DOI: https://doi.org/10.17816/uroved84474
Review

Extracorporeal magnetic stimulation in urology

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The review article is devoted to the usage of extracorporeal magnetic stimulation in the treatment of urological diseases. Based on the analysis of scientific publications in the PubMed, Medscape, Google Scholar databases, modern data on the mechanism of the therapeutic effect of this method, the method of performing the procedure, the results of clinical studies of its effectiveness in the treatment of urinary incontinence, bladder hypoactivity, chronic pelvic pain syndrome, erectile dysfunction and premature ejaculation are presented.

Keywords: extracorporeal magnetic stimulation; urinary incontinence; chronic pelvic pain syndrome; bladder hypoactivity; erectile dysfunction.

To cite this article:
Amdiy RE, Al-Shukri SKh, Kuzmin IV, Makeev VA, Sozdanov PV. Extracorporeal magnetic stimulation in urology. *Urology reports (St. Petersburg)*. 2021;11(4):345-353. DOI: https://doi.org/10.17816/uroved84474

Received: 01.11.2021 **Accepted:** 21.12.2021 **Published:** 29.12.2021

ECO•VECTOR

DOI: https://doi.org/10.17816/uroved84474
Обзорная статья

Экстракорпоральная магнитная стимуляция в урологии

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Обзорная статья посвящена применению экстракорпоральной магнитной стимуляции при лечении пациентов с урологическими заболеваниями. На основе анализа научных публикаций в базах данных PubMed, Medscape, Google Scholar представлены современные данные о механизме лечебного эффекта данного метода, методике выполнения процедуры, приведены результаты клинических исследований его эффективности при лечении недержания мочи, гипоактивности мочевого пузыря, синдрома хронической тазовой боли, эректильной дисфункции и преждевременной эякуляции.

Ключевые слова: экстракорпоральная магнитная стимуляция; недержание мочи; синдром хронической тазовой боли; гипоактивность мочевого пузыря; эректильная дисфункция.

Как цитировать:
Амдий Р.Э., Аль-Шукри С.Х., Кузьмин И.В., Макеев В.А., Созданов П.В. Экстракорпоральная магнитная стимуляция в урологии // Урологические ведомости. 2021. Т. 11. № 4. С. 345–353. DOI: https://doi.org/10.17816/uroved84474

Рукопись получена: 01.11.2021 **Рукопись одобрена:** 21.12.2021 **Опубликована:** 29.12.2021

The recent development of physiotherapeutic and physical methods of influence has resulted in an increase in the efficacy of treatment of patients diagnosed with urological diseases [1–4]. One such method, extracorporeal magnetic stimulation (ECMS), involves the use of special equipment for the generation of high-intensity alternating magnetic fields, which affect the afferent and efferent nerve fibers [1]. Impulses in the efferent nerve fibers induce contractions of muscle structures such as the pelvic floor, while activation of afferent fibers affect the sensitivity of the pelvic organs [4–8]. ECMS is believed to induce neuromodulation of the lower urinary tract function in this manner [1, 2].

The effects of ECMS are largely dependent on the frequency of the magnetic field applied, with lower frequencies (5–10 Hz) of alternating magnetic fields resulting in excitation of the afferent fibers of the vesicoprostatic nerve and transmission of impulses to the spinal cord. In the spinal cord, the impulses switch to the supraspinal pathways and propagate to the centers of urination in the brainstem. Such an effect can lead to a decrease in the tone of the centers of urination, indirect inhibition of the parasympathetic efferent pathway activity, and detrusor contraction. Existing literature refers to this mechanism as inhibition of the detrusor-activating reflex [9]. Exposure to an alternating magnetic field also results in depolarization of the autonomic sympathetic fibers of the vesicoprostatic nerve and an increase in the activity of nuclei in the thoraco-lumbar and sacral sections of the spinal cord. As a result, an increase in the sympathetic activity of the efferent pathway of the hypogastric nerve, beta-3-adrenergic receptor activity, and detrusor relaxation is observed [10].

J.S. Koh et al. [11] suggested that an additional therapeutic effect of low-frequency ECMS in an overactive bladder was the inhibition of involuntary detrusor contractions caused by stimulation of the sacral nerves, subsequent activation of the inhibitory interneuronal reflex, and inhibition of type C nerve fiber activity that affected the increase in bladder tone. This may also help explain the efficacy of ECMS in patients with overactive bladders and spinal injuries [11–13].

