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ELECTRICAL STIMULATION IN DELAYED UNION OF LONG BONES

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The role of electricity in the promotion of fracture union of long bones in human beings requires further investigation. An electric stimulator was devised through which 15 μA current was applied to the fractured long bones of 20 patients with delayed union. The best results were obtained in cases where the negative electrode was introduced at the fracture site and the positive electrode was placed proximal to the fracture area. In 90 per cent of cases treated by different methods in this series, union occurred within an average period of 9¼ weeks. The rate of infection following introduction of the electrodes for electrical stimulation was 20 per cent.

Key words: delayed union; electrical stimulation; human beings

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Friedenberg & Brighton (1966) measured the resting potentials of fractured bone in rabbits. They found that the metaphysis had a negative potential in relation to the diaphysis. Following fracture of the shaft of the tibia, the diaphysis became negative in relation to the epiphysis and the metaphyseal potential also became more negative. The negativity of the diaphysis remained until the fracture united, after which the potential returned to normal.

Bassett et al. (1964) implanted iridium electrodes on dog femurs and observed the formation of extensive callus at the cathode within a period of 15 days using a 10–100 μA current. An increased number of young mesenchymal cells and osteoblasts were found around the cathode. At the positive electrode a brownish material consisting of denatured protein was found.

Brighton & Alfred (1972) attributed the increased callus formation to the increased alkalinity and the low oxygen tension in the cathode area. He observed that the oxygen tension remained low during the phases of healing and later returned to normal when the fragments consolidated. Low oxygen tension led to calcium release from the mitochondria of cartilage cells and it initiated the pluripotential cells to differentiate into osteoblasts and chondroblasts.

Friedenberg et al. (1970) found that 5–20 μA was the optimum strength of the current. Bone destruction occurred when the current was raised to 40–50 μA. Cieszynski (1963) observed that a positive potential increased the breaking strength of rabbit bone, while a negative potential did not improve healing. Friedenberg (1971 a) and Lavine et al. (1971) reduced the period of immobilization of fractures in rabbits by electrical stimulation.

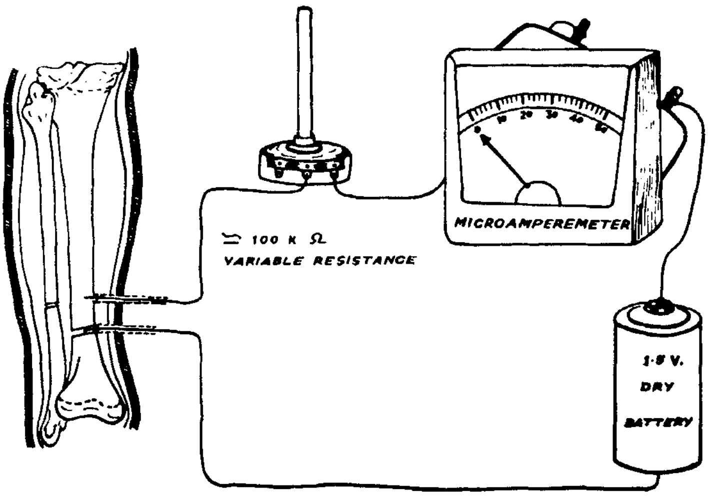

Figure 1. Diagram of the electrical circuit for electrical stimulation of bone.

Even in human beings electrical stimulation has been used successfully. Friedenberg (1971 b) achieved union in a case of non-union of the medial malleolus. Levine et al. (1972) reported union in a case of congenital pseudarthrosis of the tibia. Jorgensen (1972) has published the largest series having employed electrical stimulation in 24 cases of tibial fractures. He used a direct current of 20–100 μA in addition to alternating current and found that the consolidation time was reduced by 30 per cent. Soft tissue necrosis and infection occurred at the anode in a few cases.

