Effects of prenatal pulsed electromagnetic fields on neural stem cell proliferation and nestin protein expression in the hippocampus of rat offspring*★

Li Xia[1], Chen Rui[2], Jia Ning[3], Li Hui [4], Zhu Zhong-liang[5]

[1]Psychiatric Department, Shanxi Corps Hospital of Chinese People's Armed Police Forces, Taiyuan 030006, Shanxi Province, China; [2]Department of Gynecology and Obstetrics, First Affiliated Hospital of Xi'an Medical University, Xi'an 710021, Shaanxi Province, China; [3]Department of Pathophysiology, [4]Department of Pediatrics of the First Affiliated Hospital, [5]Department of Pharmacology, Medical School of Xi'an Jiaotong University, Xi'an 710061, Shaanxi Province, China

Li Xia★, Master, Attending physician, Psychiatric Department, Shanxi Corps Hospital of Chinese People's Armed Police Forces, Forces Taiyuan 030006, Shanxi Province, China
muyu77@sina.com

Correspondence to: Zhu Zhong-liang, Doctor, Professor, Investigator, Department of Pharmacology, Medical School of Xi'an Jiaotong University, Xi'an 710061, Shaanxi Province, China

Supported by: the National Natural Science Foundation of China, No. 30970952*

Received: 2010-05-18
Accepted: 2010-07-16
(20100501006/W)

Abstract

BACKGROUND: Electromagnetic fields can cause changes of the body, especially the nervous system. Effect of pulsed electromagnetic fields (PEMFs) on neural stem cells has been detected.
OBJECTIVE: To investigate the effect of prenatal pulsed electromagnetic fields (PPEMFs) on neural stem cell proliferation and nestin protein expression in the hippocampus of rat offspring.
METHODS: Sprague Dawley female rats weighing 240–260 g were included and randomly divided into two groups: control and PPEMFs. Rats from the control group were given no interventions. Rats from the PPEMFs group were given PEMFs stress at gestational days 14–20. Each stress was given three times daily for 10 minutes. The male and female offspring rats were sacrificed at 1 month of age and their brains were sectioned to determine the expression of nestin protein and Brdu-positive cells in the hippocampus by immunohistochemistry.
RESULTS: The expression of nestin- and Brdu-positive cells in the hippocampus of female and male PEMFS offspring were significantly higher compared with the control group ($P < 0.001$), and there was a significant difference between female and male offspring ($P < 0.001$). The nestin- and Brdu-positive cells in female offspring outnumbered those in male offspring ($P < 0.001$); however, there was no significant difference between female and male offspring in the control group ($P > 0.05$).
CONCLUSION: PPEMFs can increase the number and proliferative capability of the neural stem cells in offspring. It may be a primary stage of the cascade reaction of the body to the brain damage caused by PPEMFs stress.

INTRODUCTION

Nowadays electromagnetic pulse is widely used in such fields as industry, agriculture, communication, medicine and military affairs. However, with the increase of the electric setting, the electromagnetic radiation may produce various effects on the body. Pulsed electromagnetic fields (PEMFs), have more significant effects on the body than continuous waves[1]. Therefore, increasing attention has been paid to the effects of PEMFs on the body. Electromagnetic fields have been reported to change blood cells[2], mammalian cells[3] and human keratinocytes[4]. Furthermore, research shows the effects of PEMFs on the nervous system[5-7] and neural stem cells[8]. But there have been few papers about the effects of prenatal PEMFs (PPRMFs) on the expression of offspring neural stem cells. The present study investigated the effects of PPEMFs on neural stem cell proliferation and nestin protein expression in the hippocampus of rat offspring, hopefully to study the effects of prenatal-stage environment on the brain development and the biological effects of PEMFs.

MATERIALS AND METHODS

Design: A randomized, controlled research.

Time and setting: This study was performed at the Medical School of Xi'an Jiaotong University from 2005 to 2006.

