ANTIOXIDANT EFFECTS OF ULTRA-LOW MICROCURRENTS

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Introduction

Otto Van Guericke, who rotated a ball of solidified sulfur to create static electricity in 1672, invented the first electrical instrument made by man. Amber was the first material used to generate electricity, which could be generated by rubbing it with the hands. Static electricity machines were the first instruments and, with the machine age by the 18th century, were powerful enough to destroy superficial tissue and be used for cauterization. Ultraviolet ray machines invented by Strong in 1897 were still in use in 1937.

Direct current grew rapidly with the invention of the battery. The electric cell pile allowed the generation of higher voltages than the usual two volts by connecting them in series. This reaction then provided a convenient and readily available source of Direct Current. Salandier is credited as the first to apply direct current to acupuncture needles and later moist conductive pads were introduced. Galvanic is another word used to describe direct current therapy. Today's galvanic instruments are a direct descendant of this early invention, practically without change.

With the discovery of Alternating Current by Tesla, and the invention of the Vacuum Tube by Edison and improved by DeForrest, tubes were universally used. House mains were used to eliminate the nuisance of recharging or replacing batteries for the energy gobbling appetites of the vacuum tubes.

The limitation of tubes as far as frequencies were concerned, was primarily due to the matching transformers, which, although they did well in the audible human range of 20 to 20,000 cycles per second, did not produce frequencies below 10 Hertz because the output could not be coupled easily to the patient. With the advent of the rediscovery of solid-state technology, the transistor was capable of bridging the gap.

Frequency, which is the rate of occurrence of repetition, is used in physical therapy to describe the number of cycles per second of the output wave. Since electrical waves travel at approximately 186,000 miles or so per second, the length of each wave is calculated by dividing the repetitions per second into the known speed. In honor of Hertz, a German scientist who discovered and measured radio waves, cycles per second are termed "Hertz" or in abbreviation Hz. Clinical research has shown that the frequencies in the Ultra-low frequency range of 0.1 and 0.3 Hz, seem to have longer lasting effects, although relief is not as rapid as in higher frequencies of 10 to 100 Hz.

The initials A.C. mean alternating current. Most physical therapy equipment use electrical waves that are alternating positive then negative in each half cycle to complete one complete wave. Whereas Direct Current flows in one direction only, A.C. flows in alternating directions in accordance with it being in the negative or positive phase. The upper half is considered the positive cycle, whereas the lower portion is the negative cycle.

Radio waves overlap into frequencies in the audible range, starting as low as 5,000 Hz. Above 1,000 Hz, we do not find physical therapy using any frequencies until 2,000,000 Hertz (2 Megahertz) where interferential frequencies of 2,000 to 4,000 Hz are not considered as therapeutic since only the lower 0 to 200 Hz have been touted for therapy. Ultrasound instruments use this to vibrate their sound heads. The resulting output is mechanical, but not electrical, so that a nonelectrical conductive substance can be employed.

The next higher frequency is the short wave diathermy at 27 Megahertz. Originally these were equipped with large insulated rubber pads, however it was possible to burn the patient, so it is wise to wrap them in several layers of heavy towels for additional insulation. Most present units employ an isolating drum inductor to reduce this hazard. Outputs from these units are usually 300 to 500 watts, so care is advised on their application. The cords leading to these pads are usually cut to match the wavelength and are "hot" with Radio Frequency (RF). They also should be carefully routed to avoid painful RF burns. A safer form of diathermy is the Microwave or Radar type. At frequencies of 2,450 MHz, the wavelength is so short that a reflector type antenna can be used to direct the energy to the area desired. Most units have outputs of 100 watts, and depend upon increased circulation rather than heating. Frequencies higher are in the heat lamps, infrared and colors of the visible light ranges. Medical laser, X rays and cosmic rays complete the high end of the spectrum.

The healing effects of electricity have always been ill understood. However, with the advent of subatomic particle physics and the electron theory of electrical current, explanations of electricity acting as an antioxidant become more likely.

In order to understand how electrical currents can function as an antioxidant, the formation and effects of free radicals and their interaction with antioxidants needs to be understood.

Oxidation and the formation of Free Radicals

We know that the atom is made up of protons, neutrons and electrons. An inert oxygen molecule (fig.1) is stable because the outer shells contain 8 electrons arranged in 4 pairs. When molecules with weak bonds split they can leave atoms with unpaired electrons, which is what free radicals are. This produces an atom or molecule looking for an electron to make up a stable pair. Molecular oxygen is one of the most important substances on earth. Oxygen comprises 21% of the atmosphere 89% of seawater by weight, and at least 47% 0f the earth's crust.

