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Pulsed Electromagnetic Fields for Postsurgical Pain Management in Women Undergoing Cesarean Section

A Randomized, Double-Blind, Placebo-controlled Trial

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OBJECTIVES: To evaluate the efficacy of pulsed electromagnetic field (PEMF) in relation to reducing postoperative pain, analgesic use, and wound healing in patients undergoing Cesarean section (C-section).

METHODS: This randomized, double-blind, placebo-controlled trial evaluated 72 women who underwent elective C-section. Thirty-six patients were assigned to the active-PEMF and 36 to the sham-PEMF groups. The participants were asked to report their pain intensity on a Visual Analog Scale (VAS) at 2, 4, 6, 12, and 24 hours and 2, 4, and 7 days after surgery. The amount of analgesics used was recorded. The surgical site was evaluated to assess the wound-healing process on the seventh postoperative day.

RESULTS: Postoperative pain VAS scores were significantly lower in the active-PEMF group in all the measured periods within the early and the late postoperative periods. Fewer women in the active-PEMF group experienced severe postoperative pain within 24 hours postoperatively (36% vs. 72%, P = 0.002). Analgesic use during the first 24 hours after C-section was 1.9-times lower in the active-PEMF group (1.6 ± 0.7 vs. 3.1 ± 1.2, P < 0.001). The total analgesic use during the seventh postoperative days was 2.1-times lower in the active-PEMF group than in the sham group (1.7 ± 0.7 vs. 3.7 ± 1.1, P < 0.001). Seven days postoperatively, patients in the active-PEMF group had better wound healing with no exudate, erythema, or edema (P = 0.02).

CONCLUSIONS: PEMF treatment after C-section decreases postsurgical pain, analgesic use, and surgical wound edemat and edema significantly, and is associated with a high level of patient satisfaction.

KEY WORDS: electromagnetic therapy, healing, PEMF, postoperative, wound

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could also be used in other kinds of surgeries, especially in laparotomy and obstetrics surgeries, which are associated with significant postoperative pain and opioid use. On searching the literature, we could not find studies evaluating the effect of PEMF treatment in surgeries involving deep organs. It is still unknown whether PEMF treatment can provide an acceptable pain relief and tissue healing in these kinds of surgeries.

In view of this lack of information, we conducted this study to evaluate the efficacy of PEMF treatment in reducing postoperative pain and analgesic use in patients undergoing C-section. We also tried to evaluate the effect of PEMF treatment on wound healing, return to daily living activities, and participant satisfaction.

MATERIALS AND METHODS

Study Population and Study Design

This prospective, randomized, double-blinded, placebo-controlled trial was conducted on 72 pregnant women who were admitted to Arash Women’s Hospital (a tertiary referral center), of the Tehran University of Medical Sciences, Tehran, Iran, for elective C-section delivery from August 2014 through December 2014. Women were considered eligible if they met the following inclusion criteria: 20 to 35 years of age, singleton uncomplicated pregnancy, a gestational age of 37 to 42 weeks, and not having a history of >1 C-sections. Exclusion criteria were: having any underlying medical disease, a history of any abdominal surgery other than C-section, a history of any drug or opium dependency, and refusing to give an informed consent to participate in the study.

Randomization was performed before the surgery. A computerized random number generator was used for sequence generation, which was carried out by M.S. Simple randomization with a 1:1 allocation ratio was used in this study. We used consecutive opaque envelopes for allocation concealment, which was performed by S.S.L.R. The envelopes were opaque when held to the light, and were opened sequentially only after the participant’s name and other details were written on the appropriate envelop. The implementation of assignments was carried out by M.K. This study was double-blinded, with M.S. performing the blinding. Health care providers, participants, and data collectors were all blinded to the PEMF and sham-PEMF groups until the end of the study.

The Intervention, Data, and Specimen Collection

After explaining the procedure and obtaining a written informed consent from the participants, a standardized questionnaire was completed for the mothers who enrolled in the study through interviews and medical records. The questionnaire contained demographic, medical, gynecological, obstetrical, and social history, as well as vital signs obtained through physical examinations and the gynecological age that was calculated on the basis of ultrasound imaging. The participants were allocated randomly into 2 groups; 36 were assigned to the intervention (PEMF treated) group and 36 were allocated to the placebo (sham-PEMF treated) group (Fig. 1).

