Electrical Bone Growth Stimulation of the Appendicular Skeleton

Description

In the appendicular skeleton, electrical stimulation (with either implantable electrodes or noninvasive surface stimulators) has been investigated for the treatment of delayed union, nonunion, and fresh fractures.

Background

Electrical and electromagnetic fields can be generated and applied to bones through the following methods:

- Surgical implantation of a cathode at the fracture site with the production of direct current (DC) electrical stimulation. Invasive devices require surgical implantation of a current generator in an intramuscular or subcutaneous space, while an electrode is implanted within the fragments of bone graft at the fusion site. The implantable device typically remains functional for 6 to 9 months after implantation, and, although the current generator is removed in a second surgical procedure when stimulation is completed, the electrode may or may not be removed. Implantable electrodes provide constant stimulation at the nonunion or fracture site but carry increased risks associated with implantable leads.

- Noninvasive electrical bone growth stimulators generate a weak electrical current within the target site using pulsed electromagnetic fields, capacitive coupling, or combined magnetic fields. In capacitive coupling, small skin pads/electrodes are placed on either side of the fusion site and worn for 24 hours per day until healing occurs or up to 9 months. In contrast, pulsed electromagnetic fields are delivered via treatment coils that are placed over the skin and are worn for 6–8 hours per day for 3 to 6 months. Combined magnetic fields deliver a time-varying magnetic field by superimposing the time-varying magnetic field onto an additional static magnetic field. This device involves a 30-minute treatment per day for 9 months. Patient compliance may be an issue with externally worn devices.

- Semi-invasive (semi-implantable) stimulators use percutaneous electrodes and an external power supply obviating the need for a surgical procedure to remove the generator when treatment is finished.

In the appendicular skeleton, electrical stimulation has been primarily used to treat tibial fractures, and thus this technique has often been thought of as a treatment of the long bones. According to
orthopedic anatomy, the skeleton consists of long bones, short bones, flat bones, and irregular bones. Long bones act as levels to facilitate motion, while short bones function to dissipate concussive forces. Short bones include those composing the carpus and tarsus. Flat bones, such as the scapula or pelvis, provide a broad surface area for attachment of muscles. Despite their anatomic classification, all bones are composed of a combination of cortical and trabecular (also called cancellous) bone. Each bone, depending on its physiologic function, has a different proportion of cancellous to trabecular bone. At a cellular level, however, both bone types are composed of lamellar bone and cannot be distinguished microscopically.

Regulatory Status

The noninvasive OrthoPak® Bone Growth Stimulator (BioElectron) received FDA premarket approval in 1984 for treatment of fracture nonunion. Pulsed electromagnetic field systems with FDA premarket approval (all noninvasive devices) include Physio-Stim® from Orthofix Inc., first approved in 1986, and OrthoLogic® 1000, approved in 1997, both indicated for treatment of established nonunion secondary to trauma, excluding vertebrae and all flat bones, in which the width of the nonunion defect is less than one-half the width of the bone to be treated; and the EBI Bone Healing System® from Electrobiology, Inc., which was first approved in 1979 and indicated for nonunions, failed fusions, and congenital pseudarthroses. No distinction was made between long and short bones. The FDA has approved labeling changes for electrical bone growth stimulators that remove any timeframe for the diagnosis.

No semi-invasive electrical bone growth stimulator devices with FDA approval or clearance were identified.

Related Policies

1.01.05 Ultrasound Accelerated Fracture Healing Device
7.01.85 Electrical Stimulation of the Spine as an Adjunct to Spinal Fusion Procedures
7.01.100 Bone Morphogenetic Protein

Policy

*This policy statement applies to clinical review performed for pre-service (Prior Approval, Precertification, Advanced Benefit Determination, etc.) and/or post-service claims.

Noninvasive electrical bone growth stimulation may be considered medically necessary as treatment of fracture nonunions, delayed unions or congenital pseudarthroses in the appendicular skeleton (the appendicular skeleton includes the bones of the shoulder girdle, upper extremities, pelvis, and lower extremities). The diagnosis of fracture nonunion must meet ALL of the following criteria:

- at least 3 months have passed since the date of fracture;
- serial radiographs have confirmed that no progressive signs of healing have occurred;
- the fracture gap is 1 cm or less; and
- the patient can be adequately immobilized and
is of an age likely to comply with non-weight bearing for fractures of the pelvis and lower extremities.