Materials

Adult Sprague-Dawley rats of SPF grade from Shaanxi Province (permission No. 2007-001) were housed at 22 ℃ with free access to food and water throughout the experiment. This study was performed in accordance with the *Guidance Suggestions for the Care and Use of Laboratory Animals*[9]. Virgin female rats weighing 240–260 g were placed overnight with adult male rats for mating (3 to 1) and a vaginal smear was examined on the following morning. The day on which the smear was sperm positive was determined as embryonic day 0. The offspring rats of day 30 were used for observation. The animals were divided randomly into two groups: control group (CON, in which mother rats were left undisturbed) and PEMFs stress group, in which mother rats were exposed to PEMFs stress on days 14–20 of gestation three times daily for 10 minutes. The stress was magnetic fields pulsed by spiral tube through pulse electronic. The tube body was made of a 420 mm diameter glass bottle. When tested, the rats were put on the center axis of the spiral tube, and the magnetic field of the center axis was set as the physical parameters[10] which include intensity of magnetic fields B = 0.267T, variant rate: $dB/dt = 8.9 \times 10^2 T/S$, pulse rise time 0.3 ms, pulse width 2.4 ms, and frequency 1 per minute.
Mouse anti-nestin monoclonal antibody was purchased from Chemicon, Billerica, MA, USA; mouse anti-Brdu monoclonal antibody was purchased from Sigma, St.Louis, MO, USA; SP reagent kit was purchased from Wuhan Boster Biotechnology, China.

Methods

Nestin-positive cells in the hippocampus of PEMFs rat offspring

Six offspring rats were selected randomly and fixed by cardiac perfusion after anesthesia. Their brains were

Li X, Chen R, Jia N, Li H, Zhu ZL. Effects of prenatal pulsed electromagnetic fields on neural stem cell proliferation and nestin protein expression in the hippocampus of rat offspring. Zhongguo Zuzhi Gongcheng Yanjiu yu Linchuang Kangfu. 2010;14(40): 7588-7592.

[http://www.crter.cn http://en.zglckf.com]

removed, blocked, and sectioned (3 mm thin). After wrapping to cover up and dewaxing, sections of 5 μm were cut and covered with coverslips. After dewaxing again and antigen retrieval, the coverslips were incubated with mouse anti-nestin monoclonal antibody (1: 1 000) and had ABC dyeing. Finally the nestin-positive cells in the hippocampus were determined under the microscope.

Brdu-positive cells in the hippocampus of PEMFs rat offspring

Six offspring rats were selected randomly. After injection with Brdu (50 mg/kg, i.p., twice every 8 hours), the rats were fixed by cardiac perfusion after anesthesia. Their brains were removed, blocked and sectioned (3 mm thin). After wrapping to cover up and dewaxing, sections of 5 μm were cut and covered with coverslips. After dewaxing again and antigen retrieval, the coverslips were incubated with mouse anti-Brdu monoclonal antibody (1: 500) and had ABC dyeing. Finally the Brdu-positive cells in the hippocampus were determined under the microscope.

Main outcome measures

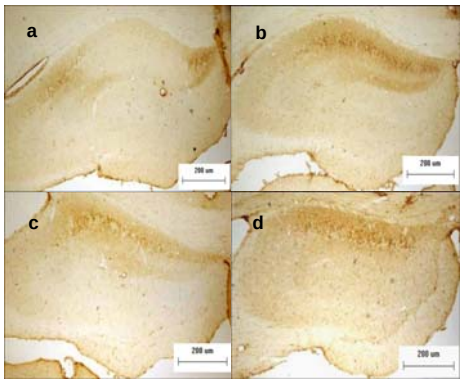
Nestin- and Brdu-positive cells in the hippocampus were determined.

Statistical analysis

Nestin- and BrdU-positive cells in two blades of hippocampal regions of each brain section were determined using Qwin 550 CW Image-collect and analysis system in the area of 2.0 × 10 μm^2. All results were expressed as Mean±SEM. The statistical difference was analyzed using SPSS 11.0 software and $P < 0.05$ was considered significantly different.

