ACTION OF DIRECT CURRENT ON BONE TISSUE

A. I. Anisimov

UDC 612.75.014.424.4

The effect of a direct current on bone tissue was studied in experiments on rabbits. Passage of a current of 15-20 μA through bone stimulates osteogenesis in the region of the cathode compared with the control (symmetrical bone of the same rabbit with implanted nonfunctioning electrodes), and in the case of fracture it promotes faster consolidation than in the control.

KEY WORDS: direct current; osteogenesis.

Fakuda and Yasuda [7] recorded the appearance of electrical potentials in bone during mechanical loading. Later, potentials were found in bone tissue not only in association with microdeformation, but also in the absence of external mechanical stimulation [4-6]. Friedenberg et al. [5, 6] and Akhalaya et al. [1] showed that if the continuity of bone is destroyed its potentials change sharply in the character of their distribution and their magnitude. These investigations, with others performed on regenerating amphibian limbs [2], suggested that electrical forces play an important role in growth and structural organization of bone tissue. Work has recently been published in which an attempt was made to use the available information on the electrophysiology of bone as the basis for its subjection to various procedures, but the results were contradictory for several reasons (difference in the character and magnitude of the stimulus used, ranging from units to thousands of microamperes, absence of a valid control, impossibility of introducing corrections and controls for the parameters of the current, which varied in the course of the experiment, leading to insufficiently strict experimental conditions, and so on). For example, Pawluk and Bassett [8] observed marked stimulation of osteogenesis in the region of the cathode and resorption of bone at the anode, whereas Cieszynski [3] obtained directly opposite results.

Considering the clinical importance of the problem of regulating osteogenesis it was decided to undertake the present investigation with the aim of clarifying the character of the action of a weak current on intact and injured bone under standard, controllable conditions.

EXPERIMENTAL METHOD

Experiments were carried out on 29 adult rabbits after simultaneous insertion of electrodes (gold and platinum) through all layers of the skin into the medullary canal of the right and left radius under aseptic conditions. The electrodes were fixed with sutures to the ulna. The proximal part of the electrodes and the connections between the electrodes and the leads were insulated with Norakril varnish. The leads were taken subcutaneously and brought out in the interscapular region, where they were connected by miniature connectors to a source of direct current consisting of 2 FBS cells connected in series and a variable resistor. The stimulator was fixed to a plaster of Paris collar around the animal's neck. Stimulation was carried out for 24 h daily, the parameters of the current were monitored each day, and if necessary the strength of the current was corrected. In some rabbits only one active electrode was inserted into the bone and the second (made of electrically conducting rubber, was applied to the skin. Osteotomy of the middle part of the radial diaphysis (experimental fracture) was performed on 13 rabbits; the ulna was left intact and served as a splint. The symmetrical ulna, with implanted electrodes and leads,

Laboratory of Pathophysiology, R. R. Vreden Scientific-Research Institute of Traumatology and Orthopedics, Leningrad. (Presented by Academician of the Academy of Medical Sciences of the USSR, P. N. Veselkin.) Translated from Byulleten' Éksperimental'noi Biologii i Meditsiny, Vol. 78, No. 9, pp. 100-102, September, 1974. Original article submitted November 23, 1973.

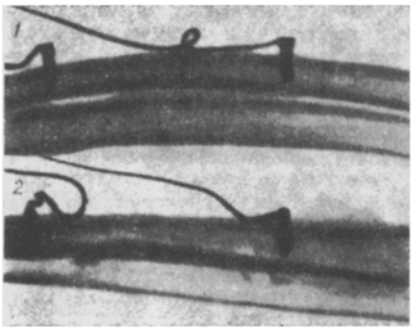

Fig. 1

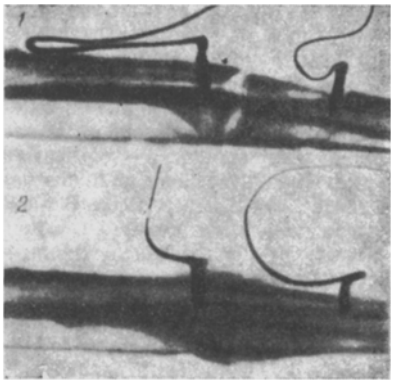

Fig. 2

Fig. 1. Roentgenograms of right (1) and left (2) forearm of a rabbit with electrodes implanted into the radius (3 times): 1) control; 2) current of 20 μA applied to the electrodes for 5 weeks: excessive periosteal osteogenesis can be seen in the region of the cathode.