METHODS

Stimulator. The electrodes were made from 28 gauge stainless steel wire insulated with polythene tube, which was sealed over the wire, the ends being left bare. A trephine and cannula were used for inserting the electrodes.

The circuit was made up of 28-gauge insulated copper wire; 1.5 V dry battery; 0–100 kΩ variable resistance (used in radio sets as a volume regulator); microampere meter with a scale of 0–50 μA.

The variable resistance and the microampere meter were connected in series with the positive end of the battery, while the negative end was connected directly to the electrode using 28 gauge insulated copper wire (Figure 1). The whole of the circuit except the microampere

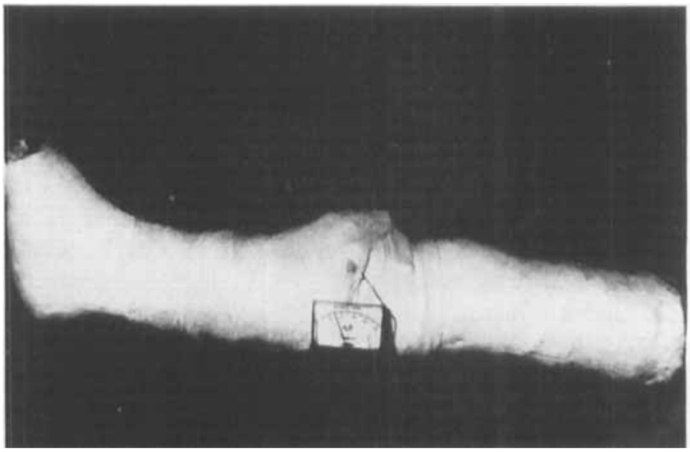

Figure 2. Microampere meter connected to the electrical circuit placed inside the plaster.

meter was fixed to the plaster (Figure 2). The microampere meter was used to check the strength of current flowing in the circuit. The current strength was kept constant by altering the resistance during the periodical checkups.

PATIENTS

In the present series, 20 cases of delayed union were studied and followed up (Table 1).

Table 1. Electrical stimulation in 20 cases of delayed union.

Bone	No. of patients	Percentage
Tibia	16	80
Humerus	1	5
Radius and ulna	3	15

All the patients had pain elicited by bending stress near the fracture site and 12 of them had slight mobility of the fragments. Only cases of delayed union with a minimum of 5 months duration and with no radiological evidence of established non-union were included in the series (Table 2).

Table 2. Interval between the time of injury and the beginning of electrical stimulation.

Interval (months)	No. of patients	Percentage
Up to 5	6	30
5–10	10	50
11–15	2	10
16–20	nil	—
Above 20	2	10

Four patients had a mild infection before starting the electrical stimulation.

RESULTS

The patients were divided into three groups (Table 3 and Figure 3). 15 μA current was given in each case. The preliminary assessment was made after 8 weeks of electrical stimulation.

Group A. In all four patients the electrodes were placed with one proximal and one distal to the fracture site. All united in the course of 8 to 12 weeks.

Group B. In this group, the positive electrodes were inserted proximal to the fracture site and the negative electrodes were inserted at the fracture site. Out of 12 patients treated in this group, 10 united within 8 weeks. In one, the electrodes were removed too early as a result of which the plaster immobilization had to be prolonged for another 4 weeks increasing the healing time to 12 weeks. The remaining fracture did not unite because the patient started weight-bearing too early. Bone grafting had to be performed in this case.

Group C. In four patients of this group the negative electrodes were inserted at the fracture site while the positive electrodes were left in the adjacent soft tissues. One united within 8 weeks, two needed further stimulation for 2½ weeks and one failed to unite due to gross infection.

Out of a total of 20 cases, 18 united within an average period of 9¼ weeks of electrical stimulation, while two cases failed to unite.

The period of hospital stay was 3–30 days in 18 cases. Two cases had to stay for longer periods due to infection.

Complications

Infection. Out of 20 cases, four became infected. One of these failed to unite due to the infection.