RESULTS

Effects of prenatal PEMFs stress on nestin protein expression in the hippocampal neuronal stem cells (Figure 1)



a: control female; b: PEMFs female; c: control male; d: PEMFs male. PEMFs: pulsed electromagnetic fields

Figure 1 The nestin-immunoreactive cells in the hippocampal CA1 and CA2 subregions of rat offspring (immunohistochemistry staining, ×40)

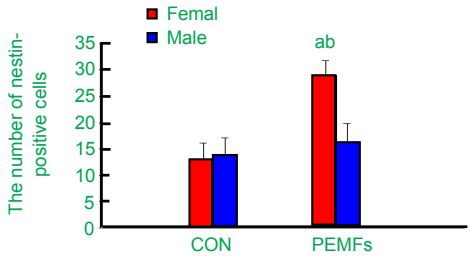
Nestin-positive cells showed almost star polygon-shaped appearance with long neurites, brown cytoplasm, and transparent nuclei

Nestin-positive cells were only determined in hippocampal CA1 and CA2 subregions in each group. Quantitation results are shown in Table 1. The nestin-positive cells in hippocampal CA1 and CA2 subregions were more in the PPEMFs group than in the control group ($P < 0.001$). The nestin-positive cells in PEMFs female rat offspring were more than those in male offspring rats ($P < 0.001$) in the PPEMFs group. But there was no significant difference between female and male offspring rats in the control group (Figures 2, 3).

Table 1 Effects of number of nestin-positive cells in the hippocampal CA1 and CA2 subregions of male an female rat offspring on prenatal pulsed electromagnetic fields (PEMFs) stress ($\bar{x}\pm s, n=6$)

Group	Female	
	CA1	CA2
Control	13.000±3.117	8.690±2.014
PEMFs	26.600±1.765[ab]	17.733±1.100[ab]
Group	**Male**	
	CA1	CA2
Control	13.570±3.435	9.280±2.228
PEMFs	19.867±1.727	13.133±1.060

[a]$P < 0.001$, *vs*. control group; [b]$P < 0.001$, *vs*. male rat offspring; PEMFs: pulsed electromagnetic field stress on days 14–20 of pregnancy



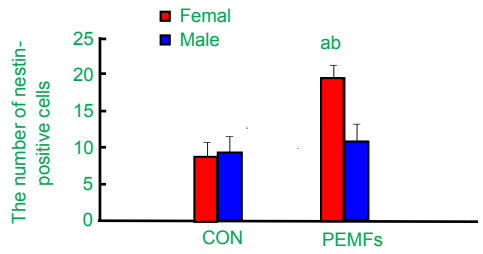
CON: control; PEMFs: pulsed electromagnetic fields stress on d 14–20 of pregnancy. [a]$P < 0.001$, *vs*. control; [b]$P < 0.001$, *vs*. male rat offspring

Figure 2 PEMFs-induced changes in the number of nestin-positive cell expression in the hippocampal CA1 subregion of male and female rat offspring

Effects of PPEMFs stress on the proliferation capability of hippocampal neuronal stem cells

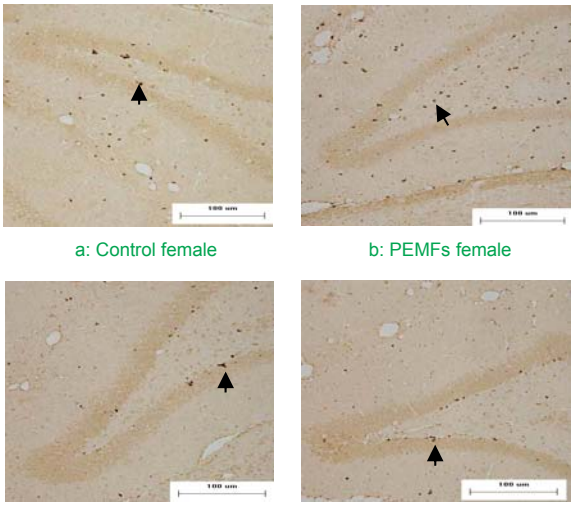
More brown Brdu-positive cells were found to be arranged along the grain bottom layer in the dentate gyrus region while few were observed in the other subregions (Figure 4). The number of Brdu-positive cells expressed in the hippocampal dentate gyrus region in each group is shown in Table 2. The Brdu-positive cells in the hippocampal dentate gyrus region of PEMFs rat offspring were more than those in control group ($P < 0.001$). Brdu-positive cells in PEMFs female rat offspring outnumbered significantly those of

male offspring rats ($P < 0.001$), but there was no significant difference between female and male offspring rats in the control group (Figure 5).



