原　著

Effect of pulsed high frequency energy on cutaneous blood flow

Toshihiro Morinaga
Shijonawate Gakuen University

Key words
pulsed high frequency energy,　cutaneous blood flow

Abstract

The purpose of this study was to examine the influence of thermal effect from high frequency energy of three kinds on cutaneous tissue blood flow. Healthy volunteer students (n=19) received continuous and two kinds of pulsed high frequency energy on their thighs. Using a laser Doppler flowmetry, blood flow volume was measured for statistical analysis. No correlation between thickness of subcutaneous fat and rate of change of blood flow with different waveforms was found. Radiation of continuous wave increased blood flow significantly 8 minutes after the start of application. SPW and LPW also increased significantly from the end of application, and this results lasted until 15 minutes. Decrease rate of blood flow after the application with both kind of PW were less than CW. The results indicate that continuous wave increased blood flow faster and greater than pulsed one. However, increased blood flow by pulsed wave lasted longer time than which was obtained by the continuous one.

Further research into combinations of pulse width and pulse repetition rates to determine whether specific conditions respond to particular setting is recommended.

Introduction

Pulsed high frequency therapy has recently gained popularity the field of physical therapy, as the number of machines in use has increased significantly through the world since 1980.

Unfortunately, there is still a great deal of confusion among the therapists as to how these beneficial results are achieved, a situation that has not been helped by the insistence that the field generated by pulsed high frequency equipments are purely magnetic, and by the use of pulsed electro-magnetic energy as a general descriptive term. The primary difference between the pulsed and the continuous high frequency energy, namely short-wave diathermy apparatus is the form and the way in which the energy is delivered to the patient's tissues.[1)]

Standard short-wave diathermy apparatus produces a continuous output of high frequency energy which, when applied to the patient with sufficient power, produces heating under the area of treatment. The continuous wave of energy generated has two components, an electrical and a magnetic field, which are out of phase with one another.

The electrical field in normally applied by means of a condenser or pad electrodes, while the magnetic field is delivered to the tissues via an inductothermy cable or monode head from which the electrical field has been eliminated by a faradic screen.

On the other hand, pulsed short-wave machines do not emit a continuous flow of energy to the tissues, instead there is a relatively short 'on' period followed by a relatively long 'off' phase before the next on phase. Because of the dispersion of any heat developed by the circulation, patients treated with pulsed high frequency energy do not normally experience any sensation of heat, unless the maximum pulse setting are used in conjunction with longer pulse widths.

Study by Nagelschmidt indicated that 'there must the some other effect not as yet realized, to account for the phenomenon which would not be reasonably attributed to heat alone'.[2]

He expanded his hypothesis by stating that there was a possibility that small currents were produce in the body due to the influence of an external electro-magnetic field and suggested that there could be an effect on general and local muscle tone, nerve conduction and the colloidal system. These effects have been studied in theory but the numerical results of application has not been reported.[3]

The purpose of this study is to examine the difference of cutaneous blood flow which has been produced after the application of three types high frequency energy.

Subjects and method

The subject group composed of 19 healthy university students (10 males, 9 females). The average age of the male students was 23.7 ± 5.1 years old, their average height was 173.2 ± 4.7cm, average body weight was 61.8 ± 5.4kg, and average subcutaneous fat was 5.6 ± 0.9mm. The average age of the female subjects was 20.8 ± 2.6 years old, average height was 161.5 ± 4.1cm, average body weight was 53.4～5.8kg and average subcutaneous fat was 8.4 ± 2.9mm.

An ultrasonic subcutaneous fat measuring device (Sekisui Chemical Co. Ltd.) was used to assess the thickness of subcutaneous fat. A laser Doppler flowmetry (Advance ALF 21R) was used to measure blood flow volume. A short-wave energy apparatus (SW-400S, Ito Co. Ltd.) was used for energy application.

