Treatment of nonunited scaphoid fractures by pulsed electromagnetic field and cast

Thirty-five of 44 nonunited scaphoid fractures that were at least 6 months old healed in a mean time of 4.3 months during pulsed electromagnetic field (PEMF) treatment using external coils and a thumb spica cast. The mean time from the onset of the fracture to treatment was 40 months. No concurrent operation was performed. Follow-up time averaged 8.4 months. Eight of nine fractures with avascular necrosis healed. Five of eight fractures in the proximal third healed. Twelve (75%) of 16 patients treated in short-arm thumb spica casts and PEMF healed versus 22 (92%) of 24 patients treated initially in long-arm thumb spica casts and PEMF. We have found PEMF to be a reliable alternative method of treating nonunited scaphoid fractures. Because of the low risk, simplicity of use, and reliability, we recommend its consideration in the treatment of undisplaced, nonunited fractures without carpal instability less than 5 years after the injury. Treatment should initially begin with a long-arm cast. (J Hand Surg 11A:344-9, 1986.)


Nonunion of the scaphoid continues to represent a challenge to the surgeon who treats hand injuries. There are many treatment modalities advocated, including benign neglect, casting, wrist denervation, bone grafting, internal fixation with compression screw, radial styloidectomy, excision of proximal pole, proximal row carpectomy, scaphoid replacement arthroplasty, wrist arthrodesis, or combined scaphoid replacement arthroplasty and limited carpal arthrodesis. No one method is suitable for treatment of all nonunited scaphoid fractures; therefore, a variety of methods must be included in the surgeon's armamentarium. Better results are achieved if union can be obtained before the development of carpal collapse and posttraumatic arthrosis.

Although the mechanisms of action on tissues are not fully understood, electrical treatment of nonunited fractures of long bones has been successful in about 80% of patients. The rate for successful union of tibias has been as high as 87%. There are two widely used but different concepts for electrical treatment of nonunions. One concept has a constant, direct 20 microampere current delivered to one or more cathodes, which are implanted directly at the fracture site, from either an "invasive" (the cathode, anode, and battery are implanted through a surgical procedure) or "semi-invasive" system (cathodes...
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Fig. 1. This method places inductive electromagnetic coils on opposite sides of the fracture site. These coils supply a 15 Hz pulsed quasirectangular electrical signal.

are drilled percutaneously across the fracture site, and the anode is a pad on the skin surface). The second concept uses a totally noninvasive system that involves placement of two electromagnetic coils outside the cast with an alignment block incorporated into the cast to center the coils over the fracture site (Figs. 1 and 2).

Although an equivalent success rate has been reported for treatment of nonunited fractures by each of the three methods, a distinct advantage of the pulsed electromagnetic field (PEMF) is that it requires no surgical procedure, it can be performed in the office, and there is no danger of introducing infection. The first report of treatment of scaphoid nonunions with an electrical field used an AO compression screw and a parallel Kirschner wire inserted into the scaphoid; both were connected to a transformer, which generated an electrical alternating current field. A 79% union rate was reported with this method, and a 60% union rate with the screw-only method. Bora et al. reported healing of 12 (71%) of 17 using the semi-invasive method on nonunited scaphoid fractures. He stated that avascular necrosis was a contraindication, but that a previous bone grafting procedure was not a contraindication.

This article presents a retrospective study designed to evaluate the efficacy of noninvasive PEMF in the treatment of nonunited fractures of the scaphoid.

Materials and methods

We reviewed all of the cases of nonunited scaphoid fractures that we treated with the PEMF system* from 1979 through 1984. We examined patients' records and information was obtained by means of a standardized protocol. To be included in this study, the scaphoid fracture had to be nonunited and at least 6 months old, regardless of previous treatment methods, with no surgical procedures having been performed during or just before initiation of PEMF treatment. None of our patients had collapse of the scaphoid or degeneration of the periscaphoid joints. Three patients showed loss of carpal alignment. This series represents consecutive cases treated by us following a standardized protocol. PEMF coils were centered over the scaphoid (Fig. 2) and attached to either a long-arm thumb spica cast or a short-arm thumb spica cast.