CON: control; PEMFs: pulsed electromagnetic fields stress on d 14–20 of pregnancy. [a]$P < 0.001$, *vs*. control; [b]$P < 0.001$, *vs*. male rat offspring

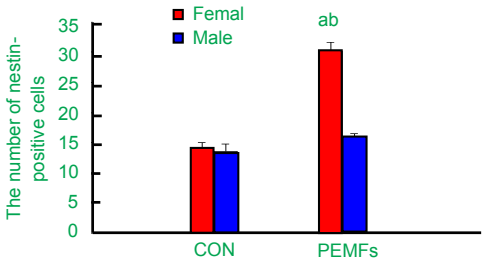
Figure 3 PEMFs-induced changes in the number of nestin-positive cells in the hippocampal CA2 subregion of male and female rat offspring



a: Control female b: PEMFs female

c: Control male d: PEMFs male. PEMFs: pulsed electromagnetic fields stress on d 14–20 of pregnancy

Figure 4 The expression of Brdu-positive cells in the hippocampal dentate gyrus subregion of rat offspring (immunohistochemistry staining, ×200)



CON: control; PEMFs: pulsed electromagnetic fields stress on d 14–20 of pregnancy. [a]$P < 0.001$, vs. control; [b]$P < 0.001$, *vs*. male rat offspring

Figure 5 PEMFS-induced changes in the number of Brdu-positive cell expression in the hippocampal dentate gyrus subregion of male and female rat offspring

Table 2 Effect of number of Brdu-positive cells in the hippocampal dentate gyrus subregion of male and female rat offspring on prenatal pulsed electromagnetic fields (PEMFs) stress ($\bar{x}\pm s, n = 6$)

Group	Female	Male
Control	14.000±1.0235	13.533±1.237
PEMFs	32.533±0.995[ab]	19.600±0.736

[a]$P < 0.001$, *vs*. contro groupl ; [b]$P < 0.001$, *vs*. male rat offspring

DISCUSSION

Effects of electromagnetic fields on the organism can be divided into thermal effect and non-thermal effect. The thermal effect makes the function of heat transmission in tissues disordered, then causing tissue damage and cell death. Non-thermal effect changes the physiological and biochemical processes of the organism, but does not cause the increase of temperature. It is generally considered that high-frequency electromagnetic waves cause mainly the thermal effect, while low-frequency ones cause the non-thermal effect. The non-thermal effect has been one of the research focuses in recent years[11]. The PEMFs used in this study belong to fast changing electromagnetic fields. Their average energy is nearly zero. Their effect on body cells is mainly non-thermal effect and is concentrated on the cell membrane[12]. As for the effect of fast changing electronic pulse, the tissue cells can produce an enhanced transmembrane potential based on primary resting potential of cell membrane. Structural changes in the cell membrane occur and the membrane becomes more permeable to molecular transport[13] which results from the formation of membrane pores (electroporation)[14-15]. Under long-time exposure to low-intensity electromagnetic pulse, the pores continue to grow, causing the loss of membrane integrity and resulting in cell death[16], which then affects the capability of learning and memory. In the present study, we determined the expression of neural stem cell proliferation and nestin protein in the hippocampus of offspring rats. The nestin-positive cells in the hippocampus of control offspring rats were concentrated in small regions of CA1 and CA2, the dye was weak, and the cell body was small. Compared with the control group, nestin-positive cells were more, the expression areas in the CA1 and CA2 subregions were larger, the neuritis of the positive cells were more, and the dye was deeper in the PPEMFs group. In the PPEMFs group, the nestin protein expression was higher in female rat offspring than in male rat offspring, but there was no significant difference between female and male rat offspring in the control group. Nestin-positive cells are regarded as progenitor neural cells[17-18], so the results indicate that certain time and intensity of PEMFs to pregnant rats could increase the number of neural stem cells. It is known that certain intensity of PEMFs can cause the damage of the organism, tissues and cells, while the neural stem cells can proliferate responsively in pathological condition such as injury[19-21]. Many studies demonstrate that different kinds of brain injuries stimulate hippocampal neurogenesis[22-24]. Therefore, we think that PPEMFs may cause cell damage in the hippocampal CA1 and CA2 subregions of rat offspring, and the neural stem cells proliferate