Short-wave energy were applied by an inductive (coil) applicator with 14cm diameter contacting the skin by three methods : continuous (CW), long pulsed (LPW) and short pulsed wave (SPW). The fundamental frequency of short wave was 27.12 MHz, output power was set to 30W, the pulse frequency of LPW was 70 Hz with 14 % duty factor, with consists of 20 mseo 'on' time. The pulse frequency of SPW was 350 Hz with same duty factor with mean 'on' time high frequency energy application of 0.4 msec in each pulse. (Fig 1)

In order to perform a measurement, we attached the laser Doppler flowmetry probe on the skin site, at 10 cm from the top end of patella on subject's right thigh, taking care to avoid placing the fiber optic ends directly over a superficial vein or hair follicle. Then high frequency energy was applied for 15 minutes as the subject reclined in a supine position.

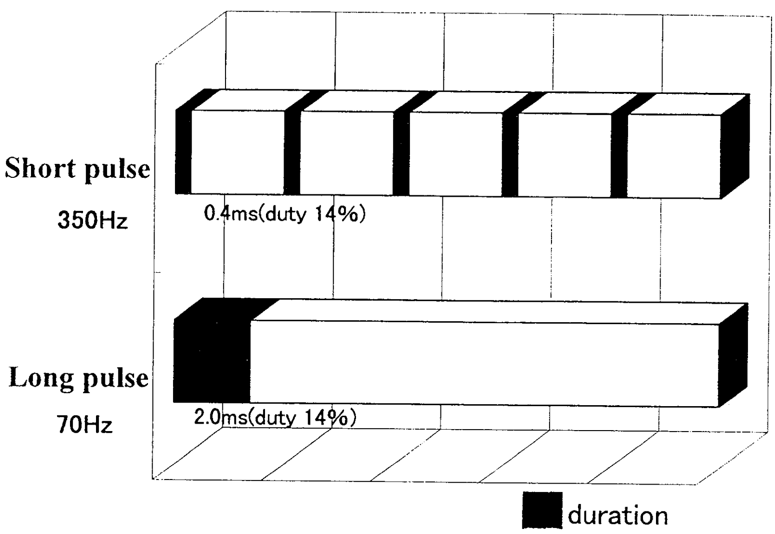

Fig 1. Schematic difference between Short and Long Pulse Wave

The subject was asked to remain motionless for another 15 minutes after the end of application. The tissue blood flow was measured at the capillary level with a 1 mm hemisphere probe, and recorded each minute from the start of the experiment to the end.

From the measurement data, we adopted the values obtained before application, 8 minutes after the start of application, immediately after the end of application, and 15 minutes after the end of application.

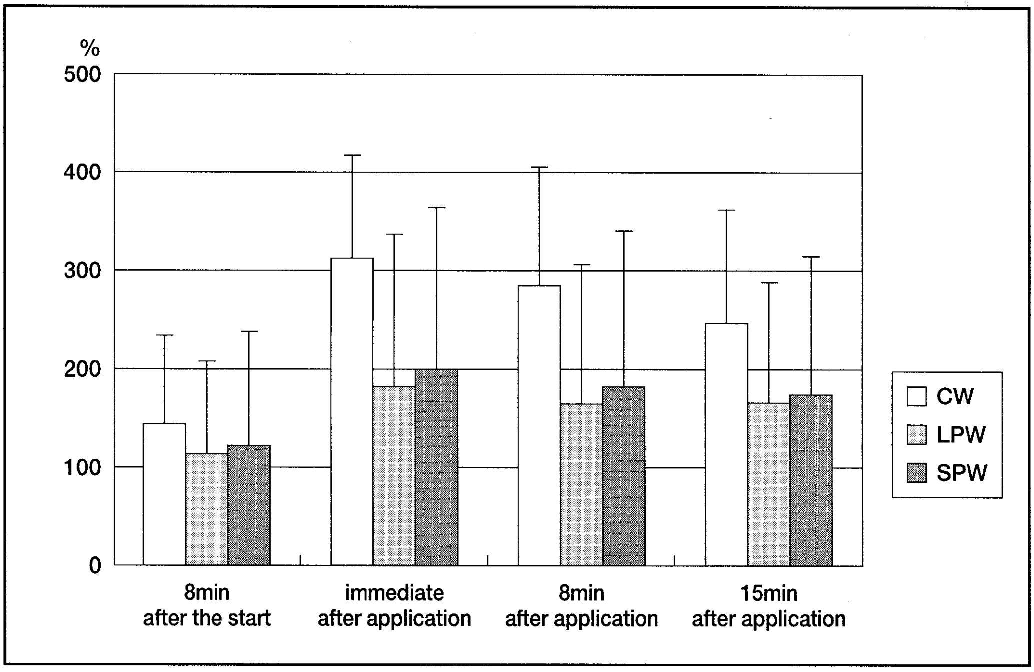

Fig 2. Changes of blood flow (% vs. before application)

