Pulsed Electromagnetic Field during Cast Immobilization in Postmenopausal Women with Colles’ Fracture

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SUMMARY
Introduction Although Colles’ fracture i.e. a dorsally displaced distal radius fracture (DRF) is one of the most common fractures, there is no enough evidence to determine the best form of rehabilitation.

Objective To assess whether the use of pulsed electromagnetic field (PEMF) therapy during cast immobilization of DRF provides beneficial effects on pain, edema, wrist range of motion and function, as well as on the frequency of complications immediately after cast removal.

Methods The prospective randomized controlled study included 60 women over the age of 55 years with extra-articular displaced DRF treated with reduction and cast immobilization. The patients were alternately allocated to either a PEMF group (n=30, received 10 days of PEMF therapy during immobilization), or a control group (n=30, without PEMF therapy). Pain, function, hand circumference, wrist and forearm range of motion and frequency of complications for each patient was evaluated within two to three days of cast removal.

Results Better mean values for the majority of examined parameters were recorded in the PEMF group than in the control group, but the difference was statistically significant just for edema (p<0.001), flexion, extension and supination range (p<0.01).

Conclusion During immobilization PEMF therapy in DRF patients gave better results immediately after cast removal in terms of edema and wrist range of motion (ROM).

Keywords: distal radius fracture; rehabilitation; physiotherapy; pulsed electromagnetic field

INTRODUCTION
Colles’ fracture is an eponym for a dorsally displaced distal radius fracture (DRF). The distal part of the radius is one of the most common fractured bones [1] and results from a fall onto an outstretched hand [2, 3]. DRF is strongly related to osteoporosis [1] and in osteoporotic patients it results from low-energy trauma [4]. The bone mineral density (BMD) in postmenopausal women with DRF is significantly lower compared to those without [4]. Several treatment options are available. Undisplaced fractures are casted and displaced fractures are reduced and casted. Unstable fractures are most often operated upon, especially if the fracture is impossible to reduce or to be retained in a reduced position [5]. Because of inherent biochemical, histological and mechanical changes during the immobilization [6], patients usually have pain, edema, reduced wrist range of motion (ROM) and disability afterwards. Rehabilitation is indicated in order to maximize functional recovery, as well as to prevent or treat complications, however usually used physical therapy modalities are not well evidenced [3].

Pulsed electromagnetic field (PEMF) devices were created to treat fracture nonunions based on the observation that electric fields occur in mechanically loaded bones [7]. Many clinical studies report that the use of PEMF stimulates healing of delayed fracture unions and non-unions [8, 9], accelerates unions in osteotomies [10, 11], increases successful fusion in patients undergoing interbody lumbar fusion [12] and accelerates healing of fresh fractures [13, 14]. But despite reported positive results and the widespread use of electromagnetic stimulation in orthopedics, the meta-analysis from 2008 reported that there were no definitive clinical data to support its use in long-bone fractures [15]. Also, PEMF relieves pain of primary osteoporosis and increases BMD in osteoporosis after spinal cord injury, but it is still controversial whether PEMF enhances BMD in primary osteoporosis [16]. In 2005, Cheing et al. [2] reported better outcome if combination of PEMF and ice therapy was used in patients with DRF after cast removal. Based on the above data, we expected beneficial effects of pain and edema if PEMF during immobilization in DRF patients was used.

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OBJECTIVE

The aim of this study was to assess whether the use of PEMF during cast immobilization of DRF provides beneficial effects on pain, edema, wrist ROM and function, as well as on the frequency of complications immediately after cast removal.

METHODS

The prospective randomized controlled single-blinded study was conducted at the Physical Medicine and Rehabilitation Clinic of the Clinical Center Niš between September 2007 and June 2009.

This study was designed to evaluate the outcome of displaced stable DRF in patients treated with PEMF during immobilization and in those who were not. A total of 74 postmenopausal women over the age of 55 years who sustained unilateral extra-articular displaced stable DRF were admitted at the Clinic Outpatient Department. All of them were treated with reduction and cast immobilization at the Orthopedic Clinic. After clinical and radiographic control 7 days after fracture, they were recruited for rehabilitation. The inclusion criteria were a low impact fracture, intact cognitive function [17] and no limitation of wrist and hand function before injury. Patients were excluded if they had bilateral wrist fractures, previous fracture of the affected or unaffected wrist, additional wrist fracture, inflammatory osteoarthritis, peripheral vascular disease and contra-indicated PEMF (patients with auxiliary organs, i.e. pace makers, all kinds of mycoses and tumors, intestinal hemorrhage, epilepsy, hyperthyroidism and acute infection).

