

## **A 30 Year History of the Application of Electric Fields to Verified Successful Tissue Regeneration and Wound Healing**

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The following presentation is a chronology of my personal experience with the use of electrical fields and their effect on living animal tissues as it relates to its sterilization, repair, and regeneration. This includes the control of cellular function and morphology, de-differentiation and re-differentiation.

### **Beginnings**

In the fall of 1973, I was privileged to work in the laboratory of Robert O. Becker, MD, then Chief of Orthopedic Surgery and head of Orthopedic Research at the Veterans Administration Hospital at Syracuse, NY and Upstate Medical Center, State University of New York Medical School. It was at that time that I became acquainted with the nearly 10 year history of Dr. Becker's attempt to understand and manipulate regeneration of lost or damaged tissues and organ systems, by applying electrical fields to the areas of injury.

### **The Salamander**

At the time of my arrival, Dr. Becker had already demonstrated the ability to artificially induce full regeneration of a species of salamander that did not normally regenerate its limbs when amputated through natural mishaps and resulting injury. He had previously noted and demonstrated that in those Salamander species that could spontaneously regenerate not only their limbs, an eye, an ear, and most of their GI track after amputation but had the ability to regenerate nearly 1/2 of their heart and 1/3 of their brain.

Although many researchers had tried to explain this well known phenomenon through biochemical mechanisms, Dr. Becker discovered that in fact, a specific "current of injury" (COI) occurred during the initial tissue damage to a given body part. This current of injury was in the form of a measurable electrical potential generated at the site of injury and was not characteristic of normal potentials observed in undamaged tissue or at the injury site of a species that did not have the ability to regenerate. After the appearance of this current of injury, an embryonic blastema like structure would form, new tissue would develop, and this would result in the complete regeneration of that damaged or missing tissue.

He reasoned that by artificially providing an equivalent electrical potential to that of the naturally observed COI at the site of a mid-forearm amputation of a salamander that did not normally re-grow its forearm, he would induce the formation of a structure resembling a blastema, and document the subsequent regeneration with complete restoration of the limb.

After publishing this result, he went on to apply this concept to young frogs. The hypothesis at that time was that the application of current in the sub-microampere range of 100 to 800 nanoamperes would cause fibroblasts and other related cells to change into a morphologically more primitive cell. This phenomenon, first observed in the nucleated frog erythrocyte, was called de-differentiation. It was further believed that an additional effect was the activating of a primitive nervous system comprised not of discrete neurons but subtle conductive pathways. These pathways were related to the dynamic conductive locations that were observed for approximately one half of the listed acupuncture points in the oriental pre-western medical literature.

It was already known that stimulation of most of the acupuncture points caused changes in circulation at remote areas of the body not directly anatomically related to the site of the stimulation. This in turn affected electrolyte and fluid flow and concentration within different tissue and organ systems.

Becker also showed that the body is electrically polarized such that its center is relatively positive and its periphery relatively negative. During injury, the wound becomes positive with respect to its periphery and thus generates the COI. This micro-current is transmitted through the Schwann and Glial cells intimately associated with the peripheral nerves and provides intercellular communication through electromagnetic signaling.

If the cells were isolated in tissue culture setting, removal of the electrical fields would result in these de-differentiated, primitive cells re-differentiating back into the same specialized adult cell type as they were before the fields were applied. However, if these same cells were de-differentiated and placed in intimate contact with a different type of specialized adult cell, they would undergo a re-differentiation process and become the same specialized cell type as their new neighboring cell. It was therefore concluded that the electro-biochemical environment caused these relatively primitive cells to be transformed by the extra-cellular signaling environment that surrounded them. The tissue structure of an amputated stump in fact resembles a blastema as in the original embryonic development of that animal.

### **The Rabbit Model**

When I arrived in his laboratory in the Fall of 1973, Dr. Becker had some limited success with a rat model and the project that I was assigned to was to attempt to regenerate a mid-forearm amputation in the rabbit. We experimented with a variety of direct current generators, with voltages in the under 1 volt DC range and with currents measured in the nanoampere range. The electrodes used also varied from stainless steel, gold, platinum, to silver.