Measurement was made for no more than one condition per day.

We used a t-test (95 % CI), variance analysis in the one-way layout ANOVA, and multiple comparison for analytical processing.

Table 1. Blood flow (immediate after application)

	male (n=10)	female (n=9)
CW	4.36±3.68	3.11±1.45
LPW	2.01±0.96	1.95±1.38
SPW	2.14±1.25	1.78±0.81

(ml/min/100g)

Table 2. Changes of blood flow

	CW	LPW	SPW
before application	2.14±1.20	2.59±1.47	2.42±1.00
8min atter the start	3.05±1.55*	2.97±1.59	2.91±1.40
immediate after application	6.68±4.04*	4.65±3.06*	4.78±3.25*
8min after application	6.07±4.17*	4.25±3.46*	4.39±2.84*
15min after application	5.25±3.42*	4.28±3.00*	4.22±2.44*

*$P < 0.05$ (unit：ml/min/100g)　n=19

Results

The means and standard deviations for the thickness of subcutaneous fat in males and females were calculated, obtaining a value of 5.56 ± 0.85mm for males and 8.40 ± 2.91mm for females. The difference between these values was significant ($p < 0.05$). In comparing the rate of change in tissue blood flow between males and females with different wave forms, higher rates of change in males was obserued than in females with all waveforms, but these differences were not statistically significant. (Table 1) Based on the result, means and standard deviations before application, 8 minutes after the start of application, immediately after the end of application, 8 minutes after the end of application, and 15 minutes after the end of application was measured and calcalated for three types of waveforms for 19 samples.

In the time series values obtained from before application to 15 minutes after the end of application with different waveforms, blood flow volume with CW increased significantly ($p<0.05$) from before application to 8 minutes after the start of application through 15 minutes after the end of application.

Blood flow volume with SPW and LPW also significantly increased from immediately after the end of application. (Table 2), and increase rate of SPW was than LPW. This tendency extended more than 15 minutes after the end of application. Figure 2 shows percentage change of blood flow compared with before application of high frequency energy. Immediately after the application indicated significant increase of blood flow than 8 minutes after the start of application.

The decrease rate of CW after application to face each other before application was greater than SPW and LPW.

Discussion

When a high frequency energy is applied to the tissue, intracellular molecules characterized by Brownian motion absorb electric energy, resulting in intensified Brownian motion. Molecules collide with other molecules, generating frictional heat.

Ionized molecules begin vibrating at high frequencies as a result of potential conversion of the high frequency electric current. Dipole molecules, electrically neutral but with electrical potentials polarized on either side, initiate an intense rotational motion due to potential conversion of the high frequency electric current. As a result, heat from friction is generated by the molecules within cells. This describes the principle of heat generation through application of a high frequency electric current.[4)]

The thermal effects resulting from electric currents such as short-wave and electromagnetic radiation are based on principles of heat generation within tissue. Generally, molecules characterized by Brownian motion and ionized molecules are found in tissues contacting high levels of water. Thus, these molecules generate heat in blood vessels and muscle containing more blood than other tissues. In contrast, the generation of heat is relatively small in skin and fat tissue. Compared to continuous waves, pulsed waves allow reductions in the rate of skin heating while permitting the heating of deeper parts with greater outputs. Thus, heating deep parts through shortwave also increase the blood flow of muscular tissue in deeper tissues, and this increase is greater in the skin.[5)]

It is beyond the scope of this study to compare the temperatures distribution within the body by numerical values, i.e., temperature values during and after the application of high frequency energy. However, examination of the effect of capillary dilation on tissue blood flow, suggest the effects of energy application in statistical analysis.