Fourteen patients were not included (9 did not meet the inclusion criteria, 3 met the exclusion criteria and 2 refused to participate). The remaining 60 patients, after their written informed consent had been obtained, were enrolled into the study. The study was approved by the Ethics Committee of the Medical Faculty, University of Niš. None of the patients dropped out of the study.

Rehabilitation procedures

Enrollment baseline data were obtained for each patient. The patients were then allocated to either the PEMF group (n=30), or control group (n=30) alternately. Each patient was taught and given instructions for a home exercise program consisting of active shoulder, elbow and finger mobilization exercises, active fisting and thumb opposition, as allowed by cast and advised to do these twice a day for 20 minutes during cast immobilization. After cast removal they were instructed to perform light activities in the pain-free ROM until the follow-up. They were also advised to elevate the wrist if they noted edema increasing.

The patients allocated to the PEMF group received PEMF therapy five days a week for two weeks (10 sessions), 30 min daily. The patient’s hand, wrist and distal forearm were placed inside a concentric coil applicator, 50 cm in diameter and 35 cm high, which generates an almost homogenic magnetic field inside the coil, with a peak magnetic field intensity of 6 mT, and supplied by electric pulse frequency of 25 Hz. This field intensity and frequency are advised for osteoporosis, soft tissue injuries and fracture treatment by the manufacturer. The PEMF therapy device was produced by the Elecsystem GMF Corporation A.G. Switzerland. The PEMF therapy always started on Monday. The patients allocated to the control group had no other therapy. X-rays were not taken after the enrollment in the study.

Outcome measures

Evaluation of subjective and objective parameters such as pain, function, hand circumference and wrist and forearm ROM for each patient was performed within two to three days of cast removal between 8 and 10 am. The presence of complications was also noted. All examined parameters were assessed by one of the authors blinded to group allocation.

Pain and function were assessed as the pain and function subscales of the patient-rated wrist evaluation (PRWE) score [18], which has been shown to be very sensitive to recovery after DRF [19]. The PRWE pain subscale has 5 items (4 on pain intensity at rest, during repeated movement, when lifting a heavy object and when at its worst, and one on pain frequency). The PRWE function subscale contains 6 specific and 4 usual activities. Each item is scored on an 11 points scale (0-10). This provides pain score 0-50. The sum of the 10 functional items is divided by two which provides functional score 0-50. The higher scores indicate greater pain and disability. Wrist evaluation form was rated by a patient in the presence of an author, who made questions clear if necessary.

Hand circumference was measured in order to quantify hand edema using the figure-of-eight measurement [20]. Measurement of each patient’s injured and uninjured hand was performed. Hand edema was expressed as the difference between hand circumferences of both hands.

Active ROM at wrist and distal radial-ulnar joints was measured using a standard full-circle goniometer and recorded in degrees according to the method suggested by the American Academy of Orthopedic Surgeons 1988 [21]. Flexion, extension, radial and ulnar deviation, pronation and supination ROM were measured. Intraobserver bias was minimized by careful technique and recordings made in triplicate and the mean of these measurements was noted.

Statistical analysis

Data were analyzed using SPSS for Windows software (version 10.0). Descriptive statistics was presented as mean ±SD, median and minimum and maximum values. The normality of distribution was tested using the Shapiro-Wilk test. To assess differences between continuous
variables in two groups the Student t-test was used. If variables were not distributed normally then the nonparametric Mann-Whitney test was employed. Proportions were compared with the chi square test. The p-value of <0.05 was considered statistically significant.

**RESULTS**

Sixty postmenopausal women with the mean age of 66.2 were included in the study. On average the PEMF group was older (67.90±5.56) than the control group (64.50±6.02). The difference was statistically significant (p=0.026), which could mean that the PEMF group had worse predisposition for functional recovery. No significant difference was seen between the groups regarding other baseline characteristics (Table 1).

The edema evaluation results, PRWE pain and function scores are presented in Table 2. Hand edema was found in nearly all of patients (except 3 patients in the PEMF group), as well as mild to moderate pain and moderate to severe limitations of functional activities. Better mean values for these three parameters were recorded in the PEMF group than in the control group, but the difference was significant just for edema (p=0.000).

