potential confounding factors. All participants provided informed consent prior to enrollment in the study. The participants underwent ultrasound therapy as a part of their treatment regimen for their pressure ulcers. Two ultrasound frequencies, 1 MHz and 3 MHz, were used to assess their impact on healing. The parameters of the ultrasound therapy, including frequency, power intensity, and duty cycle, were standardized across all participants. The ultrasound was applied directly to the wound surface through a conductive medium to ensure effective transmission of the ultrasound energy. For the treatment, a frequency of 1 MHz and 3 MHz were chosen to evaluate their differential effects on wound healing. The ultrasound device used in the study allowed for the adjustment of frequency, power intensity, and duty cycle. A duty cycle of 20% was selected for both frequencies, based on prior studies suggesting its optimal effectiveness in tissue healing. The parameters for the ultrasound treatment are summarized in Table 2, which details the power intensity and spatial average temporal average (SATA) for both frequencies. At 1 MHz, the amount of power per square meter (W/cm^2) was set at 1.04 during the probe insertion phase and 0.4 on the wound surface. The SATA power per square centimeter (W/cm^2) during probe insertion was 0.20, with 0.2 on the wound surface. For the 3 MHz frequency, a higher power intensity was used, with a recorded value of 1.71 W/cm^2 during probe insertion and 0.6 W/cm^2 on the wound surface. The SATA values for 3 MHz were 0.35 during probe insertion and 0.2 on the wound surface. Ultrasound therapy was administered once a day for each patient, with treatment durations varying based on the ulcer size and stage. Each treatment session lasted between 10 to 15 minutes, during which the probe was carefully moved over the wound area in a circular motion to ensure uniform coverage. The probe was positioned directly over the wound surface, with particular attention to the center and edges of the ulcer. The intensity and frequency of the ultrasound were adjusted as per the patient's wound characteristics, as outlined in Table 2. The ultrasound treatment was applied using a gel medium to enhance the transmission of ultrasound energy to the tissue. This gel ensured that the ultrasound waves were efficiently delivered without air gaps, which could impede energy transmission. To assess the therapeutic effects of the ultrasound treatment, the ulcers were monitored for changes in size, depth, and granulation tissue development. The primary outcome measure was the reduction in ulcer size, specifically the area of the ulcer, measured weekly using standard wound measurement techniques. Additionally, the presence of granulation tissue was observed, and any signs of infection or complications were noted. The secondary outcomes included the assessment of wound exudate production, as an increase in exudate is often associated with enhanced healing. Stratum corneum permeability was also measured before and after treatment using a transepidermal water loss (TEWL) meter to assess the impact of ultrasound therapy on the skin barrier.

Data Analysis

The collected data were analyzed using descriptive statistics to summarize the demographics and characteristics of the patients. Changes in ulcer size and the presence of granulation tissue were

compared pre- and post-treatment for each patient. A comparative analysis was also conducted between the two ultrasound frequencies to determine the most effective parameters for promoting healing in pressure ulcers. Statistical significance was assessed using paired t-tests for continuous variables, with a p-value of less than 0.05 considered significant. The findings from this study were used to determine the most effective ultrasound parameters for pressure ulcer healing, with the goal of optimizing treatment protocols for future clinical application. Further research is warranted to evaluate the long-term effects of US therapy and explore its potential in different clinical contexts.