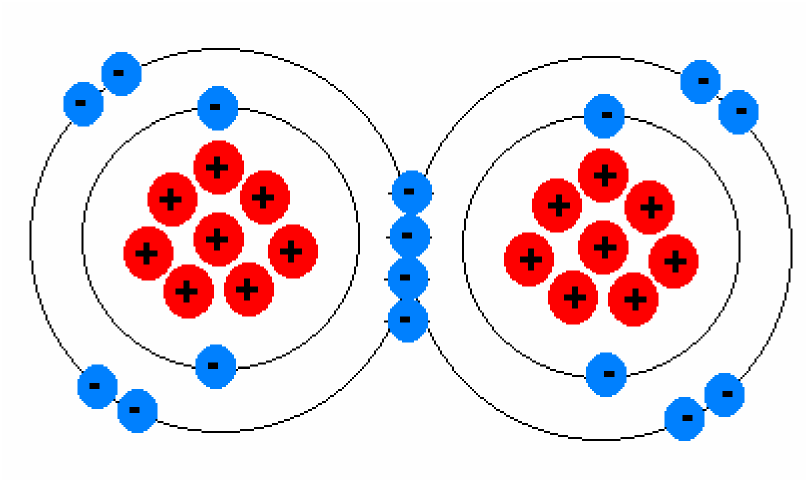


Figure 1

In the 1840's Michael Faraday discovered that oxygen is attracted to a magnet. It took until 1925 to discover why. That is when Robert Millikan explained why oxygen is magnetic using the then recently developed quantum theory. His analysis showed that molecular oxygen has two unpaired electrons in its lowest energy state (fig.2). The existence of unpaired valence electrons in a stable molecule is very rare in nature and confers high chemical reactivity, which is why oxygen is unique.

The chemical reactions leading to this are either oxidation or reduction. Oxidation is a loss of electrons while reduction is a gain of electrons. These reactions always occur in pairs, that is when one molecule is oxidized, another is reduced. Highly reactive molecules can oxidize molecules that were previously stable and can lead to unstable molecules such as free radicals.

A free radical is a chemical species with an unpaired electron which can be neutral, positively charged or negatively charged. Although a few stable free radicals are known, most are highly reactive. In free radical chain reactions the radical product of one reaction becomes the starting material for another propagating free radical damage.

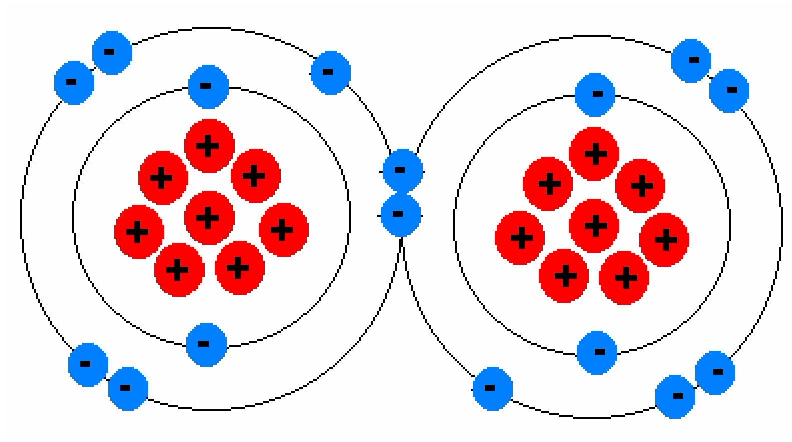


Figure 2

There are three steps to free radical chain reactions, namely initiation, propagation and termination. In the initiation phase free radicals are formed from molecules readily giving up their electrons. An example of this is hydrogen peroxide. In the propagation phase the chain carrying radicals are alternately consumed and produced. In the termination phase the free radicals are destroyed. Thus without termination by an agent such as an antioxidant, a single free radical can damage numerous molecules.

There are four common oxygen metabolites in biologic systems that are free radicals, viz., Superoxide Anion (O_2^{-}•), Hydrogen Peroxide (H_2O_2), Hydroxyl Radical (OH•) and Singlet Oxygen ($^1O_2$). The (•) represents the unpaired electron. These free radicals can be generated via a number of mechanisms including normal physiologic processes and processes resulting from external factors. For example, singlet oxygen is generated by photosensitization reactions wherein a molecule absorbs light of a given wavelength exciting the molecule. This excited molecule transfers the increased energy to a molecule of oxygen producing singlet oxygen, which can then attack other cell components. The quantum theory of atomic and molecular structure is required to explain the unique properties of molecular oxygen. Suffice it to say that ground state oxygen's valence electrons spin parallel to each other. When these electrons are elevated into a higher energy orbital, the spins are inverted to create an anti-parallel pair. This is what singlet oxygen is. There are two kinds, Σ and Δ, the former being of higher energy. The carotenoids primary function is to scavenge free radicals particularly singlet oxygen produced in this manner.

A certain amount of oxidative function is necessary for proper health. For example, oxidative processes are used by the immune system to kill microorganisms. Sometimes, however, the level of toxic reactive oxygen intermediates overcomes the antioxidative defenses of the host resulting in an excess of free radicals and a state called oxidative stress. These free radicals can induce local injury by reacting with lipids, proteins and nucleic acids. The interaction of free radicals with cellular lipids leads to membrane damage and the generation of lipid peroxide by-products.

Antioxidants and their effects on Free Radicals

Antioxidants are chemicals that have the ability to donate electrons without becoming free radicals themselves. Cells contain a number of antioxidants that have various roles in protecting against free radical reactions. The major water-soluble antioxidant metabolites are glutathione (GSH) and vitamin C (fig.3), which reside primarily in the cytoplasm and the mitochondria.