Conversely, exposure to high frequencies of ECMS (50–100 Hz) results in excitation of the sympathetic efferent fibers of the vesicoprostatic nerve, leading to increased tone and contraction of the pelvic floor muscles including the external urethral sphincter responsible for urinary retention [10].

In case of mixed urinary incontinence, a combination of low- and high-frequency exposure in each session is recommended as this approach enables the effective management of urge and stress urinary incontinence [14].

Myostatin serves as an endogenous inhibitor of muscle tissue growth, and an increase in its levels may result in impaired contractility of the pelvic muscles. Previous studies have demonstrated a decrease in the concentration of myostatin in the blood serum after ECMS [13, 15–17], suggesting that this procedure helps to restore the function of the pelvic floor muscles at the biochemical level.

The occurrence of a refractory conduction period after contraction of the pelvic floor muscles during high-frequency ECMS can block pathological and pain impulses [18], and this mechanism is particularly important when using ECMS in patients with chronic pelvic pain.

The ECMS procedure is relatively comfortable for patients, with no need for undressing or application/insertion of sensors into the vagina or rectum. The patient sits on a special chair during the procedure, and the intensity of the magnetic field strength is adjusted on an individual level to achieve a painless effect on the muscle structures and pelvic organs [19].

ECMS has beneficial effects on the psychosocial sphere of patients, thus improving their quality of life. Previous studies have reported, that after ECMS-therapy a statistically significant decrease in Beck's Depression Inventory-II scores and episodes of physical and social restrictions associated with urinary incontinence was observed. [20, 21].

Sequential contraction and relaxation of the pelvic floor muscles during ECMS can help patients understand the correct algorithm for training their pelvic floor muscles, and ECMS can also be combined with the biofeedback method [13, 22].

Stress urinary incontinence

The use of ECMS for the treatment of stress urinary incontinence was first approved in the USA in 1998 when N.T. Galloway, a notable urologist and pioneer of this method, evaluated its efficacy in the treatment of stress urinary incontinence in a sample of 83 women [23]. In this study, the patients were asked to sit on a special chair, with the source of alternating magnetic waves placed under the seat. The ECMS procedure was executed by the application of a frequency of 5 Hz for the first 10 minutes, followed by a break of 1 to 5 minutes, and then exposure to a frequency of 50 Hz for the next 10 minutes. The procedures were repeated twice a week for 6 weeks, and control examination 3 months after the end of treatment was carried out in 50 out of 83 treated patients. The findings showed that 17 (34%) female patients exhibited no episodes of urine leakage, 16 (32%) patients had to use one urological pad per day, and the remaining 17 (34%) patients had to use more than one pad per day. The number of used urological pads decreased from 2.5 initially to 1.3 per day after the end of ECMS therapy course, and the average weight of the pads decreased from 20 to 15 g. Similar results confirming the efficacy of ECMS in women with stress urinary incontinence were also observed by other researchers. A. Ünsal et al. [24] reported that, in their study, 38% of patients exhibited no signs of stress urinary incontinence and 41% of patients demonstrated a decrease in its severity one year after ECMS, indicating that its effects persisted for at least one year. It has been suggested that, in patients with stress urinary incontinence, the therapeutic effects of ECMS are associated with an increase in intraurethral pressure. T. Yamanishi et al. [25] observed an increase of 34% (from 72.0 to 96.5 cm of water column) in maximum intraurethral pressure and 20.9% (from 68.3 to 82.6 cm of water column) in maximum urethral closure pressure after a course of ECMS.

A meta-analysis of clinical studies including 232 patients with stress urinary incontinence showed a decrease in the frequency of urinary leakage (mean: 1.42 per day) and the amount of urine lost (mean reduction in the weight of the urological pad: 4.99 g) after a course of ECMS. Moreover, none of the treated patients exhibited any complications associated with the use of ECMS [26].

Urge urinary incontinence

ECMS has also been successfully used to treat patients with urge urinary incontinence. In their pilot study including patients diagnosed with the same, T. Yamanishi et al. [25] performed cystometry before and during a 15-minute session of ECMS at a frequency of 10 Hz and reported a significant increase in bladder filling volume at the first urge to urinate and also in maximum cystometric capacity after completion of the procedure. A. Ünsal et al. [24] also confirmed the efficacy of ECMS, with 7 (41.2%) out of 17 patients in their study reporting cessation of urinary incontinence and another 8 (47.1%) observing a decrease in its severity upon completion of treatment.