spontaneously in the injury area[25], and the neurites are netted to prevent the injury from expanding, which is beneficial for the reparation of the injury region. It is the compensable reaction of the body to brain injury. Researchers consider that the moving of nestin-positive cells to adjacent injury area after brain trauma may be not the representation of neural stem cells differentiation into neurons, but the reaction of astrocytes to the trauma[26-27]. Because the expression of nestin-positive cell reactive proliferation is very similar to that of astrocytes to injury area after brain trauma, so the existence of most nestin-positive cells in CA1 and CA2 subregions may be the reaction of astrocytes to brain injury. The notion that astrocytes serve as potential sources for neurogenesis remains speculative[28-29]. In addition, another aspect is the migrating of the DG cells.

Brdu-positive cells are regarded as the cells possessed activation of proliferation[30]. In the present study, we found that Brdu-positive cells were mainly distributed in the DG. The Brdu-positive cells in the DG region of PEMFs offspring significantly increased in number compared with those in the control group. The Brdu-positive cells of female offspring outnumbered those of male offspring in the PPEMFs group, but there was no significant difference between female and male offspring in the control group. It is known that the hippocampal DG is one of the regions where the neural stem cells are produced[31]. Previous studies have shown that brain injury induces neurogenesis primarily in the DG[32-34]. There are “still” and “dormant” stem cell groups in the DG region which do not express any distinctive antigen[35]. But stress and aging can cause the neurogenesis in the DG of the hippocampus[36-37]. Under the PPEMFs stress, the latent energy of splitting is activated and then the capability of proliferation increases. The migration of regenerating cells to CA1 and CA2 injury regions produces the compensable action.

In addition, the neural stem cell proliferation and nestin protein expression in PEMFs female offspring increased more significantly than those in male rat offspring. This may be because the activity of placenta 11β-HSD in female fetus is low[38]. Therefore, the damage is more serious, and neural stem cell proliferation in the injured region is greater in female rat offspring than in male rat offspring.

It is not very clear why the brain injury caused by PEMFs could induce the increase of cells produced in the hippocampal DG region and the nestin protein expression in injury region. This may be related to the change of permeability of cell membrane and the change of the ion concentration caused by PEMFs stress[13, 39]. Studies demonstrated that electromagnetic stimulation can cause the increase of cellular calcium ion density[40-41], induce the expression of certain specific genes, lead to the phosphorylation of protein, the change of cellular enzyme activity and the activation of signal transduction which modulates cell proliferation and apoptosis[42-44]. But it needs to be further investigated how these cascade reactions can affect stem cell proliferation, whether these cells can be differentiated into neural cells and whether these cascade reactions can affect the recognition and behavioral function.

