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The results of the impact of electromagnetic waves of the terahertz range on the tissues of the elbow joint with the consequences of its injury

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Abstract

Introduction Among the ranges of electromagnetic waves used in clinical practice, electromagnetic waves of the terahertz range (EMWTHR) have promising applications. The experimental and clinical studies show that they are able to provide correction of the main pathophysiological disorders of a living organism such as hypoxia, hypercoagulation, and immunodeficiency. **Purpose** To study the effectiveness and safety of terahertz electromagnetic waves in the complex treatment of patients with the consequences of fractures of the humeral condyle. **Methods** Clinical, radiological, physiological and laboratory studies were conducted in 30 patients with consequences of fractures of the humeral condyle (post-traumatic deformities, osteoarthritis of the elbow joint). Surgical treatment of patients with consequences of injuries of the elbow joint was classical and consisted of corrective osteotomies and osteosynthesis with the Ilizarov apparatus of the humerus and forearm. The main group consisted of 15 patients who underwent 10 sessions of EMWTHR exposure to the osteotomy zone, and 15 patients did not undergo physiotherapy. **Results** It was found that in patients of the main group, the average values of the intensity of pain and the deficit in the range of motion were significantly lower than the findings of the comparison group in the short term after treatment. The use of EMWTHR therapy led to differences in metabolic processes in the compared groups. There were no significant changes in radiological, physiological and laboratory parameters, as well as clinical signs that could be attributed to adverse events or complications associated with the use of EMWTHR. **Conclusion** The results of the comparative study allow us to recommend the EMWTHR therapy in the system of complex treatment of patients with the consequences of fractures of the humeral condyle and can be used as a means for local stimulation of reparative processes in target patients.

Keywords: humeral condyle, injury, consequences, deformity, osteoarthritis, terahertz electromagnetic waves, efficacy, safety

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INTRODUCTION

The use of electromagnetic waves as a method of stimulating the regeneration of supporting tissues has a sufficient theoretical justification [1–3]. Among the ranges of electromagnetic waves used in practice, electromagnetic waves of the terahertz range (EMWTHR) show promising applications. Experimental and clinical studies found that they are able to provide correction of the main pathophysiological disorders of a living organism such as hypoxia, hypercoagulation, and immunodeficiency [4–9]. It has been shown that such therapeutic procedures, that are minimally invasive and low traumatic, can be quite effective in practical traumatology and orthopedics [10, 11]. In this regard, the use of EMWTHR in the treatment of patients with orthopedic trauma profile is a promising way to stimulate tissue regeneration. The preliminary results reported by the available literature were positive.

Purpose To study the effectiveness and safety of terahertz electromagnetic waves in the complex treatment of patients with the consequences of fractures of the humeral condyle.

MATERIALS AMD METHODS

The results of clinical, radiological, physiological and laboratory studies in 30 patients with the consequences of fractures of the humeral condyle (HC) (various deformities, osteoarthritis of the elbow joint) were analyzed. The age of the patients was 18–56 years. Patients complained of deformity around the elbow joint, accompanied by impaired movements in the elbow joint during exercises and "night" pain. Radiography showed signs of stage II osteoarthritis in the elbow joint in all the cases. Fractures were sustained one to two years prior to admission. Surgical treatment of patients with the consequences of a HC fracture was classical and consisted of corrective osteotomies and osteosynthesis with the Ilizarov apparatus of the humerus and forearm.

In the early postoperative period after osteotomies of the bones forming the elbow joint, 15 patients were randomized into the experimental group and underwent 10 sessions of EMWTHR exposure to the osteotomy zone. The signal amplitude modulation mode corresponded to a frequency of 150 ± 0.75 GHz, exposure duration was

15 minutes daily. The first session started 1-2 days after the operation. The other 15 patients did not undergo this procedure (a comparison group). According to clinical and demographic data, the patients of the groups were comparable. Surgical interventions were performed by one team, the protocols for postoperative management of patients differed only in additional exposure to EMWTHR in the main group.

The source of EMWTHR was a physiotherapeutic device *Orbita* (reg. No. FSR 2009/05497). It was used according to the indications for therapeutic action on the involved pathological zone with electromagnetic waves at the frequency of the molecular spectrum of radiation and absorption of nitric oxide.

The study was approved by the ethics committee at the Ilizarov National Medical Research Centre of the Ministry of Health of Russia.

Clinical and radiographic examination Radiography of the limb segment involving the area of osteotomy and the joint under study was taken in two standard projections (anteroposterior and lateral). In the postoperative period, the dynamics of pain and range of motion (ROM) in the elbow joint were studied that were analyzed using a visual analog scale (assessment of the intensity of pain at rest, during movement in the joint, at night) and indicators of deficit in ROM in points (from 0 to 5).