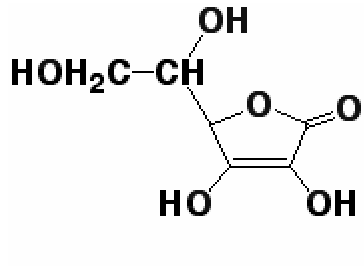


Figure 3

Glutathione (fig. 4). is a tripeptide made up of glutamic acid, cysteine and glycine covalently joined end-to-end. Glutathione peroxidase is an enzyme that catalyzes the reaction between GSH and hydrogen peroxide leading to water and oxidized glutathione (GSSH) that is stable.

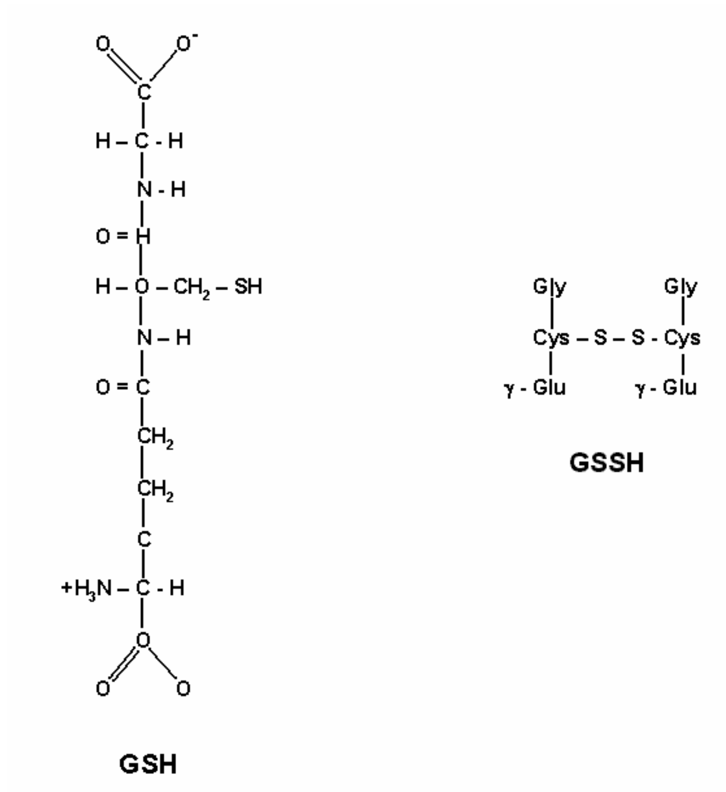


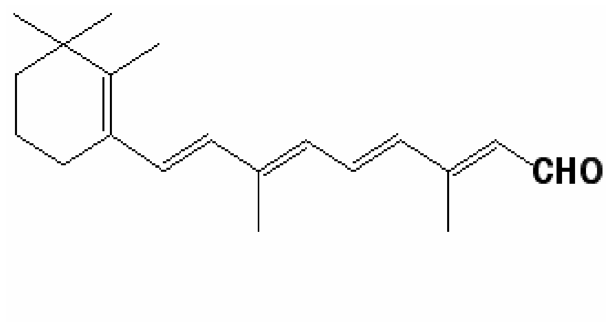
Figure 4

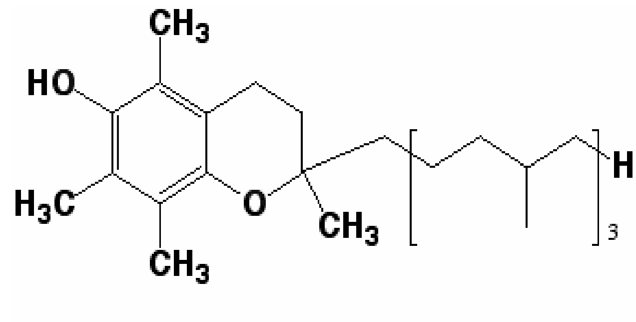
Vitamin E and the carotenoids are the main lipid-soluble antioxidants (fig. 5). Vitamin E is the major fat-soluble antioxidant in cell membrane and can break the chain of lipid peroxidation. Despite the actions of antioxidant nutrients, some oxidative damage will occur and accumulation of this damage throughout life is believed to be a major contributing factor to aging and disease.

Mitochondria and their role in Free Radical Damage

The cell is a complex structure. The mitochondrion is where most of the action takes place. This is the powerhouse of the cell and is where free radicals can do most of their damage.

The mitochondria have an outer and an inner membrane (fig. 6). The inner membrane is arranged in folds called the cristae mitochondriales. In the matrix are strands of mitochondrial DNA and ribosomes.