REFERENCES

[1] Adair RK. Effect of ELF magnetic fields on biological magnetite. Bioelectromagnetics. 1993;14:1.
[2] V. I. Kryukov. The effect of the pulse electromagnetic field on the frequencies of micronuclei induced by lead in the red blood cells of anuran larvae. Russian Journal of Ecology. 2000;31(3): 216-218.
[3] Sakurai H, Okuno K, Kubo A, et al. Effect of a7-tesla homogeneous magnetic field on mammalian cells. Bioelectrochem Bioenerg. 1999;49:57-63.
[4] Manni V, Lisi A, Pozzi D, et al. Effects of extremely low frequency (50 Hz) magnetic field on morphological and biochemical properties of human keratinocytes. Bioelectromagnetics. 2002; 23(4):298-305.
[5] Barker AT. The history and basic principles of magnetic nerves timulation. In: Pascual-Leone A, Davey NJ, Rothwell J, Wassermann EM, Pur BK, eds. Handbook of transcranial magnetics timulation(i). NewYork: Arnold. 2002;pp3(R) C17.
[6] Wiearszko A. Amplification of evoked potentials recorded from mouse hippocampal slices by very low repetition rate pulsed magnetic fields. Bioelectromagnetics. 2004;25(7):537-44.
[7] Ahmed Z, Wieraszko A. The mechanism of magnetic field-induced increase of excitability in hippocampal neurons. Brain Res. 2008;1221:30-40.
[8] Li H, Zhu ZL, Li X. Effect of pulsed current magnetic fields on neural stem cell proliferation in hippocampus of stressed rat. Xi’an Jiaotong Daxue Xuebao. 2006;40(1):1149-1146.
[9] The Ministry of Science and Technology of the People’s Republic of China. Guidance suggestions for the care and use of Laboratory Animals. 2006-09-03.
[10] Yao XL, Xu XZ , Chen JL, et al. Effect of impulse current magnetic field on the mouse marrow tumor cells. Xi’an Jiaotong Daxue Xuebao. 2002;36(2):134-137.
[11] Frohlich H. What are non thermal electric biological effects? Bioelectromagnetics. 1982;3:45-46.
[12] Pliquett U, Joshi RP, Sridhara V, et al. High electrical field effects on cell membranes. Bioelectrochemistry. 2007;70(2):275-282.
[13] Zhao YL, Yang JC, Zhang YH. Effects of magnetic fields on intracellular calcium oscillations. Conf Proc IEEE Eng Med Biol Soc. 2008;2124-2127.
[14] Weaver IC, Chizmadzhev YA. Theory of electroporation: a review. Bioelectrochem. Bioenerg. 1996; 41:135-160.
[15] Teissie J, Eynard N, Gabriel B, et al. Electropermeabili-zation of cell membranes, Adv. Drug Deliv. Rev. 1999;35:3-19.
[16] Tien HT, Ottova A. The bilayer lipid membrane (BLM) under electricalelds, IEEE Trans. Dielectr. Electr. 2003; Insul. 10: 717-727.
[17] Lendahl U, ZimmermanL B, McKay RD. CNS stem cells express a new class of intermediate filament protein. Cell. 1990;60(4): 585-595.
[18] Almazan G, Vela JM, Molina-Holgado E, et al. Re-evaluation of nestin as a marker of oligodendrocyte lineage cells. Microsc Res Tech. 2001;52(6):753-765.
[19] Gage FH, Ray J, Fisher LJ. Isolation characterization and use of stem cells from the CNS. Ann Rev Neurosci. 1995;181:159-192.
[20] Reynolds BA, Weiss S. Clonal and population analysis demon-strate that an EGF responsive mammalian embryonicCNS pre-cursor is a stem cell. Develop Biol. 1996;175(3):1-13.
[21] Komitova M, Zhao LR, Gido G, et al. Postischemic exercise attenuates whereas enriched environment has certain enhancing effects on lesion-induced subventricular zone activation in the adult rat. Eur J Neurosci. 2005;21(9):2397-2405.
[22] Parent JM, Elliott RC, Pleasure SJ, et al. Aberrant seizure-induced neurogenesis in experimental temporal lobe epilepsy. Ann Neurol. 2006;59:81-91.
[23] Rola R, Mizumatsu S, Otsuka S, et al. Alterations in hippocampal neurogenesis following traumatic brain injury in mice. Exp Neurol. 2006;202:189-199.
[24] Miles DK, Kernie SG. Hypoxic-ischemic brain injury activates early hippocampal stem/progenitor cells to replace vulnerable neuroblasts. Hippocampus. 2008;18:793-806.
[25] Yu CY, Wei XZ Song ZQ, et al. Expression and proliferation of neural stem cell induced following brain injury of mature rat. Zhongguo Linchuang Kangfu. 2002;6(12):1744-1745.
[26] Schinstine M, Iacovitti L. Expression of neuron alantigens by astro-cytes derived from EGF-generated neuroprogenitor cells. Exp Neurol. 1996;141(1):67-78.
[27] Stoll G, Jander S, Schroeter M. Inflammation and glial responses in ischemic brain lesions. J Prog Neurobiol. 1998; 56:149.
[28] Yokoyama A, Sakamoto A, Kameda K, et al. NG2 proteoglycan-expressing microglia as multipotent neural progenitors in normal and pathologic brains. Glia. 2006; 53: 754-768.
[29] Mori T, Buffo A, Götz M. The novel roles of glial cells revisited: the contribution of radial glia and astrocytes to neurogenesis. Curr Top Dev Biol. 2005;69:67-99.
[30] Ciaroni S, Cecchini T, Ferri P, et al. Impairment of neural precursor proliferation increases survival of cell progeny in the adult rat dentate gyrus. Mech Ageing Dev. 2002;123(10):1341-1342.
[31] Altman J, Bayer SA. Mosaic organization of the hippocampal neuroepithelium and the multiple germinal sources of dentate granule cells. J Comp Neurol. 1990;301:325-342.
[32] Sun D, McGinn MJ, Zhou Z, et al. Anatomical integration of newly generated dentate granule neurons following traumatic brain injury in adult rats and its association to cognitive recovery. Exp