Regarding the wrist ROM, except radial deviation ROM, which was slightly lower, the values of other examined ROMs were higher in the PEMF group, but statistically significant difference was found for flexion (p=0.003), extension (p=0.009) and supination (p=0.004) ROM (Table 3).

Complications associated with DRF were seen in 9 patients (Table 4). The most common complication was finger stiffness found in 6 patients, 5 of whom were older than 70 years. Also, 2 patients in the control group had clinical signs and symptoms of complex regional pain syndrome type 1 (CRPS 1) according to the International Association for the Study of Pain (IASP) diagnostic criteria [22], although it can be difficult to make a firm diagnosis of CRPS at early stage of the disease. Frequency of overall and individual complications was lower in the PEMF than

### Table 1. Baseline characteristics

<table>
<thead>
<tr>
<th>Parameter</th>
<th>PEMF group (n=30)</th>
<th>Control group (n=30)</th>
<th>p</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Mean±SD Median (Min–Max)</td>
<td>Mean±SD Median (Min–Max)</td>
<td></td>
</tr>
<tr>
<td>Age (years)</td>
<td>67.90±5.56 68.50 (55-78)</td>
<td>64.50±6.02 64.00 (55-78)</td>
<td>&lt;0.05</td>
</tr>
<tr>
<td>Period of immobilization (days)</td>
<td>28.17±1.68 28.00 (25-33)</td>
<td>27.67±1.91 28.00 (25-35)</td>
<td>ns</td>
</tr>
<tr>
<td>Time until PEMF (days)</td>
<td>8.67±1.40 8.00 (7-11)</td>
<td>8.97±1.16 9.00 (7-11)</td>
<td>ns</td>
</tr>
<tr>
<td>Time from cast removal to assessment (days)</td>
<td>2.40±0.50 2.00 (2-3)</td>
<td>2.60±0.50 3.00 (2-3)</td>
<td>ns</td>
</tr>
<tr>
<td>Wrist injured (dominant/non dominant)</td>
<td>17/13</td>
<td>15/15</td>
<td>ns</td>
</tr>
</tbody>
</table>

PEMF – pulsed electromagnetic field; SD – standard deviation; ns – non significant

### Table 2. Edema, pain and function within two to three days of cast removal

<table>
<thead>
<tr>
<th>Parameter</th>
<th>PEMF group (n=30)</th>
<th>Control group (n=30)</th>
<th>p</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Mean±SD Median (Min–Max)</td>
<td>Mean±SD Median (Min–Max)</td>
<td></td>
</tr>
<tr>
<td>Hand edema (mm)</td>
<td>10.20±6.14 10.50 (0-25)</td>
<td>18.17±7.44 18 (5-35)</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>Pain score (PRWE) (0-50)</td>
<td>21.60±9.07 20.50 (7-39)</td>
<td>24.47±7.45 25.00 (6-41)</td>
<td>ns</td>
</tr>
<tr>
<td>Activity score (PRWE) (0-50)</td>
<td>33.70±9.88 35.50 (10-50)</td>
<td>34.50±7.75 35.00 (12-50)</td>
<td>ns</td>
</tr>
</tbody>
</table>

PRWE – patient-rated wrist evaluation score (0 indicating the best score, 50 indicating the worst score)

### Table 3. Forearm and wrist range of motion within two to three days of cast removal

<table>
<thead>
<tr>
<th>Parameter</th>
<th>PEMF group (n=30)</th>
<th>Control group (n=30)</th>
<th>p</th>
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<tbody>
<tr>
<td></td>
<td>Mean±SD Median (Min–Max)</td>
<td>Mean±SD Median (Min–Max)</td>
<td></td>
</tr>
<tr>
<td>Flexion (degrees)</td>
<td>46.50±10.42 47.50 (22-62)</td>
<td>37.33±12.53 36.00 (18-62)</td>
<td>&lt;0.01</td>
</tr>
<tr>
<td>Extension (degrees)</td>
<td>41.43±10.95 42.00 (21-65)</td>
<td>33.27±12.71 33.50 (12-65)</td>
<td>&lt;0.01</td>
</tr>
<tr>
<td>Radial deviation (degrees)</td>
<td>10.00±4.50 9.50 (3-20)</td>
<td>11.00±5.63 10.00 (0-27)</td>
<td>ns</td>
</tr>
<tr>
<td>Ulnar deviation (degrees)</td>
<td>18.00±6.39 17.50 (5-30)</td>
<td>17.10±4.62 18.00 (5-25)</td>
<td>ns</td>
</tr>
<tr>
<td>Pronation (degrees)</td>
<td>63.57±16.41 67.50 (30-85)</td>
<td>61.03±17.50 64.50 (30-82)</td>
<td>ns</td>
</tr>
<tr>
<td>Supination (degrees)</td>
<td>54.00±11.61 53.00 (33-75)</td>
<td>45.40±10.97 43.00 (30-72)</td>
<td>&lt;0.01</td>
</tr>
</tbody>
</table>