The effects of shortwave on tissue blood flow tended to appear approximately 8 minutes after the start of application, this was examined by the pre-test measurements intervals before application, 8 minutes after the start of application, immediately after the end of application, 8 minutes after the end of application, and 15 minutes after the end of application. Tissue blood flow increased from 8 minutes after the start to immediately after the end of application with all waveforms, but only CW demonstrated significant differences. This may be because the rate of skin heating by CW was greater than pulsed waves, and subjects feel any heating sensation by PW in the experiment. It appears that PW effectively heated deeper parts such as muscles or joints rather than the cutaneous tissue.

Conclusion

We examined the differences in effects between continuous wave and pulsed wave in high frequency energy by comparing their effects on cutaneous blood flow volume, using 19 healthy young adults as subjects.

1. With all waveforms, we found no significant differences between males and females in rates of change in blood

flow volume.

2. With all wave forms, we found no correlation between rates of change in tissue blood flow and thickness of subcutaneous fat.
3. We observed significant differences in increase of blood flow volume 8 minutes after the start of application only with CW.
4. SPW and LPW also increased blood flow volume significantly after the end of application ; however there were smaller amount of CW.
5. The decrease rate of blood flow after the application was less with both of PW, when compared to CW.

There is still a need for further research into combinations of pulse width and pulse repetition rates to determine whether specific conditions respond to particular settings.

Acknowledgements

The author would like to acknowledge with gratitude the assistance given during the preparation of this article of Ito Co. Ltd.

References

1. Hayne, C. R.: Pulsed High Frequency Energy-Its place in Physiotherapy, Physiotherapy, 70:459－466, 1984
2. Nagelshimidt. K. F. :Specific effects of high frequency currents and magnetotherapy, British J. of Physical Med. Nov. 201－207, 1940
3. Frey A. H.:Differential biologic effects of pulsed and continuous electromagnetic fields and mechanisms of effect. Annals of N.Y. Academy of Sciences, 273－279, 1974
4. LehemannJ.F., McMillan J.A., Brunner G.G.:Comparative evaluation of temperature distribution producedby microwaves at 2,450 and 900 megacycle in geometically complex specimens Arch.Phys. Med 502－507, 1962
5. Morinaga T.: A comparative evaluation of temperature distributions produced by continuous and pulsed microwaves 12th WCPT congress 1995
6. Wagstaff P., Downey M.: A pilot study to compare the efficiency of continuous and pulsed magnetic energy in the relief ob back pain. Physiotherapy 1986 ; 72:563－566
7. Basset C.A.L., Mitchell S.N.: Pulsing electromagnetic field treatment in ununited fracture and failed arthirodesis. J.A.M.A. 1982;247:623－628
8. Sharrard W.J.W., Suthcliffe M.L., Robson M.J., MacEachern A.G.: The treatment of the fibrous non-union of fracture by pulsing electric magnetic stimulation. J. B.J.S. 1982 64b:189－193
9. Raji A.R.M., Bowden R.E.M.: Effect of high peak pulsed electromagnetic field on the degeneration and regeneration of the common peroneal nerve in rat. J.B.J.S 1983 65b 478－492
10. Wilson D.H.: Treatment of sofy tissue injuries by pulsed electrical energy. Br. Med J. 1972;1:269－70
11. Binder A., Hazelmann B., Parr P., Fitton-Jackson S. : Pulsed electromagnetic field therapy on rotator cuff tendonitis. A doubled blind controlled Assessment. Lancet 1985;1:656－658
12. Foley-Nolan D., Barry C., Coughland R.J., O'Corner P., Roden D., : Pulsed high frequency electromagenetic therapy for persistent neck pain. A double blind placebo controlled study of 20 patients. Orthopedics 1990;13:445－451
13. Oosterveld F.G., Rasker J.J., Lacobs J.W., Overmars H.J. : The effects opf local heat and cold therapy on the intraarticular and skin surface treatment of the knee. Arthiritis Rheum. 1992;35:146－151