Available online at www.sciencedirect.com

SCIENCE DIRECT

Microvascular Research 69 (2005) 24–27

Microvascular Research

www.elsevier.com/locate/ymvre

Short Communication

Effects of a static magnetic field of either polarity on skin microcirculation

Harvey N. Mayrovitz*, Edye E. Groseclose

College of Medical Sciences, Nova Southeastern University, 3200 S. University Drive, Ft. Lauderdale, FL 33328, USA

Received 27 August 2004
Available online 8 December 2004

Abstract

Our specific aim was to investigate whether a local static magnetic field of a permanent magnet, of either pole, affects resting skin blood perfusion. This was done by measuring skin blood perfusion (SBF) by laser-Doppler in dorsum skin of 2nd and 4th fingers of the nondominant hands of 12 volunteers. Both fingers were first exposed to sham magnets, and then the 2nd finger was exposed alternately to north and south poles of a neodymium magnet that produced a field of 4024 G at the palmar part of the finger and a field of 879 ± 52 G at the site of finger dorsum SBF measurement. Each of the three exposure intervals was 15 min. SBF values were analyzed by first computing the average SBF during the last 5 min of each of the three 15-min exposure intervals. These SBF averages were initially tested for magnet or magnet-pole effects by analysis of variance for repeated measures with finger as a factor, using SBF values for each finger as the test variable. Results of this analysis revealed a large variability in finger SBF among subjects and no significant difference in SBF between exposure conditions ($P = 0.705$) or any significant interaction between SBF and finger ($P = 0.396$). However, when intersubject variability was reduced by using the flow difference between treated and nontreated fingers in each exposure interval as the test variable, a statistically significant effect ($P = 0.016$) attributable to magnet exposure was uncovered. This effect was a reduction in resting SBF in the magnet-exposed fingers that was similar for north and south pole magnet exposure. The present findings are the first to demonstrate a direct effect of locally applied magnets on human skin blood perfusion.

Keywords: Permanent magnets; Laser Doppler; Skin blood flow; Magnetic pole

Introduction

A recent search of the internet (July 2004) has identified many commercial sites in which statements are made either suggesting or claiming that static magnetic fields from permanent magnets have a beneficial effect on blood flow. Similar claims can be found in a number of soft cover books under the broad heading of magnetic therapy (Lawrence et al., 1998; Null, 1998; Payne, 1997; Tierra, 1997). Some studies on experimental animals have provided tantalizing results, suggesting that static magnetic fields produce effects that might modify blood flow. In rats, whole-body exposure to static magnetic fields of around 80,000 Gauss (G) is reported to have reduced skin temperature and blood flow (Ichioka et al., 2000) via a mechanism that may be related to the effect of the high field intensity on skin humidification (Ichioka et al., 2003). In contrast, at a lower field strength of about 2500 G, an increase in blood circulation within the rabbit ear has been reported (Gmitrov et al., 2002). In addition, direct observation of vessels within the rabbit ear chamber indicate changes in vessel vasomotion features that occur within 1 min of applying a static magnetic field as low as 10 G (Ohkubo and Xu, 1997). These changes have been described as biphasic since the magnetic field appears to enhance the vasodilatory phase if vessels are relatively vasoconstricted and to enhance the vasoconstrictive phase if vessels are relatively vasodilated (Okano et al., 1999; Xu et al., 1998). With respect to human studies, there are a few scientific reports indicating that magnets may be useful under certain conditions (Brown et al., 2002; Man et al., 1999; Vallbona et al., 1997; Weintraub et al., 2003). However, there is no experimental evidence that magnets of field strengths in the range of 800–1000 G, which approximates surface field values of most commercial magnets, affect blood flow in humans. To the contrary,

* Corresponding author. Fax: +1 954 262 1802.
E-mail address: mayrovit@nova.edu (H.N. Mayrovitz).

0026-2862/$ - see front matter © 2004 Elsevier Inc. All rights reserved.
doi:10.1016/j.mvr.2004.11.002

studies that have investigated this question have failed to demonstrate a magnet-related effect on blood flow in humans (Martel et al., 2002; Mayrovitz et al., 2001, 2002). However, the door to possible magnet-related blood flow effects remains open since none of these previous studies systematically investigated the possible effect of the magnet's pole. Despite the fact that physics tells us that the field strength at the magnet's north and south poles are equal, it has been argued that the biological effects strongly depend on which pole is applied to the target tissue (Birla and Hemlin, 1999; Philpott and Taplin, 1990). Thus, our specific aim was to investigate whether either pole of a local static magnetic field of a permanent magnet affects resting skin blood perfusion. This was done by measuring skin blood perfusion (SBF) by laser-Doppler in dorsum skin of 2nd and 4th fingers of the nondominant hands of volunteers. Both fingers were first exposed to sham magnets, and then the 2nd finger was exposed alternately to north and south poles of a magnet. Data are presented as mean ± standard deviation unless otherwise noted.