### Table 4. Complications within two to three days of cast removal

<table>
<thead>
<tr>
<th>Parameter</th>
<th>PEMF group (n=30)</th>
<th>Control group (n=30)</th>
<th>p</th>
</tr>
</thead>
<tbody>
<tr>
<td>CRPS 1</td>
<td>0 0.00%</td>
<td>2 7.14%</td>
<td>ns</td>
</tr>
<tr>
<td>Median nerve compression</td>
<td>0 0.00%</td>
<td>1 3.45%</td>
<td>ns</td>
</tr>
<tr>
<td>Finger stiffness*</td>
<td>2 7.14%</td>
<td>4 13.79%</td>
<td>ns</td>
</tr>
</tbody>
</table>

CRPS 1 – complex regional pain syndrome type 1
* Finger stiffness – loss of digital flexion, defined as fingertip to palm distance greater than 1 cm for all fingers
in the control group, although the difference was not statistically significant. The difference would probably reach the level of significance in a larger study.

No patient had adverse effect of PEMF therapy.

DISCUSSION

This study was designed to compare the results of pain, edema and wrist ROM evaluation immediately after cast removal of displaced stable DRF in women older than 55 years treated with PEMF during immobilization and in those who were not. The results were better in the PEMF group compared to the control group, regarding edema, flexion, extension and supination ROM. Also, in the PEMF group there were no cases of CRPS 1, which is important because serious cases of CRPS 1 require a long-term physical therapy to alleviate symptoms.

Persons with DRF are usually referred to rehabilitation after a period of immobilization in order to return full function with a painless wrist. Cochrane meta-analysis reports that there was no enough evidence to determine the best form of rehabilitation [3]. This is a distressing fact, as these represent the most common fractures.

The average duration of casting in the study was 28 days. It is in accordance with several other studies [6,14], although many studies report immobilization for about six weeks [2,3,23-26].

In PEMF treated patients hand edema was significantly less in size than in the control group. For edema quantification we used the figure-of-eight method, which is shown to be a reliable and valid measure of hand size in individuals with conditions affecting the hand comparing to volumetric measurements [20]. Byl et al. [6] performed wrist edema quantification immediately after cast removal using circumferential measurements and found a significant difference between affected and unaffected wrist. Significant edema reduction was achieved after cast removal in DRF, by combination of ice and PEMF therapy [2], as well as by manual lymph drainage [27], using volumetric measurement - the gold standard for measuring hand edema. Early edema reduction is very important as the soft tissue greatly influences the final functional result. The inflammatory cascade that results in edema, pain, and joint stiffness must be treated aggressively and concomitantly with the bone injury [28].

Regarding pain the results were better in the PEMF group but did not achieve a significant difference. In contrast to our results, Cheing et al. [2] found that the combination of PEMF and ice therapy produces more significant pain reduction than ice or PEMF alone. Also, in surgically treated patients with femoral neck fracture significant pain reductions were found at day 30, 60 and 90 in patients treated with PEMF [13]. Pain assessment in our study was performed using the PRWE pain score which incorporates the whole spectrum of severity, both in intensity and frequency [19]. In the above mentioned two studies the visual analogue scale was used, but in the study of Cheing et al. [2] pain was assessed during active wrist movement, whereas the study of Betti et al. [13] did not report if pain was assessed during active movement or at rest.

As far as function is concerned it was moderately to severely impaired and there was no significant difference found between the groups. As expected, on average one month after DRF most of the activities, particularly the specific ones, are formed with severe difficulties. Moreover some are contra-indicated. Our results are in agreement with the results reported by MacDermid et al. [18] who, assessing the recovery of function in 129 DRF patients, found that the majority of recovery occurred by 6th months after fracture. Improvement in function at two months was noted, although moderate difficulty in many activities, particularly specific ones, was present.