A Visual Analog Scale (VAS) was used to determine the pain intensity; VAS is a continuous scale comprised of a horizontal line 100 mm in length. The scale ranges from 0 (no pain) to 100 (worst imaginable pain). The following cutoff points on the pain VAS were used: no pain (0 to 4 mm), mild pain (5 to 44 mm), moderate pain (45 to 74 mm), and severe pain (75 to 100 mm). Patients were educated on how to use and interpret the pain VAS; they were also asked to place a cross-line on the unmarked horizontal scale at the required times.

All participants underwent spinal anesthesia with 12.5 mg bupivacaine. Immediately after the C-section, either an active-PEMF device (RecoveryRx; BioElectronics Corp.) or a sham-PEMF device (an exactly similar device without any electromagnetic activity that was made by the same company) was placed on the surgical wound dressing continuously for 7 days (Fig. 2). The PEMF devices used in this study consisted of an elliptical coil that was 12 cm in size and a radiofrequency energy generator powered by a battery that had an emission frequency of 27.1 MHz, a pulse rate of 1000 pulses per second, a 100-µs pulse duration, and a peak spatial power density of 75 µW/cm². The circuitry consisted of low-voltage (3 V) digital or analog electronics controlling all of the timing functions to produce the therapeutic radiofrequency field with the antenna’s field directly over the site to be treated. The devices applied to patients in the placebo group were switched on in the same way as the active devices, but without producing an electromagnetic field.

Participants were asked to report their pain intensity on the basis of the VAS, and the pain intensity was evaluated at 2, 4, 6, 12, and 24 hours after surgery. After discharge, participants were asked to record their pain intensity on the second, the fourth, and the seventh postoperative days. The requirement for analgesics during the hospital admission and the amount of analgesics used were recorded. In our study, diclofenac 100 mg suppositories were used as the postoperative analgesic. The surgical site was evaluated for factors that could delay the wound-healing process, including infection, erythema, hematoma, edema, and wound edematous on the seventh postoperative day. For ethical reasons, on discharge, analgesics were recommended for all patients (diclofenac 100 mg suppositories, once a day) on an as-needed basis. Patients could choose to discontinue or use none if they had no symptoms. Participants were asked to record the amount of analgesics used from the discharge day till the seventh postoperative day. The duration needed to return to daily living activities as reported by the mother and the patient satisfaction (not satisfied, moderately satisfied, highly satisfied) from the treatment received were also recorded at the end of the study.

The primary outcome of our study was the postoperative pain intensity as reported by the pain VAS during the first 24 hours and 1 week postoperatively. Secondary outcomes were the amount of analgesic use during the postoperative period, the presence of edema, erythema, hematoma, and edematous from the surgical wound on the seventh postoperative day that could impair the wound-healing process, the duration of return to daily living activities, and overall patient satisfaction.

This study was approved by the Research Deputy and the Ethics Committee of Tehran University of Medical Sciences on July 17, 2014 (approval number: 93/D/940/130) and is registered at the Iranian Registry of Clinical Trials (http://www.irct.ir), which is a Primary Registry in the WHO Registry Network (registration number = IRCT2014070711020N3). The authors confirm that all ongoing and related trials for this intervention are registered.
Although the study was submitted to http://www.irct.ir before the expected recruitment start date, the approval process took a long time and the date of confirming the registration passed the submitted starting date; therefore, the registration timing appeared as registration while recruiting. However, officially, recruiting the patients was started after the registration approval on August 05, 2014 and was ended on the December 10, 2014, 1 month after the expected end date.

Another change that was made to the registered protocol was that in the original protocol the time point was set at 10 days after C-section; however, because significant postsurgical pain usually does not last for >1 week, and also because the first 7 days after surgery are the crucial period for wound healing, the time point was changed to 7 days.

**Statistical Analysis**

The sample size was calculated for a power of 80%, $\alpha = 0.05$, $\beta = 20\%$, and a standard effect size of 0.85. All statistical analyses were performed using SPSS statistical software (PASW version 18.0.0; SPSS Inc., Chicago, IL). Data were displayed using mean, SD, and percentage. Mean comparisons between 2 groups and variables were performed using the $t$ test for independent samples. Pearson correlation coefficient, $\chi^2$ analysis, Fisher exact test, repeated measures analysis of variance (ANOVA), and the Logistic Regression Model were also used. The level of statistical significance was set at $P$-value $<0.05$. 

