Role of Bone Scintigraphy in the Evaluation and Treatment of Nonunited Fractures: Concise Communication

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Seventy-seven patients with nonunited fractures underwent percutaneous low-grade, direct-current stimulation; the response was correlated with the scintigraphic findings obtained before the treatment. Two distinct patterns of osseous activity were noted: those with intense activity at the fracture site (Group 1) and those with a line of decreased activity surrounded by increased uptake on both sides (Group 2). The scintigrams that did not fit into either of the two patterns were considered as indeterminate (Group 3). Whereas 95% of the patients in Group 1 showed an excellent response to electric stimulation, none of the patients in Group 2 had evidence of healing. The response rate in the third group was 50%. On the basis of these preliminary data, bone scintigraphy is recommended as an important initial examination for the proper selection of patients for percutaneous electric stimulation.

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In the last decade there has been increasing enthusiasm for the treatment of nonunited fractures with percutaneous low-grade, direct-current stimulation. This treatment has been effective in 60–80% of patients with these fractures (*1,2*). In view of the natural course of the condition, this is a significant achievement. These patients have generally been treated with a variety of surgical and nonsurgical manipulations, without any evidence of success.

The rationale for low-dose, dc stimulation in nonunited fractures is based on several previous investigations (*1, 3, 4*). It has been demonstrated that a mechanically stressed bone generates an electric potential—probably piezoelectric. It has been shown that a normal bone has areas of electric positivity and negativity that are dependent on cellular activity and viability. Areas of activity are electronegative. Either a direct current or a pulsed electromagnetic field can induce osteogenesis at the cathode. Current hypothesis and available experimental work suggest that the probable mechanism of osteogenesis is the changing cellular microenvironment at the fracture site (*1,3,5*).

Percutaneous dc stimulation is thought to fail because of the formation of pseudoarthrosis, interposed muscle or other soft tissues at the fracture site, superimposed infection, or impaired blood supply, etc. In appropriate cases, these patients who fail to respond to percutaneous stimulation may be treated successfully after surgical debridement at the fracture site and subsequent electrical stimulation. It is clear that recognition of a complicated nonunited fracture before electric stimulation is of utmost importance in the proper treatment of these patients.

In this report we describe our preliminary data using bone scintigraphy as a means of selecting these two groups for the most appropriate approach.

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METHODS AND MATERIALS

Seventy-seven patients are included in this study. Cases selected for review include all patients who completed percutaneous electrical stimulation. Those with pathologic fractures and congenital pseudoarthrosis are excluded.

The diagnosis of nonunited fracture was based on clinical and radiographic findings. The radiographic diagnosis of nonunion stems from lack of healing on several radiographs. Clinically, motion at the fracture site was demonstrated in all patients except those with internal fixation devices. The duration of nonunion ranged from 5 mo to 12 yr.

All patients had gamma-camera images confined to the site of fracture. Twenty millicuries of Tc-99m methylene diphosphonate were injected intravenously and scintigrams were obtained at ~2.5–3 hr after injection. All images were obtained using a scintillation camera with a low-energy, all-purpose collimator and 250,000 counts per view. At least three to four different projections were obtained to visualize the fracture.

All patients underwent percutaneous implantation of the cathodes at the fracture site. The cathodes used were Teflon-coated steel wires with 1 cm exposed tip. Usually, four cathodes were implanted. A disposable 6-cm steel-mesh rectangular plate was used as the anode and was frequently changed. Twenty milliampere of continuous dc was administered at 7.5 V. The cathodes were left in place for approximately 12 wk.

The extremity was immobilized for 12–24 wk, depending on the particular bone involved. The usual hospital stay was about 3 days.

RESULTS

Two distinct patterns of uptake were noted at the fracture site. The first (Group 1) demonstrated intense uniform concentration of the activity at the fracture site in all projections (Fig. 1). The second (Group 2) showed a definite linear or curvilinear area of decreased activity surrounded by significant uptake on both sides (Fig. 2). Several projections were necessary because the line of photon deficiency may be identified in only one projection, particularly if the fracture line was oblique. Scintigrams that did not fit into either of the two groups were called indeterminate (Group 3). These included images with minimal increase in radioconcentration compared with the adjacent bone, and those in which one could not

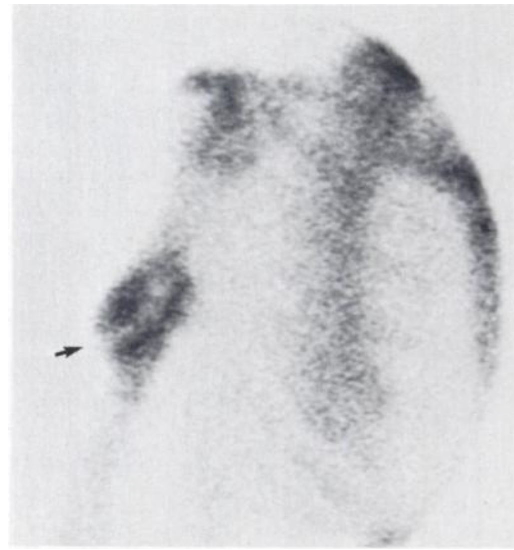

FIG. 2. Curvilinear area of decreased activity at the site of fracture in humerus, representing true pseudoarthrosis (arrow).