Not medically necessary applications of electrical bone growth stimulation include, but are not limited to, immediate post-surgical treatment after appendicular skeletal surgery, stress fractures or for the treatment of fresh fractures.

Implantable and semi-invasive electrical bone growth stimulators are considered **not medically necessary**.

**Policy Guidelines**

**Fresh Fracture**

A fracture is most commonly defined as “fresh” for 7 days after the fracture occurs. Most fresh closed fractures heal without complications with the use of standard fracture care, ie, closed reduction and cast immobilization.

**Delayed Union**

Delayed union is defined as a decelerating healing process as determined by serial x-rays, together with a lack of clinical and radiologic evidence of union, bony continuity, or bone reaction at the fracture site for no less than 3 months from the index injury or the most recent intervention. In contrast, nonunion serial x-rays (described next) show no evidence of healing. When lumped together, delayed union and nonunion are sometimes referred to as “ununited fractures.”

**Nonunion**

There is not a consensus for the definition of nonunions. One proposed definition is failure of progression of fracture-healing for at least 3 consecutive months (and at least 6 months following the fracture) accompanied by clinical symptoms of delayed/nonunion (pain, difficulty weight bearing). (1)

The original FDA labeling of fracture nonunions defined nonunions as fractures that had not shown progressive healing after at least 9 months from the original injury. The original FDA labeling defined nonunion as follows: “A nonunion is considered to be established when a minimum of 9 months has elapsed since injury and the fracture site shows no visibly progressive signs of healing for minimum of 3 months.” This timeframe is not based on physiologic principles but was included as part of the research design for FDA approval as a means of ensuring homogeneous populations of patients, many of whom were serving as their own controls. Others have contended that 9 months represents an arbitrary cutoff point that does not reflect the complicated variables that are present in fractures, ie, degree of soft tissue damage, alignment of the bone fragments, vascularity, and quality of the underlying bone stock. Some fractures may show no signs of healing, based on serial radiographs as early as 3 months, while a fracture nonunion may not be diagnosed in others until well after 9 months. The current policy of
requiring a 3-month timeframe for lack of progression of healing is consistent with the definition of nonunion as described in the clinical literature.

Rationale

Noninvasive Bone Growth Stimulation

Nonunion

The policy regarding electrical bone stimulation as a treatment of nonunion of fractures of the appendicular skeleton is based in part on the labeled indications by the U.S. Food and Drug Administration (FDA). FDA approval was based on a number of case series in which patients with nonunions, primarily of the tibia, served as their own control. These studies suggest that electrical stimulation results in subsequent unions in a significant percentage of patients. (2-6)

A 2008 systematic review of electromagnetic bone growth stimulation by Griffin et al included 49 studies, 3 of which were randomized controlled trials (RCTs). (7) The 2 RCTs that included patients with nonunion and the single RCT that included patients with delayed union are described next.

A 1994 RCT by Scott and King compared capacitive coupled electric fields with sham treatment (dummy unit) in 23 patients with nonunion (fracture at least 9 months-old and without clinical or radiographic sign of progression to union within the last 3 months) of a long bone. (8) Patients with systemic bone disorders, synovial pseudoarthrosis, or fracture gap of greater than half the width of the bone were excluded. In this trial, electrodes were passed onto the skin surface through holes in the plaster cast. Twenty-one patients completed the protocol (10 treatment and 11 controls). Six months after beginning treatment, an orthopedic surgeon and a radiologist, neither of them involved in the patients’ management, examined radiographs and determined that 6 of 10 in the treatment group healed, while none of those in the control group healed (p=0.004).