**FIGURE 1.** The flow diagram of the study showing patients’ randomization.

**FIGURE 2.** The PEMF device attached to the surgical wound dressing.
RESULTS

Descriptive Statistics

This study included 72 women with a singleton uncomplicated pregnancy with a gestational age > 37 weeks who were admitted for elective C-section. Thirty-six women were assigned randomly in the intervention group to receive active-PEMF therapy and 36 to the placebo group to receive the sham-PEMF therapy, for 7 days postoperatively. On enrollment, the mean ± SD of the participants’ age was 26.1 ± 2.6 years, the gestational age was 39.2 ± 1.5 weeks, the body mass index before pregnancy was 24.2 ± 3.9, and the body mass index upon admission was 32.1 ± 2.7. About 36 participants (50%) had a previous history of C-section. The χ² analysis showed that there were no significant differences in the demographics between the 2 study groups (Table 1).

The Effect of PEMF Therapy on Postoperative Pain and Analgesic Use

Repeated measures ANOVA and the independent samples t test demonstrated that the postoperative pain VAS scores were significantly lower in the active-PEMF group than in the sham-PEMF group in all the measured periods (Table 2 and Fig. 3). The χ² analysis showed that fewer women in the active-PEMF group experienced severe postoperative pain (VAS score of 75 to 100 mm) within 24 hours after the C-section compared with the sham-PEMF group (36% vs. 72%, P = 0.002). According to the independent samples t test, analgesic use (mean suppository counts) during the first 24 hours after C-section was 1.9-times lower in the active-PEMF group compared with the sham-PEMF group (3.6 ± ±1.3, P = 0.58) (Table 3).

The Effect of PEMF Therapy on Surgical-Site Inflammation, Patient Satisfaction, and Return to Daily Activities

We used the χ² analysis and the Fisher exact test when appropriate to compare secondary outcomes between the 2 study groups. Seven days after the C-section, mothers in the active-PEMF group had significantly higher rates of wound exudate (13% vs. 0%, P = 0.02) and edema (11% vs. 0%, P = 0.04) in the surgical site compared with the active-PEMF group. No infection or erythema was observed in any of the groups (Table 3). The satisfaction level was significantly higher in the active-PEMF group (P = 0.001): in the active-PEMF-treated group, 50% of the patients reported a high and 50% had a moderate satisfaction level with the treatment received, whereas in the sham group, 25% reported high and 44% had moderate satisfaction levels, and 30% were not satisfied with the treatment received (Table 3). Using the independent samples t test, no statistically significant differences were observed in the time to return to daily activities between the 2 groups (the active-PEMF group: 3.4 ± ±0.7 d; the sham-PEMF group: 3.6 d ± 1.3, P = 0.58) (Table 3).

DISCUSSION

This was the first study to evaluate the applicability of PEMF devices in surgeries involving deep organs and laparotomy. PEMF therapy reduced postsurgical pain and the use of analgesics effectively in the both the immediate and the late postsurgical periods in women who underwent C-section, and reproduced essential findings in studies with other surgical procedures. In the studies of Heden and Pillu11 and Rohde et al.,10 PEMF treatment provided good pain control and reduced narcotic use postoperatively in breast augmentation and reduction surgeries. In addition, in the Stocchero et al study, PEMF treatment reduced the pain after mandibular third-molar extraction significantly.

Several mechanisms involving inflammatory mediators might contribute to the analgesic effects of PEMF treatment. Studies have shown that PEMF signals increase the anti-inflammatory cytokine interleukin (IL)-10 and decrease the proinflammatory cytokine IL-1β,10,15 which is a potent hyperalgesic agent and a stimulator of nociceptors through direct and indirect pathways.16,17 Animal studies suggest that IL-1β might be a signaling molecule that can excite nociceptive fibers in as little as 1 minute in sensory transmission, and IL-1β receptors were found in many sensory neurons.16-19 IL-1β also modulates neuronal excitability through its effect on neuronal receptors such as sodium channels, GABA receptors, NMDA receptors, and through its effect on the release or the activation of nociceptive molecules such as prostaglandins, IL-6, and substance-P.17,20,21

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TABLE 1. Comparison of Demographics Between the Intervention (Active-PEMF) and the Placebo (Sham-PEMF) Groups