T. Yamanishi et al. [27] conducted a randomized controlled trial to examine the effects of ECMS at 10 Hz for 25 minutes in women with urge urinary incontinence. The sessions were performed twice a week for 7 weeks, and the study sample included 151 patients in the treatment group and 50 women in the control group. The findings showed a decrease in the number of episodes of urge urinary incontinence (from 2.65 to 1.53 per day) and the average volume of urinary output during incontinence (from 14.03 to 4.15 g) after a course of ECMS. No significant changes were noted in the control group.

Mixed urinary incontinence

A combination of high- and low-frequency ECMS is recommended in female patients with mixed urinary incontinence. D.D. Chandi et al. [14] examined the efficacy of this treatment method and found that 66.7% of patients experienced a decrease of more than 50% in the frequency of urination or the frequency of urinary incontinence episodes. However, the results of the 24-hour pad test before and after treatment did not differ significantly.

P.M. Groenendijk et al. [28] varied the frequencies of ECMS with the form of urinary incontinence, with patients diagnosed with urge urinary incontinence receiving a low frequency of 10 Hz for 20 minutes and those exhibiting stress incontinence receiving a higher frequency of 50 Hz. In the mixed form, ECMS was performed at a frequency of 10 Hz for the first 10 minutes and then at a frequency of 50 Hz for the next 10 minutes. The treatment was found to be successful in 60% of patients with urge urinary incontinence and in 66% of patients with stress and mixed urinary incontinence.

Urinary incontinence after radical prostatectomy

T. Yokoyama et al. [29] conducted a comparative study examining the efficacy of ECMS and electrical stimulation of the pelvic muscles in the treatment of patients with urinary incontinence after radical prostatectomy. The control group consisted of patients who performed Kegel exercises only. The group of patients receiving ECMS or electrical stimulation exhibited a higher level of urinary retention after treatment compared to the control group after a period of 2 months. Comparable results in the three groups were achieved only 6 months after surgery.

Rapid achievement of urinary retention through ECMS after radical prostatectomy was also noted by M. Nowak et al. [30]. In their study, 105 patients were divided into two groups, with the experimental group receiving ECMS and the control group performing Kegel exercises. After removal of the urethral catheter in the early postoperative period, 16.8% of all patients exhibited complete urine retention. Moreover, 51%, 64%, and 82% of the experimental group and 44%, 50%, and 68% of the control group achieved urinary retention after 4 weeks, 3 months, and 6 months, respectively. Pad test results after 12 months were significantly better in the experimental group compared to the control group ($p = 0.004$). The researchers concluded that ECMS significantly accelerated the recovery of urinary continence in patients after radical prostatectomy.

R.E. Amdiy et al. [31] also confirmed the efficacy of ECMS in the treatment of stress urinary incontinence in patients with a history of radical prostatectomy. In their study, ECMS was performed in 27 patients at frequencies of 10 and 50 Hz for 20 minutes 2–3 times a week, with a full course of treatment including 12 procedures. At the end of treatment, 3 (11.1%) patients still exhibited urinary incontinence, 4 (14.8%) patients used one pad per day, and 20 patients (74.1%) presented with complete urine retention. The total score on the ICIQ-SF questionnaire after the end of treatment decreased from 12.9 to 3.7.

C.A. Anderson et al. [32], in their meta-analysis of studies evaluating the efficacy of pelvic floor muscle training, biofeedback, electrical stimulation, ECMS, use of compression devices, and lifestyle changes in the treatment of urinary incontinence after radical prostatectomy, observed controversial findings and concluded that additional randomized trials were required to evaluate the long-term effects of different types of therapy.

Chronic pelvic pain and chronic prostatitis

The efficacy of ECMS in the treatment of chronic pelvic pain in men who underwent ineffective standard medical therapy with antibiotics, α-blockers, and non-steroidal anti-inflammatory and neurotrophic drugs was evaluated by M.H. Yang et al. [4]. In their study, 23 patients underwent a 6-week course of ECMS (3 sessions per week) at 10 and 70 Hz for 15 minutes. The findings showed a 36.4% (from 25.0 to 15.9 points) decrease in the total scores on the National Institutes of Health Chronic Prostatitis Symptom Index (NIH-CPSI), a 44.1% (from 11.8 to 6.6 points) decrease in the pain domain scores, and a 26.1% (from 4.6 to 3.4 points) decrease in the urination disorders domain scores. At the same time, the quality of life of patients improved by 31.4% (from 8.6 to 5.9 points). The efficacy of treatment increased with the combined use of ECMS and the biofeedback method. The decrease in pain and severity of lower urinary tract symptoms persisted for 6 to 12 months after completion of ECMS course, with the greatest efficacy being observed in relation to reduction of the severity of pain [18, 33]. The efficacy of combined ECMS in the treatment of patients with chronic pelvic pain was confirmed by T.H. Kim et al. [34] who used a combination of low-frequency stimulation at 10 Hz for the first 15 minutes and 50 Hz for the next 15 minutes.

