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Vibration Adjuvant Wound Therapy Enchances The Healing Of Diabetic Foot Ulcers: An Interim Analysis Of 31 Patients

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Abstract

Introduction: Diabetic foot ulcer (DFU) is a common complication of diabetes mellitus and remains a major global public health problem and a great challenge in the realm of clinical nursing care. Previous studies suggested that vibration can improve skin blood flow. However, there was no evidence to suggest that vibration had an effect on diabetic wound healing.
Objectives: This study is to establish whether vibration therapy, as an adjunct to standard wound care, can significantly improve the healing of diabetic foot ulcers.
Methods: In this prospective experimental study thirty one patients with grade I-III Wagner Grading of DFU in Sudarso General Hospital, Pontianak and Ade Muhammad Djoen General Hospital, Sintang, West Borneo, Indonesia, were randomly assigned to experimental group (EG, received standard wound care and vibration therapy, n = 16) and control group (CG, received standard wound care alone, n = 15).
Results: There were significant differences in total duration of wound care between EG (21.12±10.86 days) and CG (41.47±18.61 days) (*P* = .04). There were also differences in percentage of wound healing as a function of time. By the end of week 2, percentage of wound healing in EG was 25% while in CG it was nil (*P* = .038). By the end of week 3, percentage of wound healing in EG was 50% while in CG it was 13.3%, (*P* = .029). By the end of week 4, percentage of wound healing in EG was 100% while in CG it was 66.7%, (*P* = .012).
Conclusions: The findings of the present study shows that vibration therapy, as an adjunct to standard

Keyword: *Vibration Wound therapy; Diabetic foot ulceR* wound care, does significantly improve the healing of DFUs.

INTRODUCTION

Diabetic foot ulcer (DFU) is a common complication of diabetes mellitus

and remains a major global public health problem and a great challenge in the realm of clinical nursing care.[1, 2, 3]

Of the 285 million individuals with diabetes mellitus worldwide in 2010,[1,2] including 7 million diabetic patients in Indonesia, 15% will develop DFU complications during their lifetime. [4-9] DFU are a major cause of disability, morbidity, and mortality, and account for a top-heavy share of the costs associated with diabetes care. [10,16,17] DFU is one of the most common complications of diabetes that lead to hospitalization and amputation. [17-,21,27,29,36,45,56]Diabetic foot ulcers is responsible for more hospitalizations than complication of diabetes. [21-22,25,32] In Cipto Mangunkusumo General Hospital in Jakarta, Indonesia, the average length of stay of patients with DFU is 45,3 days, with the cost of care is more than IDR 1.6 million, and with amputation rate of 32.5%.[10-12]

Impaired wound healing is a prominent characteristic of DFUs. [14,16,38]

Rational and effective treatments can prevent the deterioration of ulcers, accelerate healings, and reduce the amputation rate. [25,28,36]

Principles of treatment for the DFUs consist of relief of pressure and protection of the ulcer, restoration of skin perfusion, treatment of infection, metabolic control and treatment of co-morbidities, local wound care, education of patient and relatives, determining the cause and preventing recurrence.[25,31,33,40,41,47,52,54,55,57,62,64]

Despite the fact that several surgical and medical conservative therapeutic options are already available for treatment of diabetic foot ulcers, the healing time of ulcer remains high. [33] Therefore, many new studies are conducted to enhance the healing process and to reduce the healing time of foot ulcer. [34,35,42.]Vibration therapy has been widely used in as orthopedic surgery, medical rehabilitation, and neurology. Recently, there has been an increase in research and clinical application of vibration therapy in various therapeutic disciplines, particularly in wound healing. [95] Nakagami, *et al* (2007) conducted a study on the effect of vibration on skin blood flow in an *in vivo* microcirculatory model. They found out that the used of direct skin vibration helped improving skin blood flow significantly. [85,89] Arashi, *et al* studied the use of vibrator on pressure ulcer in older adults and found that the vibration may facilitate the healing of stage *I* pressure ulcer. [81]

There is no evidence to support that vibration had an effect on diabetic wound healing. [86] The purpose of this study is to establish whether vibration therapy, in combination with standard wound care would significantly improve the healing of DFUs compared to standard wound care alone. The improvement of healing process was evaluated through measurement of wound size reduction during three weeksof intervention.

METHODS

This prospective study, evaluating wound size over 3 weeks in type 2 diabetic patient, was conducted in 2 general hospital: Sudarso General Hospital, Pontianak and Ade Muhammad Djoen General Hospital, Sintang, West Borneo, Indonesia. The clinical research ethics committees in both hospitals approved the study protocol. All patients were provided with written consent prior to study enrollment. The patients with the following inclusion criteria were enrolled in the study: age ≥ 18 years, Wagner grading of foot lesion I-III. The study excluded patient who had extensive gangrene with unavoidable below-knee amputation, poor nutritional status (albumin < 2.5 g/dL), severe co-morbidities such as stroke, uncontrolled

hypertension (systolic >160 mmHg, diastolic > 100 mmHg), or end-stage renal disease required peritoneal dyalisis or hemodialysis.