In 2003, Simonis et al. compared pulsed electromagnetic field stimulation and placebo treatment for tibial shaft fractures ununited at least 1 year after fracture, no metal implant bridging the fracture gap, and no radiological progression of healing in the 3 months before treatment. (9) All 34 patients received operative treatment with osteotomy and unilateral external fixator prior to randomization. Treatment was delivered by external coils. Patients were assessed monthly for 6 months, and clinical and radiographic assessments were conducted at 6 months. Treatment was considered a failure if union was not achieved at 6 months. In the treatment group, 89% of fractures healed compared with 50% in the control group (p=0.02). While a larger percentage of smokers in the treatment group healed than compared with those in the control group, the number of smokers in each group was not comparable, and the difference in healing rates between groups was not statistically significant. The authors conclude that the available evidence supports the use of pulsed electromagnetic field therapy (PEMF) in the treatment of nonunion of the tibia and suggest that future trials should consider which modality of electromagnetic stimulation and in which anatomical sites the treatment is most effective.
Delayed Union

Shi et al reported a randomized sham-controlled trial that included 58 patients with delayed union of surgically-reduced long-bone fractures (femur, tibia, humerus, radius or ulna). (10) Delayed union was defined as a failure to heal after at least 16 weeks and not more than 9 months following surgical reduction and fixation of the fracture. Patients with fracture nonunion, defined as failure to heal after more than 9 months, were excluded from the study. Treatment with 8 hours of PEMF per day was stopped when no radiographic progression was observed over 3 months or when union was achieved, with union defined as no pain during joint stressing or during motion at the fracture site and callus bridging for 3 out of 4 cortices on blinded assessment. Three months of treatment resulted in a slight, but not statistically significant, improvement in the rate of union between PEMF-treated patients and controls (38.7% vs. 22.2%). The success rate was significantly greater with PEMF (77.4% vs. 48.1%) after an average of 4.8 months of treatment. The time to union was not significantly different between PEMF (4.8 months, range, 2-12) and sham controls (4.4 months, range 2-7).

In a double-blind RCT by Sharrard from 1990, PEMF stimulation was compared with a sham procedure using a dummy device in 45 patients with delayed union of the tibia. (11) Stimulators were positioned on the surface of the plaster cast. Treatment began 16 to 32 weeks after injury. Patients with fracture gaps greater than 0.5 cm after reduction, systemic disease, or taking steroids were excluded, as well as patients with marked bony atrophy or hypertrophy. Fifty-one patients were recruited, and 45 completed the protocol (20 treatment and 25 control). In the treatment group, 3 patients achieved union, 2 achieved probable union, 5 showed progression to union, and 10 showed no progress after 12 weeks. In the control group, none had united, 1 had probably united, 3 progressed toward union, and 17 showed no progress.

The policy regarding electrical stimulation of delayed unions is based on a 1992 TEC Assessment of the RCT by Sharrard, (12) which offered the following conclusions:

Sharrard reported radiographic evidence of healing at the end of the 12-week treatment period. Radiographs were rated separately by a radiologist and an orthopedic surgeon. Their inconsistent rating methods and uncertain comparability in their findings make the radiographic evidence difficult to interpret. In addition, it is uncertain whether radiographic evidence of healing after 12 weeks of treatment, an intermediate outcome, predicts health outcomes such as healing and need for subsequent surgery. In this study, there were no statistically significant differences between the active and sham groups on clinical outcomes such as movement at the fracture site, pain and tenderness. Thus, Sharrard’s health outcome data do not show that noninvasive electrical bone growth stimulation delivers an advantage over placebo.

In 2011, Griffin et al published a Cochrane review of electromagnetic field stimulation for treating delayed union or nonunion of long bone fractures in adults. (13) In addition to the 3 RCTs reviewed above, the systematic review included a 1984 study by Barker et al. that randomized 17 participants with tibial non-union to electromagnetic field stimulation or sham treatment. (14) Thus, 4 studies with a total of 125 participants were included for analysis. The primary outcome measure was the proportion of participants whose fractures had united at a fixed time point. For this outcome the overall pooled
effect size was small and not statistically significant (risk ratio [RR]: 1.96; 95% confidence interval [CI], 0.86 to 4.48). Interpretation is limited due to the substantial clinical and statistical heterogeneity in the pooled analysis. In addition, there was no reduction in pain found in 2 trials, and none of the studies reported functional outcomes. The authors concluded that electromagnetic stimulation may offer some benefit in the treatment of delayed union and nonunion, but the evidence is inconclusive and insufficient to inform current practice.