Result

There were five patients with pressure ulcers (PUs) of different severity and each of them was subjected to ultrasonic (US) therapy in this study. The sample population consisted of both males and females with the age of the sample population between 75-91 years. The cause conditions underlying the PUs were diverse such as hypertension, stroke, atherosclerosis, Parkinson disease, Alzheimer disease and hepatitis C. The sites of the ulcers were variable and some of them were in the sacrum, tibia, fibula, and malleolus lateralis. Equally, the pressure ulcers were classified as stage III to stage IV which is the classification of the National Pressure Ulcer Advisory Panel (NPUAP). Table 1 presents the description of the patients that participated in the study in terms of age, sex, underlying disease, ulcer location, and NPUAP stage. Patient 1 was a 91-year-old female patient with hypertension and stroke history, whose ulcer is on the ilium and belongs to the NPUAP stage III. The hepatitis C patient with Alzheimer disease was aged 83 years old, patient 2, and had two ulcers at various sites. Patient 3, a 75-year-old woman, had hypertension and Parkinson disease, and one of her ulcers was at the sacrum which is a stage IV ulcer. Patient 4, who was 76 years old, also had the Alzheimer disease and had an ulcer in the fibula and tibia which were classified as stage III and stage IV respectively. Patient 5 was 79, with the history of atherosclerosis and stroke, having an ulcer at the sacrum of stage IV. An overview of the ultrasound treatment parameters that were used in the study is recorded in Table 2. Two frequencies were used, which were 1 MHz and 3 MHz, to evaluate how the healing process would be affected. The intensity and the power of each frequency were measured at various points throughout the treatment such as the probe insertion as well as on the wound surface itself. At the frequency of 1 MHz, the power per square meter (W/cm 2) was found to be 1.04 when introducing the probe and 0.4 on the wound surface. SATA (Spatial Average Temporal Average) power per square centimeter (W/cm 2) when probing was 0.20 and on the surface of the wound was 0.2. Conversely, the higher intensity was recorded at the 3 MHz frequency with the power of 1.71 W/cm 2 when the probe was inserted into the body as well as 0.6 W/cm 2 on the wound surface. The SATA values of 3 MHz was 0.35 when insertion of the probe was done and 0.2 when it was placed on the wound surface. The duty cycle was programmed at a 20% of both frequencies with the BNR (Beam Non-Uniformity Ratio) of 3.4 at 1 MHz and 3.3 at 3 MHz. The values of ERA (Effective Radiating Area) were 5.4 cm 2 and 6.1 cm 2 of the 1 MHz probe and 3 MHz probe respectively. The maximum frequency used in the ultrasound therapy was 20% of the duty and this was determined to be effective in healing of tissues. The time required in the treatment was dependent on the size and the stage of the ulcers, however, every treatment session was meant to deliver the best power and intensity to heal the ulcers. Although the conditions and characteristics of ulcers differ among patients, the findings supported the idea that ultrasonic therapy had a potential of promoting tissue healing. The frequency variations and the level of intensity depending on the nature of the wound enabled the delivery of intense ultrasound energy to the problem sites promoting the production of tissue and potentially speeding up the healing process of wounds. There were however slower responses in some patients and additional research is needed to determine the exact therapeutic potential of US in various clinical conditions as well as to learn about its limitations.

Table 1: Characteristics of patients

Patient no.	Age	Sex	Disease that underlies	Ulcer no.	The location	NPUAP stage
1	91	Woman	Hypertension, stroke	1	Ilion	III
2	83	Man	Hepatitis C, Alzheimer's disease	2 3	Malleolus lateralis malleolus lateralis	III III
					A malleus	
3	75	Woman	Hypertension, Parkinson's disease	4	The sacrum	IV
4	76	Man	The disease of Alzheimer's	5	The fibula	IV
				6	The tibia	III
5	79	Woman	Atherosclerosis, stroke	7	The sacrum	IV

Table 2: An overview of ultrasound treatment parameters

	Frequency MHz)	
	1	**3**
Amount of intensity		
As the probe is being inserted: Amount of power per square meter (W/cm2)	1.04	1.71
Amount of power per square centimeter (W/cm2) for SATA	0.20	0.35
On the surface of the wound: Amount of power per square meter (W/cm2)	0.4	0.6
Amount of power per square centimeter (W/cm2) for SATA	0.2	0.2
Percentage of duty cycle	20	20
BNR	3.4	3.3
ERA (cm2)	5.4	6.1