We report herein thirty one cases grade I-III diabetic foot ulcers which were randomized into two groups: 16 were assigned to experimental group (vibration and standard care) and 15were asigned to control group (standard care).

Vibration. Researchers used RelaWave® vibrators (Matsuda Micronics Corporation, Chiba, Japan), which were provided by University of Tokyo Japan. The size of the vibrator is 616 x 182x 144 mm3, weighing 4200 grams. The setting of frequency and amplitude modulation cycle, according to the previous study, were 47 Hz and 1.78 m/s² respectively. The Recommended Occupational Exposure Limits of vertical and horizontal vibration acceleration at a frequency of 50 hz and a vibration time of 15 minutes, are 13.2 m/s² or less and 37.5 m/s², respectively. Therefore, the specifications of the present vibrator are within the recommended range.

Intervention. All patients received similar standard wound care consisting of debridement, adequate off-loading, and careful daily monitoring of the ulcer. Patients in the experimental group received additional treatment after wound care, consisting of vibration application for 15 minutes 3 times a day (4-6 hours apart) for 3 weeks. To prevent skin irritations, a rubber pad was inserted between the leg and the vibrator during application.

Wounding cares and dressings. Wound cares consisted of debridement, adequate off-loading, and careful daily monitoring of the ulcer. Based on the characteristic of the wound, the dressings was changed as required (at least 3-4 times dressing changes per week). Wound dressings were standardized throughout the entire study to saline-moistened gauze.

Wound measurement. Ulcer healing was assessed by perpendicular linier dimension measurement of the wound area (mm²), particularly ellipse. The area of an ellipse is calculated by measuring 2 perpendicular diameter, such as maximum diameter (major diameter) and maximum diameter perpendicular to the first diameter (minor diameter). The calculation of area based on the formula for ellipse; π (a/2)(b/2), where *a* and *b* are the major and minor diameters. The size of wound determined by wound ruler and transparent film with millimeter block scale. The wounds were photographed after debridement and before dressing application. On weekly evaluation, the wound was assessed for closure.

Statistical Analysis. Statistical analysis included descriptive statistic, the standard error of mean, and analyses of variance using the *t* test. The statistical analyses were done using statistical program for window.

FIGURE 1. RelaWave® vibrator. It is applied for 15 minutes three times a day

RESULTS

There was no significant differences between VWT and control treatment groups in patient demographics and base line ulcer size (Tabel 1). But were significant differences (mean±S.D) in total care of ulcer for VWT group (21.12±10.86) days, and control group (41.47±18.61) days (P = .04).

No adverse events were reported with application of vibration wound therapy. In fact some patient reported a perceived sense of comfort.

Treatment with VWT had greater mean percent wound closure than control-treated ulcers at each evaluation point (Fig. 2).

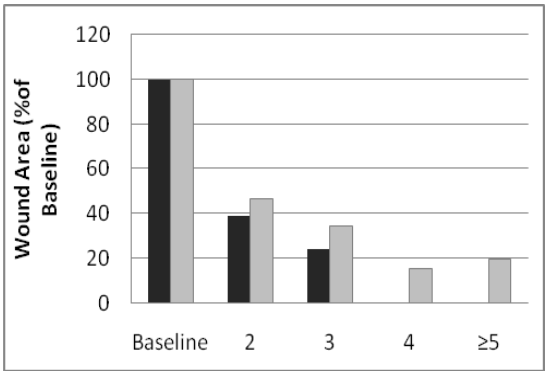


FIGURE 2 Mean percent wound area of ulcer treated with VWT and control (■) VWT; (■) control

Although the differences were notable and displayed a trend favoring VWT, the differences in healing rate was were not statistically significant (P= .228 at week 2, P=.278 at week 3).

However, there was a significant difference in wound healing. In experimental group, the wound healing was accomplished completely at the forth week; the control group still had wide wounds that tend to be healed slowly; to be completely healed the control group needed more than 5 weeks

However, there was a significant difference in wound healing. In experimental group, the wound healing was accomplished completely at the forth week; the control group still had wide wounds that tend to be healed slowly; to be completely healed the control group needed more than 5 weeks. This results showed in the table below.