Methods

Healthy subjects (N = 12, age 25.3 ± 3.7 years, 6 male) participated after signing a consent form approved by the university's institutional review board. Subjects had not previously used magnetic therapy and were not taking vasoactive medication. None were smokers and all were instructed not eat or drink for 2 h prior to testing. Their heights (1.64 ± 0.06 m), weights (59.8 ± 8.5 kg), and systolic (108 ± 9 mm Hg) and diastolic (74 ± 6 mm Hg) blood pressures were within normal ranges. The right hand was dominant for all subjects. All testing was done with subjects seated with their arms and hands resting on a padded surface attached to the chair. Prior to the start of experimentation, subjects were told that metal disks would be placed under two of their fingers and that one or both of the disks might be magnets. The subjects had no knowledge of whether a sham or magnet was being placed during any of the test intervals. The top surface of the shams and the magnets were covered with soft Velcro material, approximately 3-mm thick, on which the subject's fingers would rest. The covering provided a soft comfortable surface for the finger to rest on and also served as thermal insulation between the finger and the metal surface of the magnet or sham. A commercial molybdenum magnet (25.4 mm diameter × 12.7 mm) was used to produce the experimental magnetic field. The magnet's surface field at its center was determined to be 4028 G using a Gaussmeter (Walker Scientific, MG-3AB) and Hall effect probe (HP-13R), which has a 4-mm^2 sensing area and a stated accuracy of 1%. The south pole of the magnet was defined as the surface that attracted the north-seeking side of a standard compass. Shams, which were nonmagnetized pieces of the same dimensions as the magnet, were placed under the middle phalanges of the 2nd and 4th fingers during a 15-min control interval. Thereafter, both shams were removed and replaced with a sham for the 4h finger and an active magnet with either its North or South pole facing the skin of the 2nd finger. Selection of the pole to place during this interval was decided based on a coin flip. After 15 min of exposure, sham and magnet were removed and replaced with a second sham under the 4th finger and the magnet with the opposite polarity under the 2nd finger during a final 15-min interval. In six subjects, the North pole was placed during the second interval, and in six other subjects it was placed during the third interval.

SBF was measured continuously on the dorsum of each finger with a dual-channel laser-Doppler flowmetry system (Moor Instruments MBF3D, time constant = 0.1 s) using integrating type probes (DP7a). Principles of this method have been well described (Mayrovitz, 1998; Nilsson et al., 1980). Perfusion signals underwent A/D conversion (DataQ model 720B) at a sampling rate of 40 samples/s and were recorded at a standardized gain on a dedicated computer. Laser-Doppler SBF is expressed as relative perfusion units (rpu) since SBF cannot be calibrated directly in blood flow units. In the present report, SBF values are expressed as the values of voltage obtained from the output of the laser-Doppler monitor and recorded at a constant overall system sensitivity and gain. Probes were calibrated using a motility standard supplied by the manufacturer. In addition, prior to each experiment, outputs of each probe–channel combination were tested using a rotating disk (2 rpm) with embedded, randomly arranged particles, to simulate moving cells. The probe–channel output was monitored for 3 min and its mean output averaged. If the mean outputs between channels differed by more 4% the system was recalibrated. At the end of each experiment, the biological zero (BZ) was obtained by simultaneously stopping blood flow for 3 min in each experimental finger using vascular occluders placed around the base of each finger. This small BZ value was subtracted from all recorded SBF data, as is standard (Mayrovitz and Leedham, 2001). The magnetic field intensity at the 2nd finger dorsum SBF measurement site was measured for each subject after removal of the laser-Doppler probe. This value depended on the finger thickness, which was measured with a digital caliper. Average thickness of the 2nd finger at the site of SBF measurement was 12.0 ± 1.1 mm and the magnetic field intensity at this site was 879 ± 52 G. With the magnet in place under the 2nd finger, the field intensity measured at the dorsum of the 4th finger was 8 ± 1 G.

Blood perfusion values were analyzed by first computing the average SBF during the last 5 min of each of the three 15-min exposure intervals. These SBF averages were tested for magnet or magnet-pole effects by analysis of variance (ANOVA) for repeated measures with finger as a factor using SPSS version 7.0. To help control for variability in absolute SBF values among subjects that might obscure magnet-related effects, the data was also analyzed using

SBF differences between sham and magnet exposed fingers for each individual subject during each of the three experimental intervals. In this analysis, the difference in SBF between fingers becomes the variable that was tested by ANOVA for repeated measures. An advantage of this approach is that potential spontaneous changes in SBF due to the subject sitting still during the procedure, tiredness, or other systemic changes that might affect SBF are implicitly taken into account. This assumes that any such systemic changes would affect both fingers similarly.