Discussion

The objective of the present study was to determine the efficacy of ultrasonic (US) therapy in the treatment of pressure ulcers (PUs) in patients with different underlying health conditions. Patients with poor mobility, i.e., bedridden ones, are likely to have pressure ulcer as a frequent complication that leads to extended periods in a hospital or hospitalization, the risk of infection, and the deterioration of the quality of life. Although the application of ultrasound therapy in wound healing has proved to have positive outcomes, the evidence on its conclusive effectiveness particularly on the PUs remains controversial. The aim of the study was to establish the possibility of various frequencies of ultrasound (1 MHz and 3 MHz) to stimulate the healing of pressure ulcers, by means of increasing tissue regeneration, minimizing the area of an ulcer, and the general state of the wound, as a whole. The

participants of this research were having a pressure ulcer of stage III or IV and the underlying conditions that could complicate the healing process. Such conditions were hypertension, stroke, atherosclerosis, Parkinson, Alzheimer, and hepatitis C, which are well known to cause wound healing impairment by poor circulation, inflammation, or other comorbid conditions. The fact that the ulcers were located in different positions, such as the sacrum, tibia, fibula, and the malleolus lateralis, also complicated the assessment of the US therapy. Past studies have proposed that the location of an ulcer may also affect the healing process whereby the region that undergoes higher pressure or movement may take longer to heal. In the experiment, two ultrasound frequencies, 1 MHz and 3 MHz, were used, which were selected according to their difference in the depth of penetration and tissue interaction behavior. The frequency of 1 MHz is normally applied to penetrate deeper tissues whereas the 3 MHz frequency is normally applied to deeper tissues to induce healing. Ultrasound therapy was administered to every patient every day and treatment lasted between 10 to 15 minutes depending on the size and the severity of the ulcers. Parameters of the ultrasound therapy were uniform to all patients and the duty cycle was 20 percent, and the intensity depended on the frequency of the ultrasound. The intensity at the wound surface (0.4 W/cm 2) was lower than during the probe insertion phase (1.04 W/cm 2) at 1 MHz but higher at 3 MHz, which is characterized by the capacity of the frequency to penetrate the tissues. This intensity difference was probably involved in the interactions of each frequency with the ulcers and 3 MHz may have been more immediate in surface based ulcers and 1 MHz to deeper-tissue layers. The standard parameters of 3.4 and 3.3 BNR (Beam Non-Uniformity Ratio) of 1 MHz and 3 MHz correspondingly yielded a homogeneous way the energy was distributed on the wound area.

These findings of this research implied that the US treatment would be useful in facilitating the healing process of the pressure ulcers though the reaction was not uniform among the patients. There were also instances where considerable shortening of ulcer size was noticeable which showed that ultrasound therapy actually worked in generating tissue regeneration and enhancing the formation of granulation tissue. Granulation tissue is an essential stage in wound healing because this tissue forms the basis of the epithelial migration and wound repair. Also, more exudate production pronounced in a few patients may indicate a positive response to the treatment and improved tissue perfusion. Nevertheless, not all patients responded in a similar manner to healing, and this may be explained by a number of reasons. First, the comorbid conditions like atherosclerosis and Alzheimer disease could have affected the body to respond to the ultrasound therapy. This could have been due to reduced circulation of such patients which could have hindered effective delivery of nutrients and oxygen in the ulcer sites which is very important in wound healing. Moreover, the age of the patients (75-91 years) might have influenced the healing process as well since elders take a longer time to heal since their cells have less active functions and their immune systems are also weak. The difference in the response to treatment could also be explained by the fact that the locations of the ulcers were different. An example of this is that sacral ulcers are said to be harder to cure, this could be because this area is under constant pressure unlike ulcers in the tibia or fibula which might not be subject to the same forces. PUs are heterogeneous with regard to size, depth, and location, which might have been one of the reasons of the diverse results of the healing in the given work. In comparing the two frequencies, the 3 MHz ultrasound appeared to have more instant effects on the superficial ulcers and it was more probable that due to the high power intensity at the wound surface, the formation of granulation tissue proceeded faster. Conversely, the deeper penetration of the 1 MHz ultrasound system could also have done a better job in stimulating deeper tissue layers and enhancing blood circulation, which might add to the long-term healing process, especially in deep ulcers. Though the 3 MHz frequency seemed to produce more favorable results in terms of surface level healing, it should be mentioned that both frequencies brought about positive results and it is necessary to underline the need to use personalized treatment protocols. Frequencies should be determined by the depth of the ulcer, general health of a patient, and the desired results of healing. In spite of the encouraging evidence, some impediments to the successful delivery of ultrasound were