Vitamin A **α- tocopherol (Vitamin E)**

Figure 5

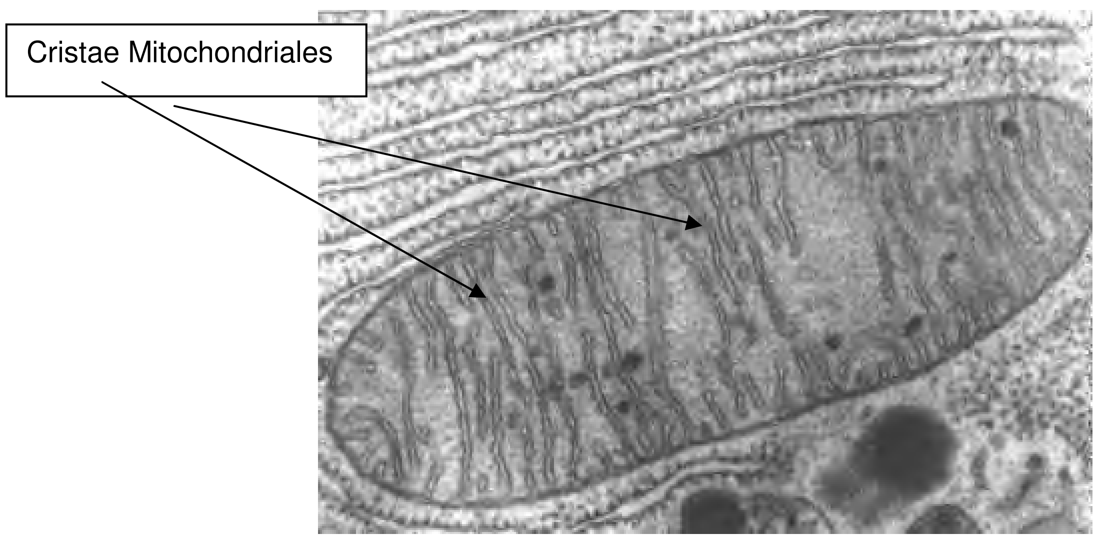


Figure 6

The food we eat is oxidized to produce high-energy electrons that are converted to stored energy. This energy is stored in high-energy phosphate bonds in the form of ATP. The metabolic process goes through the Emden-Meyerhof (Glycolysis) pathway to end in the Kreb's or citric acid cycle. The electron transfer chain is on the cristae where the ATP is produced under the influence of ATP synthase in the form of elementary particles on the cristae. The above explains how the mitochondria run the ATP pump. This is an aerobic process. In the absence of oxygen, one molecule of glucose will yield four molecules of ATP. In the presence of oxygen we get 24 to 28 molecules of ATP from one molecule of glucose going through the Kreb's cycle plus the four molecules from glycolysis. This entire oxidation process taking place in the mitochondria is what makes it more susceptible to the formation and effects of free radicals (fig. 7).

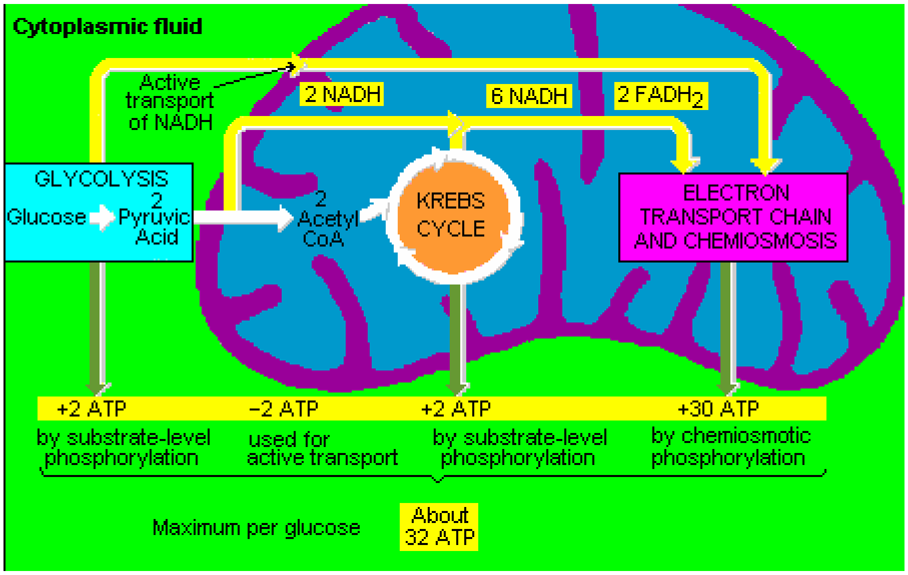


Figure 7

The Electron and its Role in Electric Currents

The oxidative process takes place at a subatomic level with the electron being the main player. Electrons are the smallest of the charged subatomic particles. They fall into a group called Leptons. Electrons have a mass (m_e) of 9.1095×10^{-31} kg (0.51100 MeV/c^2) and charge of $- 4.8032 \times 10^{-10}$ esu (1.6022×10^{-19} C), this being the lowest charge detectable.

The Electrostatic Unit or esu is the unit of electrical charge. Two equal electric charges one centimeter apart and exerting a force of one dyne on each other, each charge is one esu in magnitude.