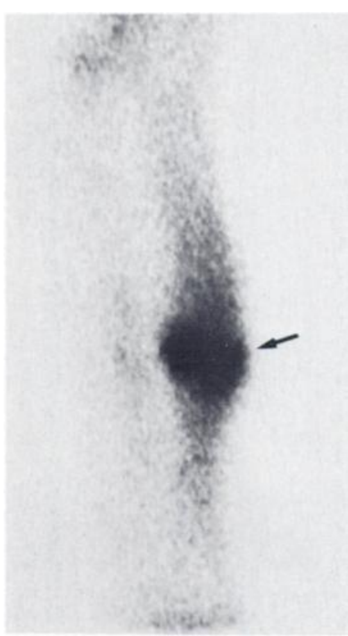

FIG. 1. Intense accumulation of radiotracer at nonunited fracture site in tibia (arrow). Slight increase in activity in adjacent fibula represents healed fibular fracture.

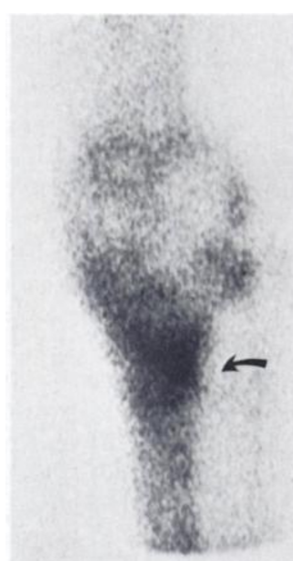

FIG. 3. Slight increase in radiotracer uptake at site of fracture (arrow). No well-defined area of decreased activity is seen in proximal tibia.

be certain whether a photopenic area was present (Fig. 3).

Sixty-four of the 77 patients showed healing after electrical stimulation for a 12-wk period. In the successful cases, radiographs showed narrowing of the distance and indistinctness of fracture margins secondary to osteoclastic resorption due to early healing. Thirteen patients failed to heal the fracture at the end of treatment; there was no radiographic evidence of progress. Scintigrams of 62 patients showed the Group 1 pattern. Fifty-nine of these were successfully treated with closed electric-current stimulation. There were five patients whose scans showed the Group 2 pattern, and in these the success rate was zero. Ten patients were classed as indeterminate. Only five patients in this group were successfully treated (Table 1).

In 13 patients whose fractures did not unite following percutaneous electrical stimulation, open surgical procedures were subsequently performed. Seven patients had true pseudoarthrosis, with a synovium-lined cavity and synovial fluid in the false joint. Three patients had low-grade staphylococcal infections. One had muscle interposed between the fracture fragments. One patient was lost to follow-up. The cause of failure in the remaining patient was not certain.

TABLE 1. RELATIONSHIP BETWEEN SCAN PATTERN AND SUCCESS OF TREATMENT OF NONUNION WITH ELECTRIC STIMULATION

Group	No. of Patients	Healed	Failed	% Success
1	62	59	3	95%
2	5	0	5	0%
3	10	5	5	50%
Total	77	64	13	83%

DISCUSSION

With the introduction of percutaneous electrical stimulation as a simple means of healing nonunited fractures, it is imperative to select those patients who are best suited for this approach.

Bone scintigraphy has been used in the evaluation of nonunited fractures treated with bone grafting both in laboratory animals and human beings (*6, 7*). While increased radioactivity at the graft site suggested that the fracture will heal, lack of increased activity indicated poor response to grafting. The dynamics of fracture healing have been studied in experimentally induced fractures of rabbit tibias (*8*). This investigation showed that in normal or delayed healing there was intense activity at the fracture site. In nonunion, however, the fracture pattern was not consistent. Some of the scintigrams demonstrated increased activity at the fracture site while others did not. Some had a photopenic defect at the fracture site. Our experience with human nonunited fractures appears to agree well with this rabbit study.