Loosening of electrodes. In four cases the electrodes were pulled out while dressings were being changed; they were reinserted.

Metallic corrosion of electrodes. The corrosion occurred at the anode, leading to longitudinal splitting and occasional breaking of the wire.

In a few cases the uninsulated part of the wire turned black.

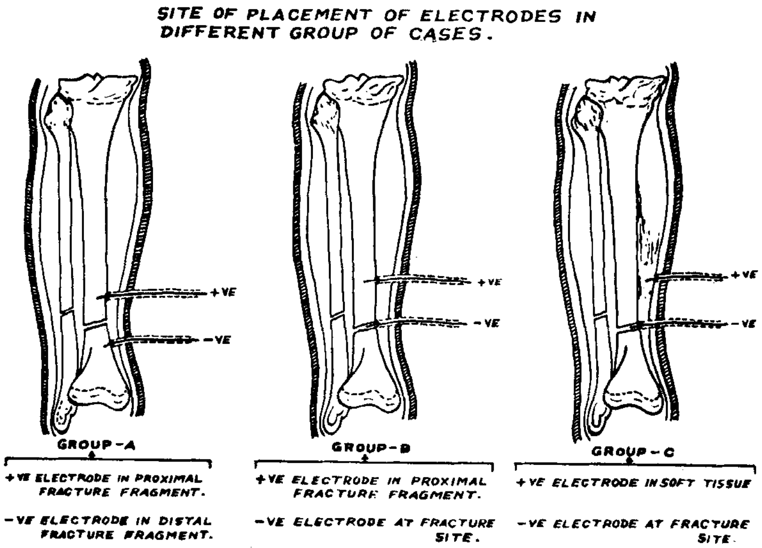

Figure 3. Diagram showing the placement of the electrodes in the three groups (A, B, C).

Table 3. Results of electrical stimulation.

Group	No. of cases	Average strength of current (μA)	Duration of electrical stimulation (weeks)	Results		
				Radiological union in 8 weeks	Radiological union in 12 weeks	No union within 12 weeks
A	4	15	8	–	4	–
B	12	15	8	10	1	1
C	4	15	8	1	2	1

DISCUSSION

The present study was based on clinical as well as radiological findings. It demonstrates that union may result from electrical stimulation in otherwise indolent cases of delayed union. The negative potentials were induced in a relatively inactive area at the site of delayed union in order to cause acceleration of cellular activity. In 90 per cent (18/20) of the cases treated in the various groups in this series union was achieved in an average period of 9¼ weeks.

Union in group A cases in this series confirmed the findings of Lavine et al. (1972) and Jorgensen (1972) but at the same time contradicted the findings of Friedenberg (1971 b), who failed to obtain acceleration of union in patients comparable with those in group A of this series. This discrepancy of results could be due to the short period of electrical stimulation used in the cases described by Friedenberg. Although union was obtained in all group A cases of this series, it took a longer time (12 weeks) than in B and C groups (8 weeks).

Results were found to be better in cases, where the cathode was placed at the fracture site (groups B and C). Best results were observed in group B, where the positive electrode was inserted proximal to the fracture site and the negative at the fracture site itself. This is in agreement with the findings of Friedenberg. The strength of current used in this series (15 μA) in all cases gave satisfactory union with no unfavourable effects on bone substance.

The infection rate in this series was 20 per cent (4/20). Two of these were superficial. Osteoporosis of the distal tibial fragment as reported by Jorgensen (1972) was not seen in this series. The feeling of warmth at the site of introduction of the electrodes was noted in a few cases in the initial stages.

Conclusions

1. Negative potentials can promote the union of fractures in cases of delayed union.
2. In 90 per cent of cases treated by various stimulation methods, union occurred in an average period of 9¼ weeks.
3. The best results were obtained when the negative electrodes were placed at the fracture site and the positive electrodes in the proximal fragment.
4. The morbidity and hospitalization period was considerably reduced.

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