<table>
<thead>
<tr>
<th>Demographics</th>
<th>PEMF Group (N = 36)</th>
<th>Placebo Group (N = 36)</th>
<th>P</th>
</tr>
</thead>
<tbody>
<tr>
<td>Participants age (y)</td>
<td>26.4 ± 2.3</td>
<td>25.9 ± 2.9</td>
<td>0.43 (NS)</td>
</tr>
<tr>
<td>(mean ± SD)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Gestational age (wk)</td>
<td>39.4 ± 1.6</td>
<td>39.1 ± 1.4</td>
<td>0.8 (NS)</td>
</tr>
<tr>
<td>(mean ± SD)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>BMI before pregnancy</td>
<td>23.8 ± 3.4</td>
<td>24.5 ± 4.4</td>
<td>0.46 (NS)</td>
</tr>
<tr>
<td>(mean ± SD)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>BMI upon admission</td>
<td>32.3 ± 2.8</td>
<td>31.8 ± 2.6</td>
<td>0.52 (NS)</td>
</tr>
<tr>
<td>(mean ± SD)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>History of previous C/S (%)</td>
<td>18 (50)</td>
<td>18 (50)</td>
<td>1 (NS)</td>
</tr>
</tbody>
</table>

BMI indicates body mass index; C/S, Cesarean section; NS, non-significant; PEMF, pulsed electromagnetic field.

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TABLE 2. Comparison of Pain VAS Scores and Analgesic Use Between the Active-PEMF and the Sham-PEMF Groups in the Measured Times

<table>
<thead>
<tr>
<th>Time</th>
<th>Mean ± SD of Pain VAS Scores</th>
<th>PEMF Group</th>
<th>Placebo Group</th>
<th>P</th>
</tr>
</thead>
<tbody>
<tr>
<td>Postoperative</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2 h</td>
<td>53 ± 18</td>
<td>63 ± 16</td>
<td>0.01</td>
<td></td>
</tr>
<tr>
<td>4 h</td>
<td>41 ± 13</td>
<td>59 ± 8</td>
<td>&lt; 0.001</td>
<td></td>
</tr>
<tr>
<td>6 h</td>
<td>37 ± 13</td>
<td>51 ± 8</td>
<td>&lt; 0.001</td>
<td></td>
</tr>
<tr>
<td>12 h</td>
<td>30 ± 5</td>
<td>38 ± 10</td>
<td>&lt; 0.001</td>
<td></td>
</tr>
<tr>
<td>24 h</td>
<td>23 ± 4</td>
<td>36 ± 12</td>
<td>&lt; 0.001</td>
<td></td>
</tr>
<tr>
<td>1 d</td>
<td>18 ± 10</td>
<td>26 ± 4</td>
<td>&lt; 0.001</td>
<td></td>
</tr>
<tr>
<td>4 d</td>
<td>6 ± 4</td>
<td>16 ± 4</td>
<td>&lt; 0.001</td>
<td></td>
</tr>
<tr>
<td>7 d</td>
<td>0.8 ± 2</td>
<td>3 ± 4</td>
<td>0.01</td>
<td></td>
</tr>
</tbody>
</table>

PEMF indicates pulsed electromagnetic field; VAS, Visual Analog Scale.
PEMF may also produce analgesic effects by affecting nitric oxide (NO) synthesis; NO exhibits analgesic effects in the periphery in early stages of inflammation, and pain intensity has been shown to correlate negatively with NO levels.\(^{22}\) PEMF increases NO synthesis through a cascade that involves calcium, calmodulin, and cGMP production.\(^{22,24}\) Another proposed mechanism is the effect of PEMF on endogenous opioids. PEMF was shown to increase endogenous opioid precursor proteins including proenkephalin, proopiomelanocortin, and prodynorphin.\(^{15}\) In the study of Ventura et al,\(^{25}\) direct exposure of isolated myocyte nuclei to PEMF enhanced prodynorphin gene transcription markedly.

In our study, PEMF was associated with a better wound-healing response at 7 days postoperatively, without any exudate, edema, or erythema at the incision site. Other studies that used PEMF in oral and plastic surgeries also reported that PEMF therapy accelerated wound healing and tissue repair.\(^{9-11}\) PEMF signals modulate Ca\(^{2+}\) binding to calmodulin and calmodulin-dependent enzymes and NO production.\(^{24,26}\) Evidence from animal and human studies indicate that NO plays a key role in wound repair, which is attributable to its functional influences on angiogenesis, inflammation, cell proliferation, and matrix deposition and remodeling.\(^{27}\) Moffett and colleagues evaluated the effect of PEMF on cultured human keratinocyte and fibroblast cells; they found that mRNA levels of many factors that are involved in tissue repair and remodeling were upregulated after PEMF treatment.\(^{28}\)