Neurol. 2007;204:264-272.
[33] Richardson RM, Sun D, Bullock MR. Neurogenesis after traumatic brain injury. Neurosurg Clin N Am. 2007;18169-18181.
[34] Urrea C, Castellanos DA, Sagen J, et al. Widespread cellular proliferation and focal neurogenesis after traumatic brain injury in the rat. Restor Neurol Neurosci. 2007;25:65-76.
[35] Fred H. Mammalian neural stem cells. Sci. 2000;287: 1433-1438.
[36] Pandey GN, Dwivedi Y. Hippocampal cell proliferation regulation by repeated stress and antidepressants. Neuroreport. 2006;17: 863-867.
[37] Drapeau E, Nora AD. Stem cell review series: role of neurogenesis in age-related memory disorders. Aging Cell. 2008;7:569-589.
[38] Montano MM, Wang MH, Vomsaal FS. Sex-differences in plasma corticosterone in mouse fetuses are mediated by differential placental transport from the mother and eliminated by maternal adrenalectomy or stress. J Reprod Fertil. 1993; 99:283-290.
[39] Liu CJ, Wang BY, Zhang H, et al. A study on the diathesis function mechanism of cell model imposed by impulse electromagnetic field. J of Biomed Eng. 1998; 15(3):294-297.
[40] Shanker VS, Simon BJ, Bax CM, et al. Effects of electromagetic stimulation on the functional responsiveness of isolated rat osteoclasts. J Cell Physiol. 1998;176:37-53.
[41] Brighton CT, Wang W, Seldes R, et al. Signal trsnsduction in electrically stimulated bone cells. J Bone Joint Surg. 2001; 83(10):1514.
[42] Foreman MA, Smith J, Publicover SJ. Characterisation of serum-induced intracellular Ca^{2+} oscillations in primary bone marrow stromal cells. J Cell Physiol. 2006;206(3):664-671.
[43] Qin Yaxin, Song Qi, Yin Ying, et al. Effect of electromagetic fields on transcript levels of apotosis-related genes in embrynic stem cell-derived neural progenitor cells. J Fourth Milmed Univ. 2008;29(10):816-879.
[44] Baureús K, Sommarin M, Persson BR, et al. Interaction between weak low frequency magnetic fields and cell membranes. Bioelectromagnetics. 2003;24(6):395-402.