Our results varied from rabbit to rabbit, but out of 6 rabbits, 2 exhibited extensive re-growth of their limb comprising all tissue types including bone, connective tissue, muscle skin and peripheral nerve. This being said, the structural relationship between the tissue types was not consistent with normal morphology. In addition, growth did not proceed beyond the proximal wrist of the animal.

### **Clinical Studies**

At about the same time, Dr. Becker had been using intramedullary electrodes to sterilize bacteria responsible for osteomyelitis in long bone non-union clinical cases. He found that utilizing a current of 60-100 microamperes over a 12-24 hr period was bacteriocidal for nearly all microorganisms that he encountered. The paper delineating this application was published in the Journal of Bone and Joint Surgery in 1978.

Among some of the non-union cases cited above, were those that involved extensive soft tissue damage. These were from a combination of crush injuries, infected lacerations, third degree burns and tissue deficits caused by tearing, avulsion or pinching forces as seen in animal bites for example. When metallic coated cloth was used as an electrode and placed in intimate contact with the wound surface, a relatively brief bacteriocidal period was observed, followed by the formation of granulation tissue from the inside of the wound growing towards the outside. It is important to keep this observation in mind when we later compare this to Dr. Wendell's electrical generators.

### **Expansion of Clinical Applications**

A number of his students went on to pursue further laboratory studies and clinical applications initially developed by Dr. Becker. In the field of orthopedics, trauma and physical medicine and rehabilitation, Dr. A. Flick and I were among those students.

For the past 27 years, I have developed and refined the use of this approach to not only accelerate and improve wound healing, but enable wounds that do not heal with conventional methods to heal. Acceleration to complete wound healing occurred in one half (1/2) to two thirds (2/3) of the time expected under conventional management and in the cases of significant ischemia and pre-infected wounds, healing occurred in 1/3 to 1/2 the normal time expected. In addition to the soft tissue cases described above, other conditions include failed multiple skin graft sites that were attempted as a result of severe burns, both thermal and electrical, and other physical injuries that caused complete loss of full thickness skin and its supporting connective subcutaneous tissue.

It is noted in these numerous case types that an antimicrobial effect occurs initially and with rapid progression within the first 72 hours of application. It should also be noted that there is an even more rapid analgesic effect of this technique, usually occurring in less than 48 hrs of application. Finally, I have observed that the extent of scarring in these cases was greatly minimized as compared to conventional surgical and medical management of these injuries.

I believe that the mechanism of action in the above described re-growth of tissue and structure is caused by an iontophoretic effect of cations emitted from the electrodes and attaching themselves to proteins and other charged macromolecules within the target tissue. Observationally, this activates the wound bed and causes it to proceed to re-grow and replace the damaged or missing tissue. As to the exact mechanism of action at a cellular receptor level and subsequent intra-cellular activation of transcription and translation, there is no published work that addresses this question and therefore the answer is unknown at this time.

### Limitations

One limitation of this approach is that of access to the treatment site. The antimicrobial, analgesic and granulation tissue formation can only occur when the electrode is in intimate contact with the immediate site of injury. The electrical environmental influences exert their effect over a maximum distance of 1 cm from the surface of the electrode. Beyond that distance, the electrical environmental change necessary to kill microbes and stimulate growth has little if any positive effect.

The second limitation is that stimulation of growth, de-differentiation and re-differentiation can not occur unless there is adequate oxygenation of tissue. This requires that the area in which the wound is located have at the minimum a near normal blood supply. Increasing an already compromised circulation in the vicinity of an injury must be accomplished by other means than the application of electrically active metallic cloth electrodes.

Thus there is a real need for a way to influence damaged, infected and / or ischemic tissue that is not readily accessible by contacting electrodes. Such an approach should ideally include the effect of enhancing circulation, encouraging an inherent improvement of immunological function, and exhibit the positive properties of the metallic cloth electrode system described above. Finally it should do all of this remotely, i.e. the electrical distribution mechanism or electrode system should exert its effect from a distance relative to the location of the injury so that its effect will be accessible to any damaged tissue within the tissue volume of the body part containing the injured site.