Physiological study The reaction of the upper limb skin was studied before the EMWTHR exposure procedure, during its implementation at the 1st, 5th and 10th procedure, 7 days after the end of exposure and at the end of inpatient treatment. In the zone of exposure to radiation, the volumetric skin capillary blood flow and the pressure of oxygen and carbon dioxide were measured. The parameters were measured with a laser Doppler flowmeter (BLF-21, Transonic Systems, USA) using a skin sensor. A transcutaneous polarographic monitor 840 (VFD, $TcpCO_2/TcpCO_2$, Novametrix, USA) was used to determine the pressure of oxygen and carbon dioxide (mm Hg). The gas composition of tissues was determined by thermal sensor (t = 44°C) with a Clark electrode for prolonged determination of $TcpO_2$ and $TcpCO_2$. Measurement of transcutaneous oxygen and carbon dioxide pressure was carried out before the start of the procedure, immediately after its session, 7 days after completion of sessions and after the end of inpatient treatment.

Laboratory tests Patients' blood serum was examined. Blood samples were taken before the start of EMWTHR therapy, after 10 sessions and at the time of discharge from the hospital. The levels of glucose, lactate (LA), total protein, total cholesterol, triglycerides (TG), urea, inorganic phosphate, total calcium, magnesium, sodium, potassium, and chlorides was determined. The activity of alkaline (AP) and tartrate-resistant acid isoenzyme (TRAP) phosphatase, transaminases (AST, ALT), creatine kinase, lactate dehydrogenase (LDH) was detected.

An automatic biochemical analyzer Hitachi/BM 902 (Japan) was used to determine the activity of enzymes and the concentration of substrates. Reagent kits from Vital Diagnostic (St. Petersburg) were used. The content of potassium, sodium, and chlorides was determined by the ion-selective method using the ion-selective block of a Hitachi/BM 902 biochemical analyzer.

Statistical evaluation The arithmetic mean and standard deviation (Xi ± SD) were determined. Using the Shapiro-Wilk test, the normal distribution of samples was revealed. The procedure for statistical assessment of the significance of differences in indicators within the study groups (before and after treatment) was performed using the Wilcoxon W-test. The Mann-Whitney T-test was used to determine the statistical significance of the obtained indicators between the groups.

RESULTS

Changes in pain intensity and ROM deficit are presented in Table 1.

It was found that the average values of the intensity of the pain and the deficit in ROM in the patients of the experimental group in the short term after treatment were significantly lower than the values of the comparison group.

The use of EMWTHR therapy led to differences in metabolic processes in the compared groups (Table 2). Thus, if the activity of ALP in patients of both groups did not differ significantly, then in the patients of the experimental group there was a significant decrease in the activity of TRAP during treatment, and a month after treatment, the activity of this enzyme in patients of the experimental group was higher than the initial (before therapy) level, and the values of patients in the comparison group.

Table 1

Pain intensity changes and ROM deficit in both groups (Xi ± SD)

Groups	Pain (points up to 5)		ROM deficit, %	
	Before treatment	At discharge	Before treatment	At discharge
Experimental group	2.5 ± 0.3	0.4 ± 0.2*#	34 ± 0.2	22 ± 0.2*#
Comparison group	2.7 ± 0.3	1.0 ± 0.2*	36 ± 0.2	34 ± 0.1

Notes: * – significant difference compared with the value before treatment $p < 0.05$; # – significant difference with the comparison group at $p < 0.05$

Table 2

Dynamics in blood serum parameters that had significant changes in patients of the groups (Xi ± SD)

Term	Group	AP, u/l	TRAP, U/l	LA, mmol/l	TG, mmol/l
Before EMWTHR exposure	E	108 ± 41	4.50 ± 0.28	1.9 ± 0.2	1.3 ± 0.7
	C	104 ± 24	4.20 ± 0.47	2.1 ± 0.2	1.1 ± 0.2
After 10 sessions	E	111 ± 32	3.00 ± 0.63*	2.1 ± 0.1	1.3 ± 0.8
	C	102 ± 20	3.40 ± 0.14*	2.4 ± 0.1	1.1 ± 0.8
On theda of discharge	E	95 ± 9	2.55 ± 0.07*#	2.3 ± 0.3#	0.8 ± 0.4#
	C	97 ± 16	5.61 ± 1.11	2.9 ± 0.3	1.3 ± 0.1

Notes: E – experimental group; C – comparison group. * – significant changes relative the values before EMWTHR therapy at $p < 0.05$; # – significant values that differ from the values of the comparison group at $p < 0.05$

Moreover, one month after the use of EMWTHR, there were significant differences (decrease) in the level of lactate and triglycerides in the blood serum in patients of the experimental group relative to patients in the comparison group. All other biochemical parameters during treatment did not differ significantly between the groups (data not shown). The observed changes in the blood serum of energy metabolism products (lactate and TG) in the patients of the experimental group indicated a higher intensity of aerobic metabolism, which may have been associated with an improvement in the blood supply to the soft tissues of the operated segment during the application of EMWTHR.