By knowing the charge of an electron we can see that one esu is equivalent to two billion ($2 \times 10^{9)}$ electrons. Another unit of charge commonly used is the Coulomb (C). One Coulomb is a unit equivalent to three billion (3×10^9) esu or six billion billion (6×10^{18}) electrons. One Ampere (Amp. or A) is one Coulomb per second. Therefore, a current flow of one Amp. is equivalent to the flow of 6×10^{18} electrons per second.

In order for an electric current to flow it needs a pathway called a conductor. Certain materials, such as metals, are better conductors than others. The reason is the ability of a good conductor to propagate the flow of electrons. Copper is an excellent conductor because of the single electron in its outer shell (fig. 8).

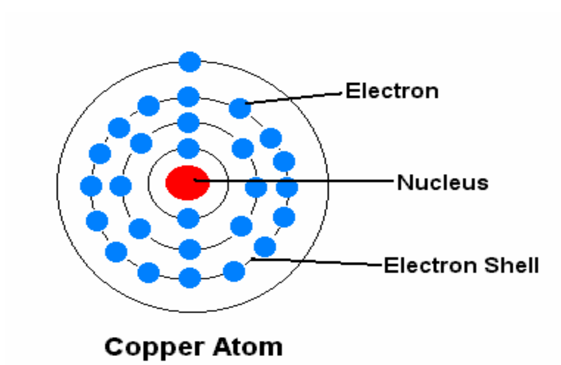


Figure 8

The ease of flow of an electrical current depends not only on the conductive material but also on the size of the current and the width of the pathway. For instance, a current of a constant size, will pass more readily down a wire of wide diameter than it will down a wire of narrow diameter. The narrower wire has a higher resistance.

The same will apply if the diameter of the wire is constant but the size of the current varies. A smaller current will pass more readily than a larger one. Voltage is also required to propagate the current. Voltage is a measure of the electrical potential. Simply put, Voltage is a measure of the electrical pressure trying to force the propagation of current flow. If the resistance increases due to either a decrease in the diameter of the conductor or an increase in the size of the electrical charge the effect will be an increase in the conversion of energy to heat. Applied to the human body this heat can be damaging.

Ultra-low level Microcurrents as Antioxidants.

Ultra-low level microcurrents are those below the milliAmp. range as seen below (table 1).

TABLE 1

milliAmpere (mA) = 10^{-3} A
microAmpere (μA) = 10^{-6} A
nanoAmpere (nA) = 10^{-9} A
picoAmpere (pA) = 10^{-12} A
femtoAmpere (fA) = 10^{-15} A
attoAmpere (aA) =10^{-18} A

Low Level Microcurrents

To see if these ultra-low currents could work as an antioxidant, the model chosen was chronic skin wounds. The reason for this was that most of these lesions are found in debilated patients with poor immune systems who probably have a high concentration of free radicals. Further, the wounds themselves are generally necrotic and infected with poor healing potential again indicating a high concentration of free radicals in the local area. The idea was to isolate the injured area as part of the circuit and thereby infuse a steady stream of electrons through the area with as little resistance as possible. The resistance would be reduced by using a low level current and by increasing the diameter of the conductor. Also, the frequency of the current would have to be low in order to prevent the electrons from traveling in short bursts. A low frequency would allow the electrons to move in a steady stream.

Method

A device* (fig. 9) was used that produced a current range of 3mA down to 100 nA. The frequency used produced a cycle lasting approximately 23 minutes. The device was designed to switch the direction of current flow half way through the cycle. The device runs on a rechargeable battery producing a square wave bipolar current with a Voltage ranging between 5V up to a maximum of 40V. The Voltage range will vary proportionately with the resistance in the tissues. The device will not function if the range goes beyond 40 Volts.

The electrodes are applied (fig. 10) in two layers using tap water as the conducting medium. Water is a very poor conductor of electricity, but the minerals in tap water are sufficient to carry the current into the tissues. Also, the wraps cover a large surface area thus reducing resistance and allowing an optimum number of electrons to flow freely into the tissues.

Patients were treated for approximately 3½ hours per day, five days a week until the lesion had healed. A twelve-week maximum was allowed for healing to take place. All patients were in-patients and were on wound care treatments for at least three months prior to this study, with no observable improvement in their condition.