### An Alternative Approach

There are a hand full of previously published researchers exclusive of Dr. Becker that have made significant contributions to our understanding of the relationship between inter and intra-cellular function and changes in the electromagnetic micro-environment. These include C. A. L. Bassett, Bjorn Nordenstrom, M. D., and Dr. Richard Borgens,

Prominent among these was Bjorn Nordenstrom and Albert Szent-Gyorgyi. Dr. Nordenstrom describes tissues as consisting of biologic batteries. Thus these create separated charges and the intra-cellular connection of these charges constitutes a closing of the circuit and an ionic flow of electrons.

Albert Szent-Gyorgyi, a 1937 Nobel Prize winner in Physiology and Medicine, appreciated the significance of energy production and resulting electron transfers. He noted the exclusive use of hydrogen as a mammalian fuel, and the way in which cells act as solid state devices in response to changes in their electromagnetic environment. In 1968 he wrote, "No doubt, molecular biochemistry has harvested the greatest success and has given a solid foundation to biology. However, there are indications that it has overlooked major problems, if not a whole dimension, for some of the existing questions remain unanswered, if not unasked. It failed to explain the wonderful subtlety of cellular regulations. Neither did it explain the mechanism of energy transduction, the transduction of chemical energy into mechanical, electric, or osmotic work. These transformations are closely connected to the very nature of life"

He was one of the early pioneering researchers to look outside of biochemistry for mechanisms that could better explain cellular function and repair. He is quoted as saying that: "Discovery consists of seeing what everybody has seen and thinking what nobody has thought."

With this thought in mind, I would like to explain the audience reaction to a lecture presented by Dr. Alfred Koonin at the Los Angeles Gerontological Research Group (LAGRG) hosted by the University of California, Los Angeles (UCLA). Dr. Koonin explained that he was involved in the clinical studies of wound healing utilizing a new micro-current device. This device was among a family of devices invented and developed by Dr. Keith Wendell, who will later present a more detailed discussion of its development and use after this lecture.

Dr. Koonin presented many cases of slowed or intractable healing of ischemic and/or infected wounds that responded to a unique application of DC current. Many of these wounds and related conditions were essentially untreatable by conventional means of medical and surgical management; although none of these cases were previously treated with metallic coated electrodes as had been my practice.

### **Opposition and Skepticism to New Ideas**

Dr. Stephen Coles and I co-founded the LAGRG nearly 14 years ago with its initial mission as follows: "Our goal is to educate our members on the latest progress on theories of aging and their long-term implications for clinical practice." ([www.grg.org](http://www.grg.org)). This goal has been expanded to include all scientific and medical fields of study that seek to understand the underlying mechanisms that control growth, development and aging, including the clinical applications that are subsequently developed from this new understanding.

Thus, we have encouraged the presentation of new and controversial theories and treatments to be held to the highest standards of the scientific method and critical analysis. Equally importantly, we encourage an open minded approach to the evaluation of new ideas so that valuable advances in medicine and scientific research will not be overlooked or underestimated.

In spite of our relatively open minded membership, Dr. Koonin's presentation of a new micro-current device was met with unusually harsh skepticism. Despite numerous photographic examples of extraordinary results as well as references to validation in the hands of reputable, university based physicians and surgeons, many LAGRG members did not appreciate its clinical significance.

I believe that this deep rooted disbelief of electrical applications to clinical practice comes from the massive numbers of claims throughout the last hundred and twenty five years of electrical devices that were purported to cure virtually every illness and disorder. Few of these claims have proven true in the light of randomized double blind studies with efficacy proven in limited applications of physical therapy to relieve pain and muscle spasm. More recently bone growth stimulators have been FDA approved to stimulate areas of non-union in orthopedic fractures.

### **Credibility - What is True and Not True**

There is a basic problem of credibility in claiming that a purely electronic process can be directed to activate cells and tissue, and restore homeostasis after major traumatic or degenerative damage. This concept is totally foreign to most scientists and physicians understanding of the physiological and biochemical basis of function as learned during their educational experiences. It has taken many decades to accept the clinical legitimacy of acupuncture in the United States, but over the last 20 years there is now a recognized acupuncture department or sub-department in every medical school in the country.