There were 50 patients initially treated. Three patients failed to return for follow-up examination after immobilization was stopped and the electrical treatment coils were removed. Although their fractures had healed these patients were excluded from our final study. There were three additional patients who received inadequate treatment of 2 months or less (this did not conform to our protocol), and they were also excluded from the study. All of the remaining 44 patients were followed until their fractures healed, or until this method of treatment failed. There were 41 male and 3 female patients in this group. Their ages ranged from 14 to 46 years,

Fig. 2. The electromagnetic coils are attached by a Velcro strap over a thumb spica cast and applied to a patient with a scaphoid nonunion. The box transforms 110 volt AC line current to the proper pulsed signal. The patient wears the apparatus 8 to 10 hours a day.

*Bi-osteogen, System Electro-biology Inc., Fairfield, N.J.
with a mean age of 25 years. In 8 patients the fracture was localized to the proximal third of the scaphoid, in 33 patients to the middle third, and in 3 patients to the distal third. Nine patients had had one previous bone graft and two patients had two bone-grafting procedures before PEMF treatment was initiated. Nine patients had x-ray evidence of avascular changes of the proximal fragment. The length of time from injury to PEMF treatment ranged from 6 to 241 months with a mean of 40 months. All of the patients who were included in our final study were examined from 1 to 33 months, with a mean of 8.4 months, after immobilization and electrical treatment was stopped.

Results

The fractures healed in 35 (80%) of the 44 patients, as shown in Fig. 3. Five (62.5%) of the eight fractures in the proximal third of the scaphoid healed and 30 (83%) of the 36 fractures in the middle and distal thirds healed with electrical treatment. Fractures of eight (89%) of the nine patients who had avascular necrosis before treatment healed. Eight (73%) of the eleven patients who had undergone previous bone-grafting procedures healed. The mean duration of electrical treatment and casting was 4.3 months, with a range of 2.5 to 9 months. Only four patients had PEMF treatment for longer than 6 months.

Fig. 3. Uncomplicated healing of nonunited scaphoid with PEMF. A, Unhealed proximal third fracture 6 months after injury. B, Eight months after fracture when PEMF began. C, Appearance 3 months after beginning PEMF. D, Eight months later.
In four patients, records failed to indicate whether above-elbow or below-elbow immobilization was used. Of the remaining 40 patients, healing occurred in 12 (75%) of the 16 who were treated in a short-arm thumb spica cast and in 22 (92%) of the 24 patients who were treated initially in a long-arm thumb spica cast. The duration of long-arm cast immobilization ranged from 4 to 20 weeks, with a median of 6 weeks and was followed by below-elbow immobilization for the balance of the PEMF treatment.

Of the 35 patients with healed fractures, 33 returned to their pre-injury work, 11 to heavy labor, 13 to moderately strenuous work, and 9 to light work. One patient who performed heavy labor was not able to resume his previous occupation, and in one patient this information was unknown.

At follow-up on the patients with healed fractures, wrist extension had a mean of 85.3%; flexion, 93.1%; radial deviation, 85.0%; and ulnar deviation, 91.1% of the opposite normal wrist. Grip strength at follow-up averaged 83% of the opposite hand.

Analysis of failures

Of the nine patients whose fractures failed to heal, one had a synovial pseudarthrosis of the distal third of the scaphoid (that was proven by an arthrogram), 132 months after the fracture (Fig. 4). Three patients had dorsal intercalated segment instability (DISI) pattern (shown on x-ray films) and should not have been considered for this type of treatment. Two patients showed poor cooperation and removed their own casts more than once during treatment. There were only three failures among the patients who conformed to the criteria for inclusion in this study.

The fractures that failed to unite with PEMF had a mean duration of fracture of 81 months (range 6 to 241 months) versus a mean of 27 months for the fractures that healed. Fig. 5 shows that in fractures that were more than 60 months old, only 2 (29%) of 7 healed, but 27 (90%) of 30 of fractures that were less than 60 months old healed. This difference is statistically significant ($p < 0.001$).