Attempts have been made to separate delayed healing from nonunion based on the scintigraphic findings (*9, 10*). In our study, approximately 80% of patients with nonunion showed intense tracer concentration at the

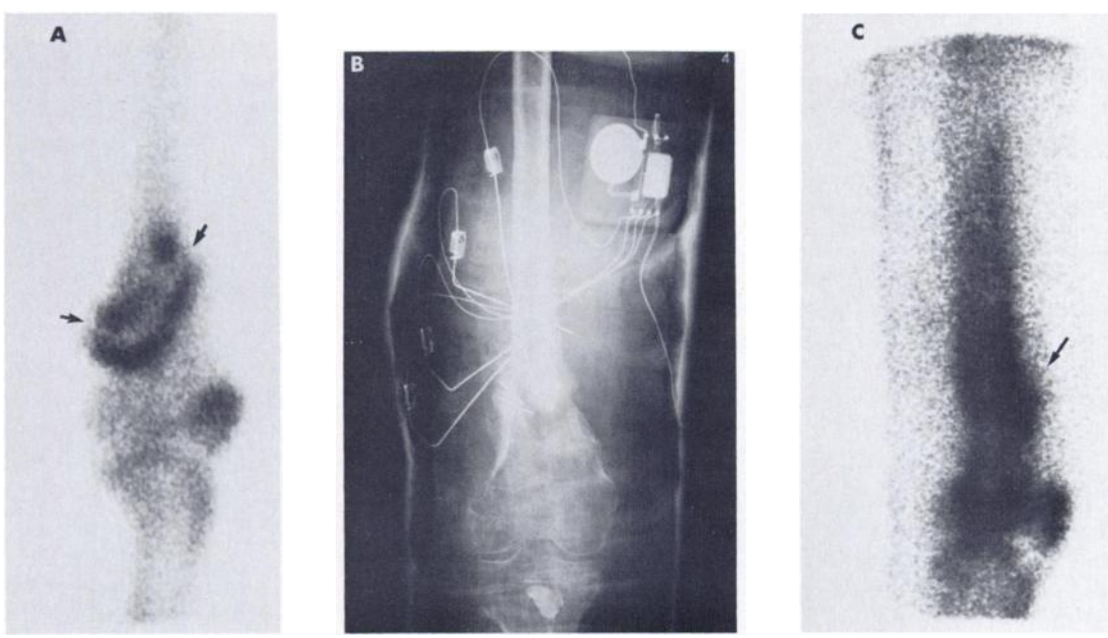

FIG. 4. (A) Another patient with Group 2 pattern has true pseudoarthrosis at fracture site (arrow). (B) Corresponding radiograph showing cathodes at fracture site, anode, and battery pack. (C) Scintigraphic appearance after surgical treatment for true pseudoarthrosis and retreatment with dc stimulatioh. Curvilinear area of decreased activity is not seen (arrow).

fracture site, as does a fracture undergoing normal or delayed union. Therefore, differentiation of a normal or delayed union from nonunited fracture may not be possible by scintigram alone. Clinical findings along with roentgenograms are usually adequate to distinguish delayed healing from nonhealing. On the other hand, scintigraphy appears to be of great value in the diagnosis of complicated nonunited fractures. In these patients, clinical examination and roentgenographic findings offered no help in this regard (*2*).

Since patients with complicated nonunited fractures fail to respond to percutaneous electric stimulation, scintigraphy appears to be of considerable help in screening these patients before treatment with this modality. It is a sensitive indicator of osseous metabolic activity and hence is of considerable value in predicting the response of a nonunited fracture to electrical stimulation. It appears that in patients with diffuse increase in activity at the fracture site (Group 1), there is a physiological attempt to heal the fracture despite the long-standing nonunion. The activity at the fracture site is thought to represent callus that has not ossified. This is obviously an important phase in fracture healing. In these patients, percutaneous stimulation results in complete healing of the fracture with a probability of 95%. Increased activity at the bone end, with decreased activity at the fracture site (Group 2), or findings of an overall diminished uptake (Group 3), probably reflects failure of the healing process to bridge the gap between the fracture fragments. This may be secondary to the formation of a true pseudoarthrosis with synovial lined cavity and synovial fluid, interposition of soft tissues, presence of infection, or impairment of blood supply. In this group, percutaneous electrical stimulation is of no value and should be avoided if the diagnosis can be made in advance. In these complicated nonunited fractures, the response to electrical stimulation is significantly improved when the cause of nonunion is eliminated by surgical or other means (Fig. 4).

In conclusion, bone scanning appears to provide a good screening test to separate patients who will respond favorably to percutaneous electrical stimulation from those who are poor candidates for this simple approach. The latter group generally will require surgical intervention.

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