Fig. 2. Roentgenograms of the right (1) and left (2) forearm of a rabbit 5 weeks after transverse osteotomy of the radius: 1) control; the plane of the fracture can be seen throughout its length; 2) a current of 20 μA applied from a cathode in the region of the fracture: bony callus is present at the site of the previous osteotomy.

but not connected to the stimulator, served as the control. In animals with an experimental fracture stimulation began on the day after the operation, but in other animals it began after healing of the operation would, i.e., 8-10 days after the operation. The effect of the current on the bone tissue was monitored by roentgeongraphy (usually with enlargement of the roentgenograms) and clinical methods, supported by macroscopic examination of the limb tissues post morten.

EXPERIMENTAL RESULTS

Passage of a current stronger than 100 μA (150-1200 μA) through electrodes implanted into the intact bone had a marked destructive action on the bone tissue (amounting sometimes to charring) 10-14 days after the beginning of stimulation. Observations on these rabbits showed that they quickly became adynamic and avoided touching the floor with the injured paw. At autopsy changes indicating aseptic necrosis were found in the tissues. The action of the cathode and anode on bone in the animals of this group could not be differentiated. Meanwhile a current of 4-6 μA caused no reaction in the bone tissue. A current of 15-20 μA had the most marked action. In the region of the cathode 10-14 days after the beginning of stimulation a periosteal reaction developed, but none was found at the anode or at the electrodes on the control limb. Considerable proliferation of bone was observed roentgenologically in the region of the cathode 4-6 weeks after the beginning of stimulation, but no such reaction was present in the region of the anode (Fig. 1). On macroscopic examination an osteophyte, sometimes reaching as far as the skin, could be seen in all of eight rabbits. No macroscopic changes were found in the region of the anode. The reaction around the electrodes was virtually absent in the control limbs.

In 13 rabbits the action of a direct current of 15-20 μA on the course of an experimental fracture of the radius was investigated. If a current of negative polarity was applied to the electrode located near the osteotomy, healing of the fracture took place faster than in the control limb (Fig. 2). Whereas in the control the first roentgenologic signs of healing (a periosteal reaction) appeared after 2.5-3.5 weeks, in experimental limb they were found on the average 1 week earlier, and bony callus was formed on the average 2 weeks earlier. In some cases the anode was applied to the skin and the cathode in the bone. Under these conditions also an effect of stimulation was found. Acceleration of consolidation was also observed if the cathode was placed not by the fracture but 20-30 mm away from it. Quickening of healing of the fracture by the action of a current of negative polarity, compared with the control, was observed in 7 of 8 rabbits ($P < 0.05$ with respect to the criterion of signs). If the anode was placed in the bone and the cathode on the skin, no acceleration of healing was observed and in 2 of the 5 rabbits the fracture did not unite, although it did so in the control limb.

It can thus be concluded that a direct current of 15-20 μA induces the stimulation of osteogenesis in the region of the cathode and, in the case of a fracture, it shortens the period of consolidation. The effects observed require further study.

LITERATURE CITED

1. M. G. Akhalaya, K. A. Zakaraya, and M. S. Kakiashvili, Ortoped. Travmatol., No. 9, 41 (1971).
2. R. O. Becker, J. Bone Joint Surg., 43, 643 (1961).
3. T. Cieszynski, in: Callus Formation, Symposium on the Biology of Fracture Healing, Budapest (1967), p. 269.
4. R. Dyer and Z. B. Friedenberg, J. Bone Joint Surg., 52A, 599 (1970).
5. Z. B. Friedenberg and C. T. Brighton, J. Bone Joint Surg., 48A, 915 (1966).
6. Z. B. Friedenberg, R. Dyer, et al., J. Dent. Res., 50, 635 (1971).
7. E. Fukada and I. Yasuda, J. Physiol. Soc. Jap., 12, 1158 (1957).
8. R. Pawluk and C. A. Bassett, Calcified Tissue Res., Suppl., 4, 120 (1970).