孕期脉冲电磁场与子代大鼠海马神经干细胞增殖及巢蛋白的表达*★

李 霞[1]，陈 蕊[2]，贾 宁[3]，李 晖[4]，朱忠良[5]([1]武警山西总队医院精神卫生科，山西省太原市 030006；[2]西安医学院第一医院妇产科，陕西省西安市 710021；[3]西安交通大学医学院病理生理教研室，陕西省西安市 710061；[4]西安交通大学医学院第一附属医院，陕西省西安市 710061；[5]西安交通大学医学院药理教研室，陕西省西安市 710061)

李霞★，女，1977 年生，山西省高平市人，汉族，2004 年西安交通大学医学院毕业，硕士，主治医师，主要从事产前应激对子代情感性精神障碍的基础与临床研究。
通讯作者：朱忠良，博士，教授，研究员，西安交通大学医学院药理教研室，陕西省西安市 710061

摘要

背景：电磁场能对机体产生影响，尤其对于神经系统。研究已发现了脉冲电磁场对神经干细胞的影响。

目的：观察产前脉冲电磁场对子代大鼠海马神经干细胞增殖及巢蛋白表达的影响。

方法：选用体质量 240~260 g SD 雌性大鼠为母鼠，随机分为 2 组。对照组孕期不给任何干预；产前脉冲电磁场组于怀孕 14~20 d，给予脉冲电磁场刺激，3 次/d，10 min/次。于雌、雄仔鼠 1 月龄时每组随机各组 6 只行脑组织切片，应用免疫组织化学方法检测海马中 Nestin 蛋白和 Brdu 阳性细胞的表达。

结果与结论：产前脉冲电磁场组雌雄子代海马 Nestin 蛋白和 Brdu 阳性细胞表达均较对照组多($P < 0.001$)，且产前脉冲电磁场组雌性子代海马 Nestin 蛋白和 Brdu 阳性细胞表达较雄性子代的多，差异具有非常显著性意义($P < 0.001$)，对照组雌雄子代之间差异无显著性意义($P > 0.05$)。结果表明，产前脉冲磁场能引起子代海马神经干细胞数增多及增殖能力增加，这可能是机体对产前脉冲电磁场所致脑损伤的代偿性反应。

关键词：脉冲电磁场；孕期；神经干细胞；巢蛋白；海马；大鼠
doi:10.3969/j.issn.1673-8225.2010.40.041
中图分类号: R394.2 文献标识码: B
文章编号: 1673-8225(2010)40-07588-05
李霞，陈蕊，贾宁，李晖，朱忠良. 孕期脉冲电磁场与子代大鼠海马神经干细胞增殖及巢蛋白的表达[J].中国组织工程研究与临床康复，2010，14(40):7588-7592.
[http://www.crter.org http://cn.zglckf.com]
(Edited by Yin GC/Song LP/Wang L)

来自本文课题的更多信息--

基金资助：国家自然科学基金项目资助(30970952).

利益冲突：课题未涉及任何厂家及相关雇主或其他经济组织直接或间接的经济或利益的赞助。

课题的创新点：国内外关于脉冲磁场对生物体的影响均给予了较大的关注并做了不少的研究工作。如电磁场对血细胞、成骨细胞、人表皮细胞等的影响，作者前期报道了电磁场对本代大鼠神经干细胞的影响，然而关于孕期接受脉冲电磁场对其子代神经干细胞的影响,国内外少有报道。通过本研究为进一步探讨产前环境因素对子代脑发育影响以及脉冲电磁场的生物学效应提供理论依据。

课题评估的“金标准”： 本研究主要通过以海马 Nestin 蛋白和 Brdu 阳性细胞表达为观察指标，以探讨产前脉冲电磁场对子代海马神经干细胞数及增殖能力的影响。这两项指标在神经干细胞的研究中已应用非常广泛。

设计或课题的偏倚与不足：对于选取 6 只子鼠来说样本量仍显得较少。

提供临床借鉴的价值：通过本研究提示孕妇需要无长时间电磁场暴露的良好环境。