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what's new in orthopedics

The Current Status of Electrically Stimulated Bone Growth

The use of various types of electrical stimulation to produce bone growth has attracted considerable interest in the orthopedic community. At present the technique is considered experimental only and its use must be in accord with the requirements for human experimentation. An insufficient number of cases have been done to assess objectively or statistically the effectiveness of the procedure. However, animal experimentation and preliminary reports from those centers involved indicate a generally favorable response.* Clinically the conditions that are being treated are those in which inadequate bone growth has occurred, such as congenital pseudoarthrosis of the tibia.

A variety of techniques are being tested at the various centers involved. One technique has been single metallic electrodes inserted directly at the site of desired bone growth. Inserted electrodes that have been tested so far include pure silver wire and stainless steel; different advantages have been shown for each. Regardless of the type of electrode, position or material, a small battery-powered, electronically controlled circuit device is connected externally to the electrodes to deliver a precise amount of current and voltage. In general, most groups have used current as the controlled parameter (the devices then adjust their voltage to deliver the desired current). Current values are low, ranging from 100 nanoamperes (a nanoampere is a billionth of an ampere) to 10 microamperes (a microampere is a millionth of an ampere). A technique is being developed obviating the need for direct electrode implantation. This involves the use of two external wire coils which, when properly powered, produce an induced electrical field at the same site which will similarly stimulate bone growth. Technical refinements are continually being made in the areas of electrodes and types of generating circuits and details consequently are not furnished. At the present time, scientifically valid statements cannot be made concerning the optimum ranges of current and voltage to produce bone stimulation. Besides the obvious possible complication such as infection, there are a number of possible side effects associated with this technique. Electrode breakage can occur if motion occurs between the patient's extremity and any plaster cast that is traversed by the electrode wire. Should the generating devices produce voltages in excess of 1 volt, electrolysis, gas formation, and marked pH changes will occur in the vicinity of the electrodes, principally the positive electrode. Such changes are known to be deleterious to tissue locally. We have found further that when more than one site is to be treated, electrical interference will occur between

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the two circuits and control will be difficult. In the techniques using magnetic fields to induce an appropriate environment, these problems are obviated; however, systemic effects of electromagnetic fields have been described which may possibly restrict the use of this technique.

The general concept of electrically stimulated growth processes is exciting and holds much promise for the future. At present, similar techniques have been experimentally shown to be capable of stimulating the regrowth of joint cartilage in rabbits and the regeneration of major parts of amputated foreleg in rats. Growth retardation has similarly been shown by appropriate use of the technique and this has proven to be clinically useful in controlling bacterial infection in areas of insufficient blood supply such as in osteomyelitis and chronic decubitus ulcers.

While specific techniques and areas of application are still being developed and changing, an understanding of the background of basic research that led to this development is very useful in providing the rationale for all such types of treatment.

One of the basic attributes of living things is their ability to heal injuries by cellular growth. While this ability is present in all animals to a degree, the competency of the process varies enormously. For example, the salamander can regenerate a complete extremity, one third of the brain and half of the heart; such regenerative powers in the human are limited to the ability to regrow very limited portions of the bones in response to fracture. Fifteen years ago I began looking for the differences that enabled some organisms to regenerate compared to others of very closely related types that could not. I found that there were major differences in the electrical phenomena that appeared at the site of the injury. Today we are able to relate these local electrical processes to the operation of a previously undescribed data transmission and control system that functions in concert with the central nervous system, recognizes the injury, and subsequently produces at the site an electrical field that stimulates cells to multiply and replace the injured or absent tissue. In the case of fracture healing, this system functions in concert with certain electrical activity. This electrical activity begins at the time of the fracture and ends (in the human) four to six weeks later. If the fracture has been appropriately reduced and stabilized, healing will be well underway by then. If for some reason the healing processes at each bone end have failed to unite, one will have nonunion. No amount of immobilization will bring about any further healing unless the cells are restimulated. This can be accomplished by surgically freshening the bone ends and grafting (a process that in essence "re-fractures" the bone, thus restarting the electrical growth system) or by some method producing the appropriate environment that simulates that which was present as a result of the initial fracture. So the use of electrical stimulation of bone growth is not magic or a happy accident, but the application of the same biological control system that was put into effect by the original fracture.

Should the technique, in its present limited application, prove to be useful and without side effects, I expect that the future will see such applications as the electrically stimulated regeneration of joint structures and of gaps in long bones, obviating much of the need for prosthetic replacement. Further in the future may well be complete growth control by such techniques, including tumor inhibition as well as the stimulation of the regeneration of damaged tissues such as myocardium and kidney.

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