In this study, PEMF was associated with a better wound-healing response at 7 days postoperatively, without any exudate, edema, or erythema at the incision site. Other studies that used PEMF in oral and plastic surgeries also reported that PEMF therapy accelerated wound healing and tissue repair.\(^{9-11}\) PEMF signals modulate Ca\(^{2+}\) binding to calmodulin and calmodulin-dependent enzymes and NO production.\(^{24,26}\) Evidence from animal and human studies indicate that NO plays a key role in wound repair, which is attributable to its functional influences on angiogenesis, inflammation, cell proliferation, and matrix deposition and remodeling.\(^{27}\) Moffett and colleagues evaluated the effect of PEMF on cultured human keratinocyte and fibroblast cells; they found that mRNA levels of many factors that are involved in tissue repair and remodeling were upregulated after PEMF treatment.\(^{28}\) In this study, postoperative PEMF therapy was safe and easily applicable, and the mothers were highly satisfied with using this device in the postsurgical period. The

### TABLE 3. Comparison of the Outcomes Between the Active-PEMF and Sham-PEMF Groups

<table>
<thead>
<tr>
<th>Outcomes</th>
<th>PEMF Group (N = 36)</th>
<th>Placebo Group (N = 36)</th>
<th>P</th>
</tr>
</thead>
<tbody>
<tr>
<td>Experiencing severe pain within 24 h PO (%)</td>
<td>13 (36)</td>
<td>26 (72)</td>
<td>0.002*</td>
</tr>
<tr>
<td>Analgesic use within 24 h PO (mean ± SD [sum of suppository count])†</td>
<td>1.6 ± 0.7</td>
<td>3.1 ± 1.2</td>
<td>&lt; 0.001*</td>
</tr>
<tr>
<td>Analgesic use within 7 d PO (mean ± SD [sum of suppository count])†</td>
<td>1.7 ± 0.7</td>
<td>3.7 ± 1.1</td>
<td>&lt; 0.001*</td>
</tr>
<tr>
<td>Duration to return to daily activities (mean ± SD) (d)</td>
<td>3.4 ± 0.7</td>
<td>3.6 ± 1.3</td>
<td>0.58</td>
</tr>
<tr>
<td>Satisfaction levels (%)</td>
<td></td>
<td></td>
<td>0.001*</td>
</tr>
<tr>
<td>High</td>
<td>18 (50)</td>
<td>9 (25)</td>
<td></td>
</tr>
<tr>
<td>Moderate</td>
<td>18 (50)</td>
<td>16 (44)</td>
<td></td>
</tr>
<tr>
<td>Low</td>
<td>0</td>
<td>11 (30)</td>
<td></td>
</tr>
<tr>
<td>Surgical wound infection (%)</td>
<td>0</td>
<td>0</td>
<td></td>
</tr>
<tr>
<td>Surgical wound exudate at 10 d PO (%)</td>
<td>0</td>
<td>5 (13)</td>
<td>0.02*</td>
</tr>
<tr>
<td>Surgical wound edema at 10 d PO (%)</td>
<td>0</td>
<td>4 (11)</td>
<td>0.04*</td>
</tr>
</tbody>
</table>

*Statistically significant P-value (< 0.05).
†Diclofenac 100 mg suppositories.
PEMF indicates pulsed electromagnetic field; PO, postoperation.

**FIGURE 3.** Mean pain Visual Analog Scale (VAS) scores between the pulsed electromagnetic field (PEMF)-treated (thick line) and the placebo-treated (thin line) groups during the 7 postoperative days.

**FIGURE 4.** The number of Diclofenac suppositories used within 24 hours and 7 days postoperatively in the treatment versus the placebo group.
available literature supports the safety of PEMF devices in long-term applications. These promising results show that PEMF therapy can be used as an effective and safe modality for postoperative pain management, with positive effects on wound healing that is associated with high maternal satisfaction in the postoperative period. In addition, by decreasing maternal requirement for systemic analgesics and opioids during the postoperative period, and subsequently decreasing neonatal exposure to these drugs, PEMF therapy could also have potential benefits to the neonates. However, effects of PEMF therapy on lactation, neonatal wellbeing, and mother-infant interaction requires investigation in future studies.

REFERENCES