Figure 9

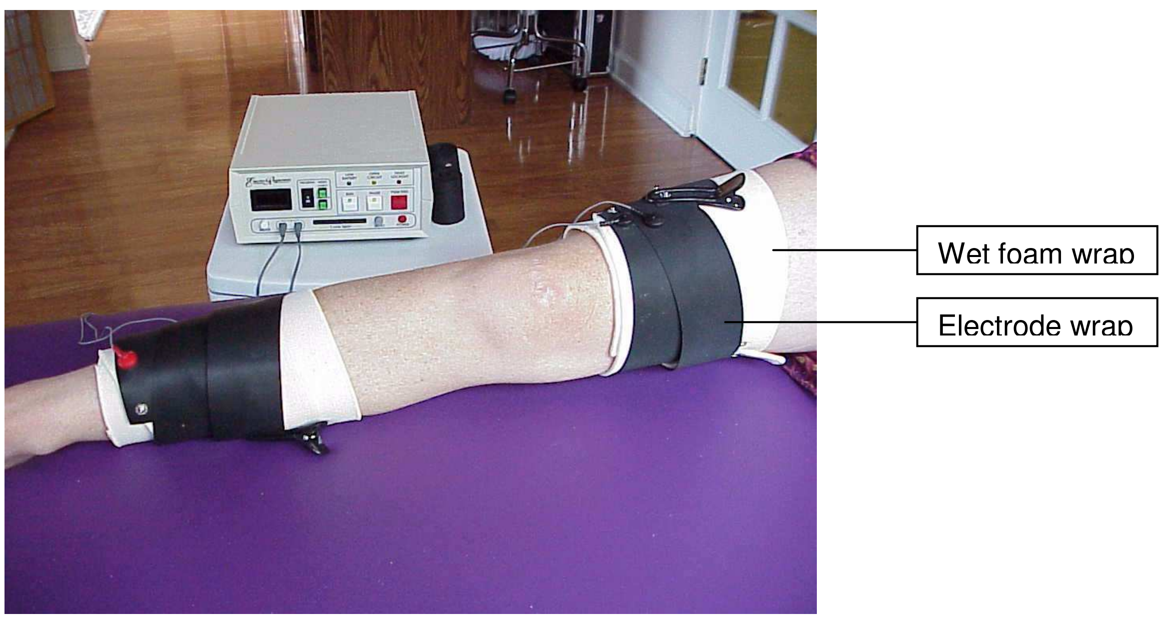


Figure 10

The 25 patients treated had lesions present for an average of 18.5 months. The etiology of the lesions varied (table 2).

For approximately 23 minutes per day the subjects were wrapped with spongy bandages, soaked in water, above and below the wound. Conductive silicone electrodes were then wrapped over these and attached to the device with stud clips (fig. 10). For the first cycle (23 minutes) the device was set at a current output of 3 mA. For the subsequent eight cycles of treatment (approximately three hours) the device was set at an output of 400 nA. Twenty-five chronic wounds were treated. These were present for a period ranging from 3 to 60 months and did not respond to standard therapy. Ages of the patients in the study varied from 20 to 85 years old. Twenty-three of the lesions were stage III or IV.

TABLE 2

AIDS
Arterial Insufficiency
Cerebro-Vascular Accident
Chronic Obstructive Pulmonary Disease
Chronic Renal Failure
Congestive Cardiac Failure
Spinal Cord Injury
Traumatic Brain Injury
Venous Stasis

Etiology of Chronic Wounds

Results

92 % of the lesions were stages III or IV. The age of the lesions varied from 6 to 60 months with an average of 18.5 months.

100% of the lesions healed in an average of 48 hours of treatment, i.e. an average of 16 days.

Some of the results are summarized as follows:

Patient #5 (fig.11a): This patient was a 74-year-old male with diabetes, congestive cardiac failure and chronic obstructive pulmonary disease. This chronic stage IV ulcer of his right heel had been present for 3 years. He had been in hospital for 6 months during which time he had specialized care to the ulcer with no noticeable improvement. The only change to his regular treatment and dressing regimen was the addition of the electrical therapy as described. After 10 treatments over a two-week period there was complete healing of the wound (fig.11b).

Patient #12 (fig. 12a): This patient was a 22 year old male paraplegic with a stage IV decubitus ulcer of his left heel present for over 1 year. The standard wound care over a 5-month period produced no change in the ulcer. After 26 treatments over 6 weeks with the ultra-low current electrical device there was complete healing of the lesion (fig. 12b).

Patient #17 (fig. 13a): This patient was a 53-year-old paraplegic with a stage III ulcer of the right knee present for over 9 months. He had been under his present wound care regime for 3 months with no improvement. After 3 treatments with the ultra-low current electrical device the lesion was completely healed (fig. 13b).

Of the 25 chronic wounds treated, 8 were under the age of 50 years, 7 were between 50 and 70 years old and 10 were over 70.

Rate of wound closure was measured by the reduction of size in square centimeters per day. The rate of closure was then averaged according to the three groups described above, i.e. under 50 years of age, between 50 and 70 and over 70.

Comparison was also made between the length of time the lesion was present and the length of time of treatment.