The data of physiological studies speak in favor of the latter assumption. It was found that the volumetric rate of capillary skin blood flow in the area of EMWTHR exposure increased consistently during the session on average from 3.0 ml/min*100 g before the start of the procedure up to 4.4 ml/min*100 g 2 minutes after the start of the session and up to 6.2 ml/min*100 g after 10 minutes following the procedure. After applying EMWTHR, increased capillary blood flow in the affected area persisted for up to 10 minutes.

Table 3

Values of transcutaneous pressure of oxygen and carbon dioxide in the experimental group (Xi ± SD)

Values of pressure (mm Hg)	Before treatment	Session 5	Session 10
Oxygen	60 ± 3	75 ± 5*	77 ± 4*
Carbon dioxide	67 ± 3	54 ± 2*	50 ± 2*

Note: * – significant difference as compared with before treatment at $p < 0.05$

During exposure to EMWTHR, the gas regime of tissues also increased (Table 3). Significant changes in the average values of oxygen pressure (its increase) and carbon dioxide (its decrease) in patients of the experimental group were noted already after 5 sessions of EMWTHR therapy. Elevated values of oxygen pressure all patients of the experimental group persisted for at least 7 days after the end of exposure.

There were no significant changes in radiological, physiological and laboratory parameters, as well as clinical signs that could be attributed to adverse events or complications associated with the use of EMWTHR. This circumstance indicates the acceptable safety of its use in the system of treatment of target patients.

DISCUSSION

The study found that the use of EMWTHR for the consequences of HC fractures contributes to the activation, first of all, of local, in the fracture zone, reactions, which generally lead to positive clinical effects on pain and ROM deficiency. This effect is achieved due to the activation of local blood flow in the area of surgical intervention under the influence of EMWTHR. It led to a local increase in oxygen supply to tissues. This, in turn, at the molecular level caused the intensification of local aerobic processes, which led to an acceleration of the repair of all tissues of the musculoskeletal system [12, 13].

However, the analysis of literature data shows that the use of these waves in the complex treatment of orthopedic patients has limited availability, and they are often used on an individual basis [14]. Few systematic studies have been carried out. Thus, a group of authors [15] used this therapy in the complex treatment of 18 patients with fractures of the olecranon. The authors observed that the use of EMWTHR contributed to a reduction in the period of temporary disability of the patients, in contrast to the comparison group. In another study [16], the technology was applied in 32 patients with fractures of the bones of the lower extremities. The researchers stated that the use of EMWTHR led to an improvement in the rheological properties of blood in patients in comparison with the generally accepted scheme for the prevention of deep vein thrombosis. Using EMWTHR in the complex treatment of 12 patients with penetrating stab wounds of the chest, V.V. Maslyakov et al [17] noted that this procedure prevented the development of changes in the rheological properties of blood. At the same time, the authors point to good tolerance of this procedure. There is also experience in the use of EHF-therapy as a means to stimulate the regression of neuroorthopedic disorders in patients with lumbar osteochondrosis and osteoarthritis [18]. In general, our study, in conjunction with other works,

indicates the effectiveness of EMWTHR in the treatment system of target patients.

Despite the existing modest experience in the use of EMWTHR, it should be noted that the use of electromagnetic exposure has been currently finding increasing practical application for the treatment of patients with various orthopedic pathologies. [19–23]. Moreover, indications are expanding not only for stimulating bone reparation, but also in terms of applying exposure to an electromagnetic field in case of cartilage damage [24, 25]. Potential effects of such exposure are possible by combining the electromagnetic waves [26].

Summing up the experience of the clinical application of electromagnetic stimulation in the practical traumatology and orthopedics, L. Caliogna notes that the main clinical effect of such stimulation is pain relief and the ability to stimulate the healing process locally without causing systemic effects and adverse reactions [27]. The effectiveness of electromagnetic stimulation in terms of reducing the time of bone fusion, according to the literature, does not look quite obvious [28–31]. In general, these data are consistent with our results. Exposure to EMWTHR contributes to the development of local effects, pain relief, improvement of function, without a significant reduction in treatment time, and features acceptable safety.

Undoubtedly, our results have limitations in terms of the small sample of patients. Obviously, evidence of the effectiveness of EMWTHR in the patients with orthopedic and trauma consequences needs to expand the number of observations and the number of studies in general. However, our experience of application so far confirms the initial hypothesis about the effectiveness of using this procedure in a complex of measures for the treatment of target patients.

CONCLUSIONS

The results of this comparative study allow us to recommend the EMWTHR therapy in the system of complex treatment of patients with the consequences of fractures of the humeral condyle. The technique can be used as a means for local stimulation of reparative processes in target patients.

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