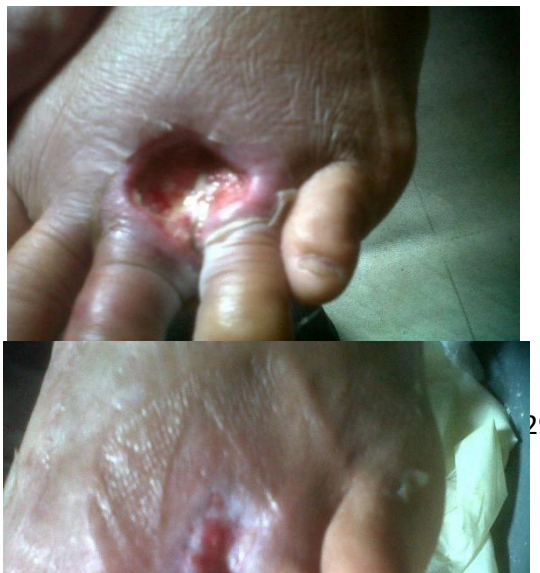
TABEL 1 Characteristics of Patient on addmission

	VWT (n=16)	Control (n=15)
Sex		
Female, %	75	53.3
Male, %	25	46.7
Age (years)	55.19±7.67	59.27±8.72
BMI (kg/m²)	24.01±2.21	25.28±2.67
Diabetes duration (years)	9.25±7.90	8.4±6.84
HbA1c (%)	8.23±2.18	8.29±1.97
Ulcer area (mean, mm²)	291.24±137.82	278.11±152.20
Total care of ulcer (days)	21.12±10.86*	41.47±18.61

Data are n or means ±S.D.
Age, BMI, Diabetes duration, HbA1c and Ulcer area did not differ the groups
*P< .05 comparing total care until healed (days) between VWT group and control group

Significant difference was acquired from the percentage of wound healing. The wound healing of experimental group started at the second week of treatment (25% of experimental group completely healed after 2 week of treatment, P=.038) (Fig.4)

After 3 weeks, 50% of the ulcers treated with VWT had healed compared to 13,3% for the control group (P= .029). After 4 weeks 100% the ulcer treated withVWT healed compared with 66,7% for the control group (P= .012). Ulcer photographs showing the sequence of healing in a patient treated with VWT are shown in Figure 3.



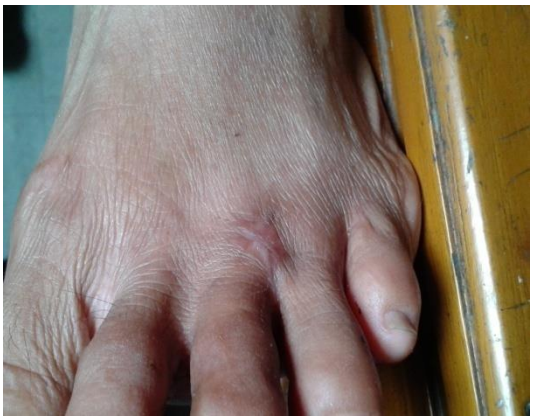


Figure 3 Ulcer photographs showing sequence of healing in apatient (49 year) treated with VWT. The ulcer is on the center aspect of the left foot and had remained open for 1 weeks. (*A*) Diabetic footulcer before treatment (day 0, wound measures 397.2 mm²). (*B*)Wound after 3 week of therapy with VWT. (*C*) Study woundhealed after 4 weeks.

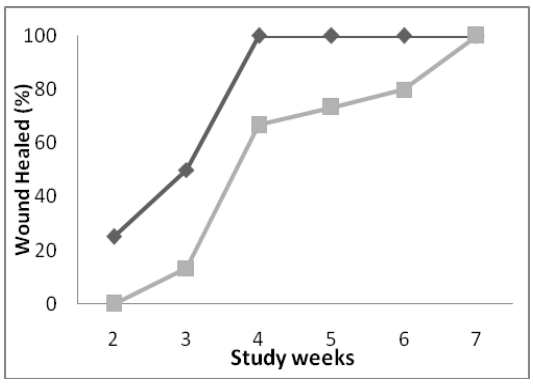


FIGURE 4 Effect of VWT on the proportion of wound healed. (◆) VWT; (■) control

DISCUSSION

Diabetic foot problem, due primarily to resulting microcirculatory damage, imposes considerable morbidity, length of care, and cost to individual as well as for societies.[1-3] The exact pathophysiologycal mechanisms for this condition have not yet beenelucidated.

The most feasible explanation for the improved healing of diabetic foot ulcer treated with VWT was by promoting the blood supply. Because the application of vibration induced shear stress to endothelial cells, the adjacent vascular smooth muscle cells dilate blood vessels. This vasodilatory actionmay enhance tissue microcirculation and promote healing. It is known that diabetic patients suffered from decreasing bioavailability of nitric oxide (NO) resulting in the damage of endothelial cells of blood vessels.