Erectile dysfunction and early ejaculation

ECMS can also be used quite successfully for the treatment of patients with erectile dysfunction. In this case, the magnetic coil can either be built into a special chair or be portable, where it is applied to the base of the dorsal surface of the penis. A. Shafik et al. [35] used an alternating magnetic field at a frequency of 20 Hz to influence the cavernous nerve. The study sample was divided into the treatment group and a control group without electromagnetic exposure. Penile rigidity was observed in the treatment group, while no such change was seen in the control group. Upon repetition of the exposure phase, patients in the experimental group exhibited erections while those in the control group did not. These findings indicate the efficacy of direct exposure of the cavernous and deep dorsal nerves to an alternating magnetic field in the achievement of an erection.

R.B. Pelka et al. [36] randomly distributed patients to the treatment or control groups (n = 10 each), with the former receiving an alternating magnetic field pulse frequency of 18 Hz. At the end of the treatment course, 8 patients (80%) in the experimental group reported an overall improvement in the quality and duration of erection, while the remaining 2 patients (20%) reported only a slight improvement. In the control group, 3 patients (30%) observed an overall improvement, while no changes were seen in the remaining 7 (70%) patients.

D.Yu. Pushkar et al. [37] suggested using ECMS at a frequency of 6–8 Hz with rest intervals of 3–4 s for the treatment of erectile dysfunction. To achieve an effect, 8–10 procedures each lasting 15–20 minutes were necessary.

ECMS is also used in the treatment of early ejaculation [38]. The mechanism of action involves reduction of the tone of the ejaculation center in the spinal cord. When exposed to a frequency of 20 Hz, a persistent increase in intravaginal latent ejaculation time was noted, and this was directly related to the duration of the treatment course. The results of such treatment were comparable with behavioral and pharmacological therapies.

However, many aspects of the efficacy of ECMS in the restoration of erectile function remains unclear, and additional research is necessary in order to identify the optimal modes of exposure [31].

Urinary bladder hypoactivity

Sacral stimulation is an effective treatment for detrusor hypoactivity [39]. The mechanism of action involves neuromodulation of the functioning of micturition centers [40]. In their pilot study, R.E. Amdiy et al. [41] showed the possibility of using ECMS in patients with detrusor hypoactivity, with an improvement in symptoms and a decrease in the volume of residual urine being observed in 37.5% of patients receiving ECMS at the same frequency as that used for sacral stimulation.

CONCLUSION

The efficacy of ECMS in the treatment of diseases of the pelvic organs has been established, and this method has been shown to be advantageous when compared to other conservative methods of treatment for urological diseases due to its non-invasive nature and painless effect on deeper structures. Moreover, this method is easy to use, has a minimum number of contraindications, and does not require expensive consumables.

The physiological effects of ECMS depend largely on the frequency used, with low frequencies (5–15 Hz) of an alternating magnetic field being effective in the treatment of urge urinary incontinence through reduction of the tone of the micturition centers in the sacral spinal cord and relaxation of the detrusor and pelvic floor muscles. High frequencies (50 Hz), on the other hand, affect motor neurons of the pelvic floor muscles, inducing contraction and resulting in a better understanding of the correct algorithm of contractions in the patient. The mechanism of action of ECMS includes neuromodulation of the nervous system activity through excitation of the afferent nerves of the organs and muscles of the pelvic floor.

Further practical research is necessary in order to determine indications, identify suitable patients, and establish the most effective modes of exposure to ECMS.

DOI: https://doi.org/10.17816/uroved84474

ADDITIONAL INFORMATION

Author contributions: All authors confirm that their authorship complies with the international ICMJE criteria (all authors have made a significant contribution to the development of the concept, research, and preparation of the article, and have read and approved the final version prior to publication).

Conflict of interest: The authors declare no conflicts of interest.

Funding: The study received no external funding.

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