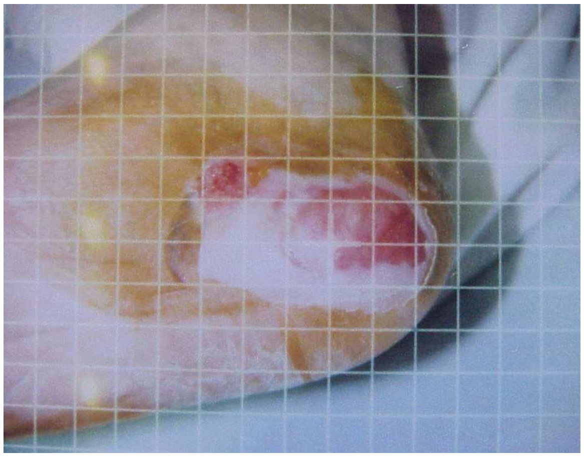


Figure 11a

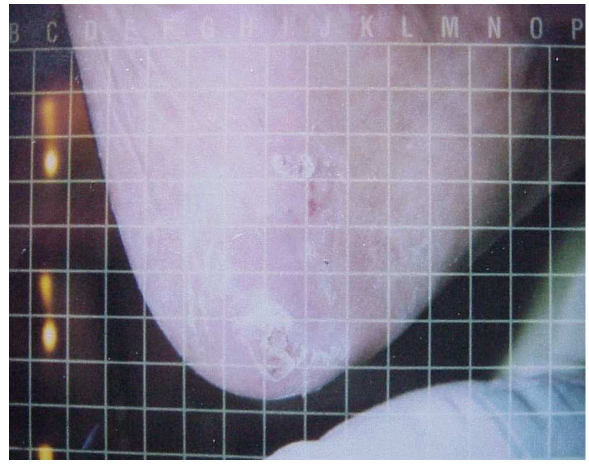


Figure 11b

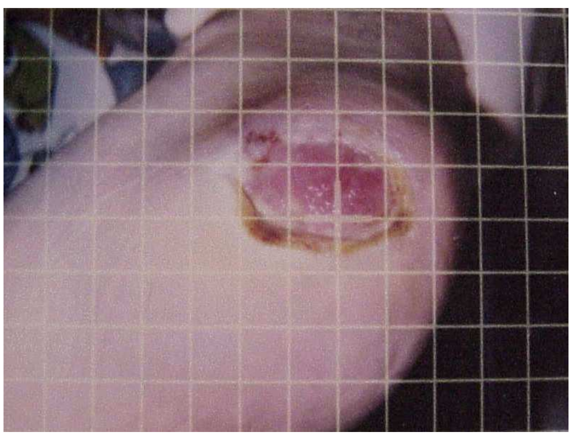


Figure 12a

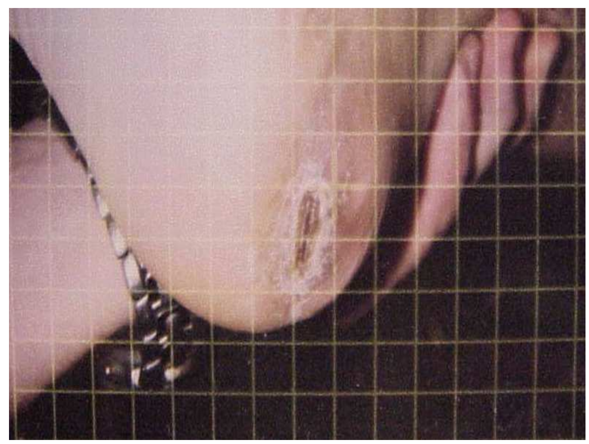


Figure 12b

Figure 13a

Figure 13b

Two of the wounds were rated as stage II, the rest were stage III or IV.

The average rates of healing for the three age groups were (fig. 14):
20 – 50 years of age – 0.74 cm^2/day
50 – 70 years of age – 0.73 cm^2/day
>70 years of age – 0.73 cm^2/day

It was also found that the length of time that treatment was necessary for complete healing was directly proportional to the time of duration of the lesion (fig. 15).

No surgical debridement was performed yet all the necrotic tissue appeared to reabsorb spontaneously and be replaced with healthy granulation tissue and/or skin.