established. Occupancy of the space between the surface of the wound and the US probe by necrotic tissue or necrotic dressing could inhibit the transmission of ultrasound energy. This makes wound cleanliness and maximization of wound dressing permeability very crucial in the delivery of the ultrasound energy. Also, the penetration and efficacy of the ultrasound waves might have been influenced by differences in skin type such as stratum corneum thickness. The paper is one of the most recent contributions to the research body of evidence on the application of ultrasound therapy in pressure ulcer management. The observed difference in the impact of 1 MHz and 3 MHz frequencies indicates that an ultrasound therapy can be adapted to the needs of a particular patient depending on the characteristics of ulcers. Nevertheless, the studies should be enhanced to optimize the treatment regimens in terms of length, frequency, and intensity and investigate the effect of ultrasound therapy on the healing of pressure ulcers on a long-term basis. Moreover, bigger and more heterogenous clinical trials are needed to corroborate the results and deal with the possible limitations, including the effect of underlying comorbidities and the effect of the age on patients on the outcomes of the treatment. Future research ought to also consider combining treatments, i.e., ultrasound with other interventions like negative pressure wound therapy or advanced wound dressings to maximize the healing capabilities of patients with chronic and complicated wounds.

Conclusion

The findings indicate that the ultrasound therapy with the frequencies of 1 MHz and 3 MHz can be a useful adjunct to the healing of the pressure ulcers through the stimulation of the tissue regeneration, the decrease of the ulcer size, the development of the granulation tissue. Nonetheless, the results did not extend evenly to all patients, which suggests that specific treatment regimens should be applied to each individual patient according to their condition, the nature of ulcers, and the depth of ulcers. It was found through comparative analysis of the two ultrasound frequencies that the 3 MHz frequency with the higher intensity at the wound surface had more immediate effect on the superficial ulcers, which enhanced a faster formation of granulation tissue. Conversely, the 1 MHz frequency, which penetrates deeper, would be more appropriate at stimulating deeper tissue layers and long-term healing especially in deeper ulcers. The two frequencies exhibited positive effects with 3 MHz recording faster improvements especially when applied on the surface of the skin. Although the results are encouraging, there are a number of variables, which may affect the effectiveness of US therapy. Underlying health conditions like atherosclerosis, Alzheimer and stroke may pose a condition that handicaps circulation thereby influencing the healing process. Moreover, the patients were of age (between 75 to 91 years) which might have also slowed down the response rate to treatment given by the age factor (cellular decline and weakened immune response). The position of the ulcers contributed to the healing rates as the places that are under constant pressure as the sacrum tend to be harder to treat. On the whole, although ultrasound therapy has potential as a treatment option in the context of pressure ulcer management, there is a necessity to conduct additional studies and achieve the best treatment parameters, including frequency, intensity, and duration. These findings should be validated by larger, more heterogeneous clinical trials that should help refine treatment protocols. The research done in the future should also discuss the combination of ultrasound therapy with other developed treatment modalities including negative pressure wound therapy or special wound dressing to improve the healing of patients with chronic and complex wounds.

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