Medicine has historically been very slow to accept new ideas even when there is substantial proof of their efficacy. The new concept is generally in opposition to a long held view of how things work and what treatments are effective even when these dogmas have little or no evidence behind them. It is this culture within the medical community that forms one of the significant obstacles to progress. Dr. Wendell's device and the revolutionary concepts that form the basis of their design unfortunately fall into this category.

### **Significant Parallel Observations**

In that my personal experience with the electrical application of very specific modalities had been extensive over the last 25 years, I was one of the few members to realize the significance of this work. After the presentation, I talked at length with Dr. Koonin about his findings with a variety of wound and other clinical conditions and was particularly intrigued by its parallel to my work with the direct applications of electrodes to the site of injury.

Both methods of intervention used direct current in the micro-ampere and lower range, and resulted in these observations when electrical fields were applied:

1. There was an anti-microbial effect within 24 to 48 hours.
2. There was a significant analgesic effect with its onset within 24 to 48 hours.
3. Granulation tissue began forming from the inside of the wound, growing towards the outside skin or subcutaneous surface.
4. There was a rapid epithelialization of cutaneous tissue to replace missing skin as the granulation tissue growth reached the subcutaneous borders.
5. Healing occurred in a fraction of the time that would be normally expected.
6. The resulting healed wound left little or minimal scarring, also unexpected by conventional methods of treatment.

This new method of micro-current therapy had some very distinct advantages that over came the limitations of the metallic electrode method as described above. It was for this reason that I decided to employ two of Dr.Wendell's devices known as the Q4Z in the USA and the Jai for a select number of my patients.

### Case Histories

Two of the most impressive cases that I have observed are present below:

1. Mr. PB was an otherwise healthy 44 yr old male who in February of 2002 suffered a fall from a ladder resulting in a complex fracture of the right tibia and fibula just distal from the tibia plateau. Due to several complications and delays in treatment at a local California hospital the reduced and plated fracture became infected. A lengthy series of intravenous antibiotic courses were instituted and all metal was removed from the fracture site. In the subsequent months that followed, a callus formation failed to materialize and the patient was left with a non-union, dependent on crutches and unable to maintain weight bearing without moderate to severe pain.

In September of 2002, after the local non-union orthopedic specialists from University of Southern California Medical School (USC) had pronounced him un-repairable without additional surgeries, we started on micro-current therapy utilizing the Q4Z and Jai devices. Having baseline and subsequent MRIs and CT scans we have been able to follow his progress. Within the first few sessions we was changes in the post-operative scars surrounding his fractured knee and leg observing increased temperature, pinker color and softening, reflecting increased blood flow. Shortly thereafter, he experienced a reduction of pain and could weight bear on the injured leg for increasing periods of time before pain re-occurred.

As of this writing, MRI's, CT scans and subsequent evaluations for the orthopedic specialists confirm that calcification and bone re-growth in the site of the former non-union has occurred no longer "requiring " surgical intervention. No sign of infection were seen.

2. Mr. RF was a 66 yr old male, with a 30 yr history of adult onset diabetes now insulin dependent who suffered a breakdown of the soft tissue in the right heel and osteomyelitis of the calcaneous. This wound occurred spontaneously without any traumatic event preceding its appearance. Four years prior to this occurrence, he experienced that same event and without the osteomyelitis and it took nearly 1 year of all known standard wound treatments to effect healing. On this occasion he was admitted to Standford University Hospital and vascular surgeons remove extensive soft tissue from the heel and about 1/3 of the proximal portion of the calcaneous leaving a large wedge shape deficit.

Within 2 weeks of treatment with the Q4Z and Jai micro-current devices, the wedge shaped deficit was filling in with granulation tissue and he was able to put weight on the heel without pain. Slides of the progression of this healing process will be shown. Near complete healing and return to normal ambulation occurred in about 90 days.

### Conclusion

These two cases demonstrate the extraordinary effect the Wendell micro-current therapy on improving circulation and acceleration of healing even with pre-existing severely compromised blood flow in the area of injury. We are just beginning to understand the broad scope of applications that this approach can have on a wide spectrum of diseases, disorders and traumatic injuries. Please keep an open mind in this new exciting field of regenerative medicine as more information develops and becomes available in the medical and scientific literature.

References:

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