Studied conducted by Lohman , et al[86] indicated that there was significant increased of skin blood flow in lower extremities with application of vibration therapy at a 30 hz frequency and a 3 second vibration time. It was assumed that the increasing blood flow was influenced by several factors. The blood flow is regulated by extrinsic and intrinsic factors . Extrinsic factors are factors that originates from external blood vessel such as sympathetic nerve and humeral factors. Primary role of extrinsic control regulated arterial blood pressure. Intrinsic factor, such as local metabolism products originated from endothelial cells and vascular smooth muscles, regulates local blood flow to tissues.

Lohman, et al[86] discovered that muscles exercices could be improved by vibration through stimulation local blood flow. This finding revealed that local factor is responsible for the increased perifer blood flow. Intrinsic factor that stimulated vasodilatation of blood vessel including *nitric oxide* (NO), *prostacyclin*(PGI_2), *endothelial derived hyperpolarization factor* (EDHF).

One of the mechanisms to release the metabolites mentioned above was *shear stress.* It was possible that endothelial cells considered vibration as

shear stress and in turn, increased *nitric oxide* (NO), *prostacyclin*(PGI_2), *endothelial derived hyperpolarization factor* (EDHF). Studies on experimental animal and research on cells level with *shear stress* indicated that NO played primary role in smooth muscle vasodilatation as a result of *shear stress*[96].

Despite the mechanism mentioned above, it was obtained that during inflammation stage of the healing wound of chronic diabetic there was occurrence of decreasing NO percentage as well as collagen production and the power of healing wound.

The decrease of NO percentage caused difficulty on inflammation stage of wound healing; thereafter postponed the wound healing. It was supported by research that on diabetic person, endothelial cells less responsive to shear stress. In addition, from time to time, aging and diabetic can decrease NO sysntessa or in other words, bioavailability of NO decreases. For that reason, it is necessary to evaluate foot ulcer of diabetic patients to know whether perifer blood flow increase with vibration

This research was necessary to be conducted to support the finding of Ichioka[84] that vibration applied with optimal frequency and intensity will be converted to mechanical power that stimulate endothelial cells of blood vessel to release *nitric oxide* (NO). NO was known as vasodilator that played important role in increasing blood flow and the healing of common wounds. This research was supported by finding of Maloney[86] that revealed vibration was capable of increasing blood flow of healthy adult as well as type II DM patients. The increasing of blood flow is known through NO-increasing mechanism that triggered by vibration

In addition, this research was supported by Nakagami, at al[88] in his study "*Effect of vibration on skin blood flow in vivo microcirculatory model*", that fit into basic thinking about the way of blood flow mechanism occurred. Vibration, applied to the mouse, provided 2 mechanisms of increasing vasodilatation of blood vessel. First, the effect of direct application of vibration to the surface of the tissue was stress mechanism including the blockage of stress, compression and elongated of endothelial cells. This will increase blood flow through *Nitric Oxide* (NO) mechanism. related to vasodilatation of vein blood vessel

The second mechanism was that application of vibration caused the stimulating impulse through polymodalities receptor that was distributed to the surface of skin So that, there was the release of P substance and *calsitonin gene-related peptide* that caused dilatation of blood vessel. Intensity ,of vibration applied , provided in several power that were: 600 mVpp, 800 mVpp and 1000 mVpp keep to a 47 hz frequency (based on *preliminary studied*) . Subsequently, 5 and 15 minutes after vibration blood flow was tested as well as viscosity and blood vessel measurement . The result indicated the occurrence of increased blood flow to the skin. The vasodilatation of blood vessel turned into strong basic of wound healing process, however it required more clinical evidenced.

To find out how effective was vibration therapy to facilitate the healing of pressure ulcer stage 1 toward geriatric patients, research by Nakagami was continued by Arashi[80]. This nonrandom, blinded research was conducted toward patients, hospitalized for a long time , with pressure ulcer stage 1. Experimental group was given standard treatment for pressure ulcer and vibration therapy; the control group was given unaided standard treatmentfor pressure ulcer. Vibration

therapy was applied continuously for 15 minutes, 3 times a day, for 7 days intervention (frequency: 47 Hz; time 10 second; amplitude modulation cycle: 15 seconds)..

The result, using Logrank test, specify that the use of vibration can shorten the healing time of pressure ulcer stage (for complete healing, p=.o33; for healing time, p=.018.

SIMPULAN

The findings of the present study shows that vibration therapy, as an adjunct to standard

SUGGESTION

The result, indicated that vibration wound therapy can enhance the wound healing of diabetic patients, can be observed through the decrease of hospitalization time that significantly differ compare to control group. The impact not only to shorten the wound care time but also to decrease the cost of health in general and finally improve the quality of life of patients suffering diabetic foot ulcer (DFU).

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