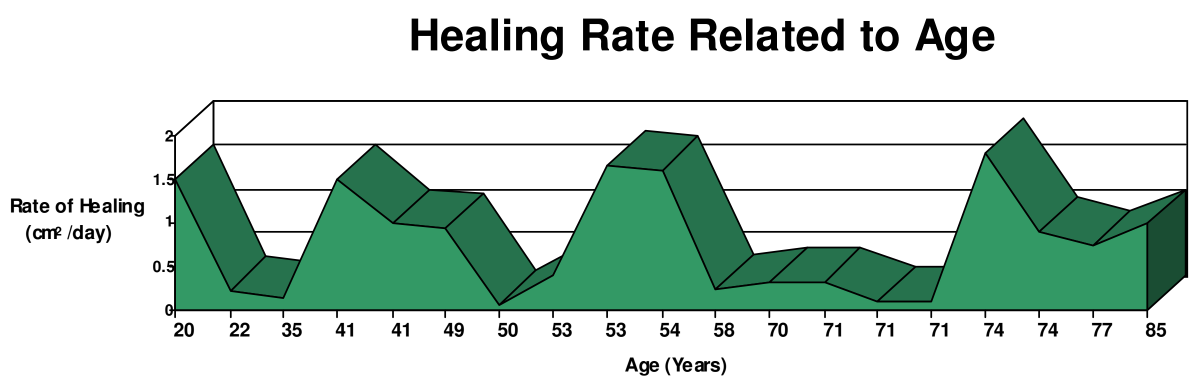


Figure 14

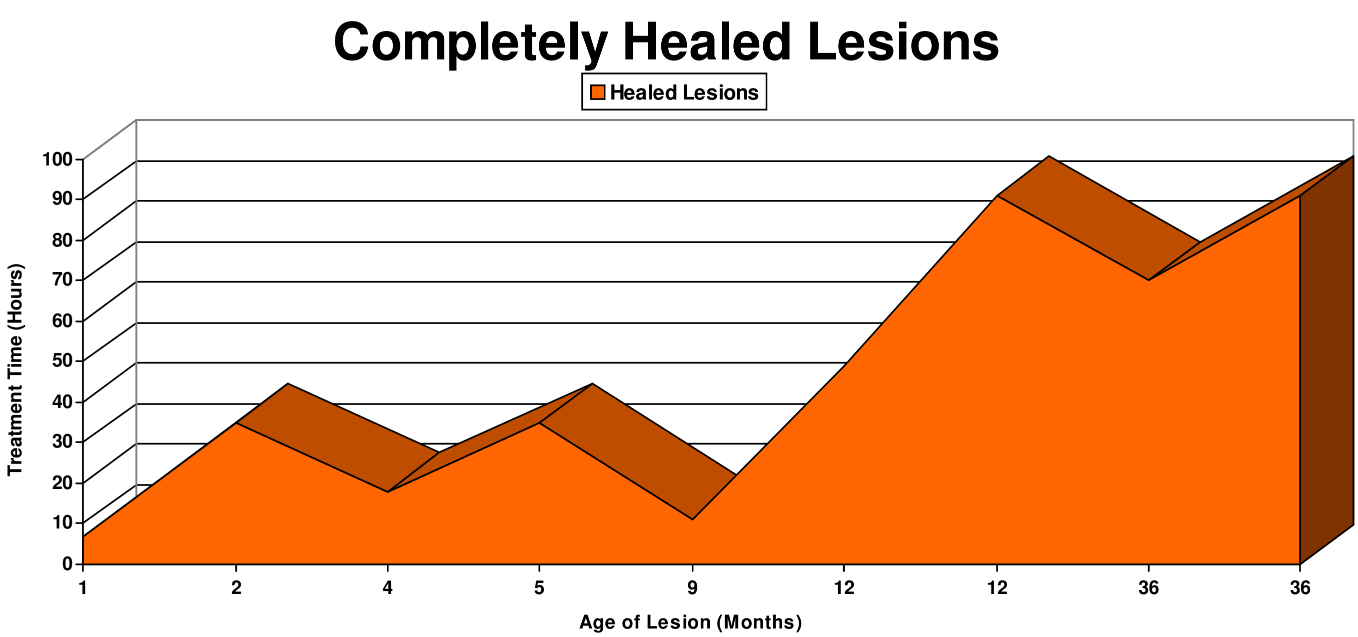


Figure 15

Conclusion

In conclusion, 25 chronic skin ulcers present for an average of 18.5 months and not responding to standard conservative treatment in a hospital setting were treated with the ultra-low current, ultra-low frequency device. 100 % showed response to the treatment. 100 % healed in a maximum time of 7 weeks. Average time of healing was 48 hours of treatment over 16 days. Surgical debridement was unnecessary as the necrotic tissue appeared to disappear spontaneously. The ages of the patients ranged between 20 and 85 years of age. The patients were divided into three age groups, viz., 20 to 50, 50 to 70 and greater than 70 years of age. The rate of healing was measured in cm^2/day. The length of time of treatment was also compared to the duration of the lesion (fig.15).

Many studies have shown that the rate of wound healing of an individual is directly proportional to their age. From this study it can be seen that treating chronic skin ulcers with the ultra-low current device eliminates the age factor by equalizing the healing rate at all ages (fig.14). The only limiting factor in healing time with this method seems to be the duration of the lesion (fig.15). This study therefore suggests that treatment with the ultra-low current device eliminates the restrictions that aging brings to the healing process.

It has also been known that the lower the frequency of an electrical device, the more permanent the effects of that device. This observation was borne out in this study. None of the healed lesions has shown any sign of recurrence to date after a period ranging from six to eighteen months.

From what we know about the effects of free radicals and the mechanism of antioxidants in neutralizing them, we can see a remarkable similarity in the action of the ultra-low currents used in this study. The steady flow of electrons in a relatively low concentration appears to act exactly as one would expect from any antioxidant. The fact that these electrons are focused on a small region of the body may explain why healing changes appeared so rapidly. The actual regeneration of the tissue coupled with the absence of the age factor in healing and the concomitant improvement noticed in the patients' general condition all point to a highly potent antioxidant effect on the local tissues as well as generally.

Further studies need to carried out such as skin biopsies, tensile strength, tissue oxygenation and more accurate assessment of the patients' general condition. A larger double-blind placebo study is being set up at the moment to cover these and other parameters.

I feel that there is enough evidence to show that a low concentration steady stream electron flow produced in the manner described acts as a highly potent antioxidant that can be focused to any area of the body. This study opens a door to studying this type of technology in the many disease processes that are initiated by free radicals.

* The G4 Ultra-low Current device supplied by EPRT Technologies, Inc. (formally Electroregenesis, Inc.), PO Box 278, Pacific Palisades, California, 90272

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