MECHANISM OF THE STIMULATING ACTION OF AN ELECTRIC CURRENT ON REPARATIVE REGENERATION OF BONE TISSUE

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The dynamics of the ATP concentration in regenerating bone tissue was studied in experiments on rabbits after incomplete osteotomy or resection of a piece of bone and also during stimulation of reparative osteogenesis in the region of a bone defect by means of a pulsed electric current. The ATP concentration in the callus after incomplete osteotomy and during electrical stimulation was found to be higher than in regenerating bone tissue after resection of the bone fragment in the absence of stimulation. It can be concluded that improvement of the energy supply for fracture healing is an important factor in the mechanisms of the stimulating effect of an electric current on reparative regeneration of bone tissue.
KEY WORDS: reparative regeneration; stimulation; healing of fractures.

Many studies of the stimulating effect of a weak electric current on reparative regeneration of bone tissue have been published in recent years. However, the mechanism of this effect has not previously been studied, and the only pronouncements on this subject are hypothetical in nature [4, 5, 8, 10, 11]. An important contribution to the study of this problem could be to obtain information on changes in the metabolism of regenerating bone tissue under the influence of a weak electric current. However, no such observations have yet been published.

The character of the tissues which occupy a bone defect during reparative regeneration is known to depend on the state of the local tissue metabolism [9], which, in particular, determines the supply of energy for the process of reparative osteogenesis.

The object of this investigation was to study the dynamics of the concentration of ATP, the universal source of biological energy, in regenerating bone tissue during reparative regeneration and changes in this index under the influence of electrical stimulation.

EXPERIMENTAL METHOD

Incomplete osteotomy was performed in the middle third of the radius in the rabbits of one group and 0.5 cm of the diaphysis of the radius was resected in the same region in the rabbits of another group. The last model also was used in the third group to study the stimulating effect of a pulsed low-frequency electric current with a strength of 8-10 μA, applied to electrodes inserted into the region of the fracture. Full details of the experimental method were given previously [1-3]. Observations on the animals continued for three weeks after injury.

Tissue located in the defect between the fragments was taken for investigation. The ATP concentration was determined by the method described in [6, 7] and expressed in milligrams percent per gram of the test tissue.

EXPERIMENTAL RESULTS

On the seventh day after trauma the ATP concentration in the animals receiving electrical stimulation after resection of a fragment of diaphysis reached 260 mg %. In experiments in which stimulation was not

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applied after resection the ATP concentration varied between 89 and 102 mg %/g test tissue. In the animals with incomplete osteotomy the ATP concentration reached 148 mg %.

Two weeks after the operation the mean ATP concentration in the animals receiving electrical stimulation was 69 mg %, with fluctuations from 49 to 96 mg %/g callus tissue. In the absence of stimulation the ATP concentration was lower, with a mean value of 43.25 mg % and fluctuations from 41 to 55 mg %. During primary healing of the bone defect the ATP concentration was higher, with a mean value of 85.3 mg % and fluctuations from 75 to 94 mg %. In this period, in all three cases the ATP concentration was thus lower than the corresponding values for the previous period.

Three weeks after trauma mainly a further decrease in the ATP concentration in the bone callus was observed. At the same time, the ATP concentration still remained dependent on the type of injury and on the presence or absence of stimulation of regeneration. For instance, after incomplete osteotomy of the radius the mean ATP concentration was 19.5 mg % with fluctuations from 17 to 22 mg %/g callus tissue, although in individual cases it was as high as 70 mg %. In animals undergoing resection of a fragment of the radius the mean ATP concentration was 14.3 mg %, with fluctuations from 13 to 15 mg %. Meanwhile, during electrical stimulation of reparative osteogenesis the ATP concentration in the callus was higher than the figures just given, with a mean level of 38.7 mg % and fluctuations from 20 to 73 mg %. In individual experiments the ATP concentration reached 140 mg %.

The results thus show that the ATP concentration in regenerating bone tissue depends on the character of healing of the bone wound and, consequently, as is confirmed by data in the literature, on the state of the local tissue metabolism. The aerobic type of carbohydrate oxidation, the most efficient type from the energetic point of view, is more strongly represented after incomplete osteotomy than after resection of a fragment of bone, when bone formation takes place against the background of chondro- and fibrogenesis. As the writers showed previously [1-3], the stimulating effect of a pulsed electric current on reparative osteogenesis is manifested as an increase in the quantity of bone in the callus and a correspondingly weaker development of cartilage and fibrous tissue. The study of the dynamics of the ATP concentration and its comparison with the character of healing of the bone wound demonstrate that the ATP concentration after incomplete osteotomy is always higher than during healing of a bone defect. The method of electrical stimulation used, leading to an increase in the ATP concentration in the regenerating bone tissue, improves the supply of energy for the healing of the bone wound.

It can thus be tentatively suggested that an improvement in the energy supply for the process of fracture healing is an important factor in the mechanism of the stimulating action of a weak electric current on reparative regeneration of bone tissue.

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