Regarding ROM, a significantly better flexion, extension and supination ROM, found in the group with PEMF may be the consequence of minor edema. In the PEMF group flexion and extension ROM were greater than in many other studies, immediately after cast removal [2,6,23-25]. In some studies extension ROM was less than 30 degrees [23,25], though it is important for the wrist function to be greater than 40 degrees, which was achieved in the PEMF group. Concerning that wrist flexion and extension ROM are most affected after DRF, the achieved flexion and extension at one month after the fracture was very satisfying. The supination ROM was better than in the study of Cheing et al. [2] and similar as in the study of Key et al. [24] It is probable that better ROM in our study was partly due to the shorter period of immobilization.

Although different physical therapy modalities used in the rehabilitation of DRF to resolve edema and pain, increase circulation and accelerate osteogenesis, up-to-date there is only a limited research evaluating their effectiveness. Cheing et al. [2] used ice and PEMF treatment after casting, i.e. during hard callus phase, whereas in our study the PEMF was used during the initial 4 weeks, that is the soft callus or the fibroblastic phase [28].

We found only one study which utilized PEMF stimulation during immobilization in women with extra-articular Colles’ fracture [14]. The author using bone scintigraphy in the evaluation of fracture healing noted a significantly increased healing activity at weeks 1 and 2, but not significant at weeks 4 or 8.

Although a considerable basic and clinical research on PEMF has been reported, their mechanism of action is not completely clear [29]. PEMF elicits a biological effect independent of any thermal influence or observable physical interaction with tissue [30]. It is known to have effects directly on the cellular level.

An in vitro study has shown that the local application of PEMF can elicit a significant arteriolar vasodilatation [30] and increase in vivo and in vitro angiogenesis through the endothelial release of fibroblast growth factor 2, an important angiogenic factor [31]. These effects on the circulation could be a possible explanation for better results that we detected in the PEMF group.

We noted some limitations of our study. The PEMF group was on average 3.5 years older than the control group. In our opinion this is without clinical significance,
because there were no limitations of wrist and hand function before injury. Another shortcoming is that the patients were not followed during a longer period to evaluate if there would be a longer-term difference in outcome, as at the beginning we aimed to evaluate the condition immediately after cast removal. Also, we could have measured grip strength, but we found it more important to be done in a later follow-up.

Strength of this study is the careful selection of similar extra-articular DRF with exclusion of all patients with conditions which could influence the results of treatment outcome.

REFERENCES

Примена импулсног електромагнетног поља током гипсане имобилизације жене с преломом дисталног окрајка радијуса у постменопаузи

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КРАТАК САДРЖАЈ
Увод Иако је прелом дисталног дела радијуса са дорзалном дислокацијом дисталног фрагмента – или Колесов (Colles) прелом – један од најчешћих, нема доволно доказа да се одреди најбољи облик рехабилитације.
Циљ рада Циљ рада био је да се процени да ли примена терапије импулсним електромагнетним пољем (ИЕМП) током гипсане имобилизације жене с преломом дисталног дела радијуса позитивно утиче на бол, оток, обим покрета и функцију ручног зглоба, као и на учесталост компликација непосредно након скидања гипса.
Методе рада Проспективна рандомизирана, контролисана студија је обухватала 60 жена старијих од 55 година с екстракартулярним дислокацијама преломом дисталног дела радијуса збирним репозиционим и имобилизацијом гипсаном лонгетом. Испитиванце су наизменично утапљене у групу оних које су лечене применом ИЕМП (30 жена, примена 10 дана терапије ИЕМП током имобилизације) или у контролну групу (30 жена, без терапије ИЕМП). Код сваке испитиване се другог или трећег дана након скидања имобилизације процењиване су степен бола, функција ручног зглоба, обим шаке, обим покрета ручног зглоба и подлактице, као и на учесталост компликација.
Резултати Забележене су боље просечне вредности већине испитиваних параметара у групи жена које су лечене применом ИЕМП, али је разлика била статистички значајна само за оток (p<0,001) и обим покрета флексије, екстензије и супинације (p<0,01).
Закључак Терапија ИЕМП током имобилизације особа с преломом дисталног дела радијуса довела је до бољих резултата у погледу субјективног бола и повећања обима покрета ручног зглоба непосредно након скидања гипсане имобилизације.
Кључне речи: прелом дисталног дела радијуса; рехабилитација; физикална терапија; импулсно електромагнетно поље

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