**Section Summary:** Two randomized sham-controlled trials have been identified on the treatment of delayed union with PEMF. In the Sharrard study, radiographic healing was improved at 12 weeks, but there were no statistically significant differences between groups for clinical outcomes. In the study by Shi et al, only the rate of healing at an average of 4.8 months was statistically significant, and it is not clear if this is a prespecified endpoint. The time to healing was not reduced by PEMF. Additional study is needed to permit greater certainty regarding the effect of this technology on delayed unions.

**Appendicular Skeletal Surgery**

A comprehensive search found 2 small RCTs on noninvasive electrical bone growth stimulation after orthopedic surgery. In 1988, Borsalino et al reported a randomized double-blind sham-controlled trial of pulsed electromagnetic field stimulation (8 hours a day) in 32 patients who underwent femoral intertrochanteric osteotomy for osteoarthritis of the hip. (15) Radiographic measurements at 90 days revealed significant increases in the periosteal bone callus and in trabecular bone bridging at the lateral, but not the medial cortex. The study is limited by the small sample size and the lack of clinical outcomes.

A 2004 trial randomized 64 patients (144 joints with triple arthrodesis or subtalar arthrodesis) to pulsed electromagnetic field stimulation for 12 hours a day or to an untreated control condition. (15) Patients at high risk of non-fusion (rheumatoid arthritis, diabetes mellitus, or on oral corticosteroids) were excluded from the study. Blinded radiographic evaluation found a significant decrease in the time to union (12.2 weeks for talonavicular arthrodesis vs. 17.6 weeks in the control group; 13.1 weeks for calcaneocuboid fusion vs. 17.7 weeks for the control group). Clinical outcomes were not assessed.

**Fresh Fractures**

A multicenter, double-blind, randomized sham-controlled trial evaluated 12 weeks of pulsed electromagnetic field stimulation for acute tibial shaft fractures. (17) The endpoints examined were secondary surgical interventions, radiographic union, and patient-reported functional outcomes. Approximately 45% of patients were compliant with treatment (>6 hours daily use), and 218 patients (84% of 259) completed the 12-month follow-up. The primary outcome, the proportion of participants requiring a secondary surgical intervention because of delayed union or nonunion within 12 months after the injury, was similar for the 2 groups (15% active; 13% sham). Per protocol analysis comparing patients who actually received the prescribed dose of pulsed electromagnetic field stimulation versus sham treatment also showed no significant difference between groups. Secondary outcomes, which included surgical intervention for any reason (29% active; 27% sham), radiographic union at 6 months (66% active; 71% sham), and the SF-36 Short Form Physical Component Summary (SF-36) (44.9
active; 48.0 sham) and Lower Extremity Functional Scales at 12 months (48.9 active; 54.3 sham), also
did not differ significantly between the groups.

Hanneman et al reported a multicenter double-blind, randomized, sham-controlled trial (N=102) that
found little advantage of 6 weeks of PEMF for the treatment of fresh (≤5 days from injury) scaphoid
fractures. (18) Outcomes included the time to clinical and radiologic union and functional outcome at
6, 9, 12, 24, and 52 weeks. Radiologic union measured by computed tomography was not significantly
different between the 2 groups. The median time to clinical union was 6 weeks in both groups. The
return to normal range of movement at the wrist was 12 weeks in both groups. Grip strength of the
dominant hand returned to normal earlier with PEMF, but there was no significant difference in return
of grip strength of the nondominant hand.

These sham-controlled RCTs do not support a benefit for electromagnetic stimulation as an adjunctive
treatment for fresh fractures.

**Stress Fractures**

In 2008, Beck et al reported a well-conducted RCT (n=44) of capacitively coupled electric fields
(OrthoPak) for healing acute tibial stress fractures. (19) Patients were instructed to use the device for
15 hours each day and usage was monitored electronically. Healing was confirmed when hopping 10
cm high for 30 seconds was accomplished without pain. Although an increase in the hours of use per
day was associated with a reduction in the time to healing, there was no difference in the rate of
healing between treatment and placebo. Power analysis indicated that this number of patients was
sufficient to detect a difference in healing time of 3 weeks, which was considered to be a clinically
significant effect. Other analyses, which suggested that electrical stimulation might be effective for the
radiologic healing of more severe stress fractures, were preliminary and a beneficial effect was not
observed for clinical healing.