Discussion

Although there is some controversy in the literature regarding the need to treat asymptomatic nonunions of the scaphoid, \textsuperscript{4,16} recent reports indicate that the longer...
the duration of the nonunion, the greater the degenerative changes about the scaphoid.\textsuperscript{28, 29} Mack et al.\textsuperscript{28} suggest that "asymptomatic patients with an undisplaced stable nonunion should be advised of the possibility of late degenerative changes." This study of PEMF treatment was designed for this type of patient.

We believe that the main problem in objectively evaluating the efficacy of PEMF treatment is the lack of a reliable double-blind study between like series of patients treated with immobilization alone, and those treated with immobilization and PEMF. However, there are too many other variables for such a study to be accurate. Instead, in our opinion, the patients in these studies themselves provided the comparison for the efficacy of PEMF since in many cases, immobilization alone was used unsuccessfully. In our series, with PEMF and casting, healing occurred in an average of 4.3 months. In addition, a meaningful comparison may be made between our patients and a reported series of patients with nonunited scaphoid fractures that were treated with immobilization alone. Stewart\textsuperscript{2} reported such a series. Ninety scaphoid fractures, which were more than 1 month old, were treated with casting alone; they had a healing rate of 57% and a "probable" healing rate (i.e., lost to follow-up) of 73%. The average length of immobilization was 20 weeks. Some patients were treated with immobilization for as long as 59 weeks. Immobilization of the fracture began an average of 5 months after the injury. Although Stewart’s series and our series were not strictly comparable, the union rate of our patients’ fractures was considerably greater (80% versus 57%). This becomes significant because of the longer time from injury to treatment in our series, 40 months versus 5 months. Finally, union occurred slightly faster in our series, a mean of 4.3 months versus 4.7 months.

Our results with PEMF are comparable to bone grafting where union rates of 50% to 100% have been reported.\textsuperscript{4, 5, 15, 20} However, PEMF may not be quite as effective as the Russe bone graft technique; a recent review of the literature reported it to lead to union on an average of 90% of patients.\textsuperscript{31} Our results are better than those reported following open reduction and internal fixation with compression screw osteosynthesis; the latter technique has a reported success rate of 17 to 73%.\textsuperscript{7, 15}

The above-elbow immobilization clearly seems to enhance the success rate of PEMF treatment. This is confirmed by Beckenbaugh,\textsuperscript{23} who reported that healing occurred in only 7 of 10 patients who were treated in short-arm casts versus 12 (87%) of 14 of patients treated in long-arm immobilization with the addition of PEMF.

Final grip strength in our patients (83% of normal) is comparable to that obtained following direct electrical current treatment (76%)\textsuperscript{26} or bone grafting (85%).\textsuperscript{31} The overall mean range of motion of the wrist in our patients was 89% of normal. This was much greater than that reported using the semiinvasive method (50% of wrist dorsiflexion and 42% of wrist palmar flexion).\textsuperscript{26} Thus, preservation of motion with noninvasive techniques seems to provide a distinct advantage over the semiinvasive method.

From our experience, PEMF treatment is contraindicated for displaced fractures, for synovial pseudarthrosis,\textsuperscript{23} in the presence of periscaphoid osteoarthrosis, and for wrists that exhibit a loss of normal radiocarpal alignment. Adherence to these contraindications would have eliminated four out of the nine patients in our failure group.

Our results also suggest that nonunited scaphoid fractures that are older than 5 years are much less likely to unite with PEMF. Other techniques are recommended for these fractures. Finally, patient selection is important, because this method requires the patient’s cooperation in order to be successful. A newer portable, battery-operated unit is now available* and should allow for easier patient compliance.

The advantages of PEMF treatment are evident: no pain, no anesthetic, no surgical risk, and no known complications. The cost of this treatment is less than the combined cost of hospitalization, anesthetic, and surgical fees. The length of treatment is comparable to that following bone grafting procedures. We believe that PEMF treatment should be specifically considered as an alternative method for treatment when previous surgery has failed, for problems fractures in the proximal third of the scaphoid, and whenever surgery is not safe or is rejected by the patient.

*EBI Bone Healing System Model 420, EBI Medical Systems, Fairfield, N.J.

REFERENCES