**Invasive Bone Growth Stimulation**

A comprehensive search for implantable bone stimulators identified a small number of case series, all
of which focused on foot and ankle arthrodesis in patients at high risk for nonunion (summarized in
reference in Petrisor and Lau (19)). Risk factors for nonunion included smoking, diabetes mellitus,
Charcot (diabetic) neuroarthropathy, steroid use, and previous nonunion. A case series described
outcomes of foot or ankle arthrodesis in 38 high-risk patients. (21) Union was observed in 65% of
cases by follow-up evaluation (n=18) or chart review (n=20). Complications were reported in 16 (40%)
cases, including 6 cases of deep infection and 5 cases of painful or prominent bone stimulators
necessitating stimulator removal. A multicenter retrospective review described outcomes from 28 high-
risk patients with arthrodesis of the foot and ankle. (22) Union was reported for 24 (86%) cases at an
average of 10 weeks; complications included breakage of the stimulator cables in 2 patients and
hardware failure in 1 patient. Five patients required additional surgery. Prospective controlled trials are
needed to evaluate this procedure.
The 1992 TEC Assessment indicated that semi-invasive bone growth stimulators are no longer in wide use. (12)

Practice Guideline and Position Statements

None identified.

U.S. Preventive Services Task Force Recommendations

Not applicable.

Summary

There is evidence from randomized controlled trials (RCTs) and systematic reviews of clinical trials that noninvasive electrical stimulators improve fracture healing for patients with fracture nonunion. This evidence is not from high-quality RCTs; however, and systematic reviews provide qualified support for this conclusion. Based on the available evidence and the lack of other options for patients with nonunion, electrical stimulation may be considered medically necessary for the U.S. Food and Drug Administration (FDA)-approved indications of fracture nonunions or congenital pseudoarthroses in the appendicular skeleton when specific criteria are met.

There is insufficient evidence to permit conclusions regarding the efficacy of noninvasive electrical bone growth stimulation for treatment of stress fractures, or following surgery of the appendicular skeleton. In addition, a recent randomized trial found no benefit of electrical bone growth stimulation for fresh fractures. Use of noninvasive electrical bone growth stimulation for these conditions is considered not medically necessary.

The literature for implantable bone stimulators of the appendicular skeleton consists of a small number of case series. In addition, no semi-invasive devices have FDA clearance or approval. The use of invasive or semi-invasive electrical bone growth stimulators is considered not medically necessary.

Medicare National Coverage

Noninvasive stimulators are covered for the following indications (23):

- Nonunion of long bone fractures.
- Failed fusion, where a minimum of 9 months has elapsed since the last surgery.
- Congenital pseudoarthroses.

Invasive stimulators are covered for:

- Nonunion of long bone fractures.
Effective for services performed on or after April 1, 2000, nonunion of long bone fractures, for both noninvasive and invasive devices, is considered to exist only when serial radiographs have confirmed that fracture healing has ceased for 3 or more months prior to starting treatment with the electrical osteogenic stimulator. Serial radiographs must include a minimum of 2 sets of radiographs, each including multiple views of the fracture site, separated by a minimum of 90 days.

References


Policy History

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<thead>
<tr>
<th>Date</th>
<th>Action</th>
<th>Reason</th>
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<tbody>
<tr>
<td>June 2012</td>
<td>New Policy</td>
<td>Clinical input reviewed; references 1 and 16 added. Policy statements unchanged, policy summary revised with no change to intent. Policy guidelines added for consistency with policy Number 1.01.05.</td>
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<tr>
<td>September 2013</td>
<td>Update Policy</td>
<td>Policy updated with literature review; references 10, 18, &amp; 19 added; delayed union added to medically necessary statement, stress fractures added to not medically necessary statement; compliance with non-weight bearing clarified.</td>
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<td>Update Policy</td>
<td>Policy updated with literature review; reference 18 added; policy statement unchanged.</td>
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Keywords

Bone Growth Stimulation, Electrical, Appendicular Skeleton
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This policy was approved by the FEP® Pharmacy and Medical Policy Committee on March 20, 2015 and is effective April 15, 2015.

Signature on file

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