Results

Results of the ANOVA, using the absolute values of each finger's SBF, revealed a large variability in finger SBF among subjects and no significant difference in SBF could be detected between exposure conditions ($P = 0.705$). Table 1 shows the summary of absolute SBF values obtained during each exposure condition. Although there appeared to be a tendency for SBF of the 2nd finger to be higher than that of the 4th finger during the sham control interval, this difference was not found to be significant ($P = 0.285$). In contrast, when the data was analyzed using SBF differences between fingers as the test variable, highly significant ($P = 0.016$) magnet-related changes were detected for both south and north pole magnet exposure (Table 1). Exposure to the magnet resulted in a reduction in SBF of the magnet-exposed finger as compared to the sham-exposed finger in 11 of the 12 subjects tested for both north and south exposure intervals. Thus, whereas prior to magnet exposure the percentage difference in SBF between fingers was 20.3 ± 14.7%, it was reduced ($P < 0.01$) to 8.6 ± 23.6% and 3.8 ± 22.4% as a result of exposures to north and south poles of the magnet, respectively. There was no significant difference between effects of north and south poles ($P = 0.875$).

Discussion

As far as known to the authors, the present findings are the first that demonstrate an effect of a local static magnetic field on human skin blood perfusion using a static magnetic field strength at the target site (879 G) similar in value to surface fields of many commercial magnets (800–1000 G). Because previous work had failed to reveal any magnet-related effects (Mayrovitz et al., 2001, 2002), it is of interest to examine factors that might account for these divergent results. We believe that a major factor may be the magnitude of the field achieved at the site of SBF measurement. In previous studies, ceramic magnets were used with surface fields between 800 and 1000 G. These magnets were applied either under the finger as in the present study (Mayrovitz et al., 2001) or adjacent to the SBF measurement site on the forearm (Mayrovitz et al., 2002). As a consequence, the field strength at the SBF measurement sites was 100–130 G. This is in contrast to the present design, in which the use of a molybdenum magnet, which has a greater surface field intensity, allowed for an average field intensity at the SBF measurement site of 879 G. Thus, this nearly sevenfold greater field intensity may account for the positive results herein found. However, the existence and magnitude of a threshold field intensity needed to produce circulatory effects has not yet been established. The larger surface field of the molybdenum magnet also resulted in a larger field gradient between palmar and dorsal surfaces of the finger. This larger gradient may have had biological significance.

Table 1
Skin blood perfusion (SBF) and difference in SBF between fingers for each exposure condition

	Shams (both fingers)	North pole (2nd finger)	South pole (2nd finger)
Finger	SBF	SBF	SBF
2nd	2.38 ± 1.35	2.09 ± 1.56	2.18 ± 1.60
4th	1.81 ± 1.22	1.88 ± 1.63	1.84 ± 1.49
SBF difference	0.426 ± 0.356	0.003 ± 0.473*	0.170 ± 0.289*

Values are mean SBF (volts) during the last 5 min of each experimental interval ± SD.
The SBF difference was significantly less during north and south pole exposure intervals as compared to the baseline sham interval.
* $P = 0.016$.

The direction of the change in SBF attributable to the magnet was unexpected. Most claims as to the effects of magnets on human blood circulation imply an augmentation of blood flow. The present results indicate otherwise; magnet exposure was associated with a reduction in SBF. However, this finding should be viewed in the context of reports of biphasic responses to static magnetic fields found in animal models (Okano et al., 1999; Xu et al., 1998). These authors describe biphasic responses in which magnetic fields appear to enhance vasodilation if vessels are relatively vasoconstricted and to enhance vasoconstriction if vessels are relatively vasodilated. Based on this premise, one could speculate that the magnet-induced SBF reduction we observed was related to the fact that the magnet-exposed finger (2nd finger), even prior to magnet exposure, tended to have a larger SBF than the sham control finger (4th finger). The source of this consistent but not statistically significant baseline difference in finger SBF is unknown but may be related to differences in their respective innervations. Had the magnet been applied to the 4th finger, it is unknown whether its SBF would have increased, decreased or would have been unchanged.

Magnetic-related mechanisms that might account for the observed relative SBF reduction have not been unambiguously identified but some work suggests that magnetic field effects on calcium dynamics may be implicated. In human leukocytes, a magnetic field of 10,000 G induced an increase in Ca^{2+} influx that was blocked by calcium channel antagonists (Papatheofanis, 1990). In GH3 cells, calcium channel function has been reported to be altered as a result

of exposure to a 1200 G static field (Rosen, 1996). In macrophages and lymphocytes, exposure to static magnetic fields between 250 and 1500 G increased Ca^{2+} influx and its intracellular concentration (Flipo et al., 1998). Whether and how such modulations of calcium dynamics alter SBF are unknown since Ca^{2+} can be involved in both vasoconstrictive and vasodilatory processes depending on the cell type (endothelial or vascular smooth muscle) that is affected. No studies of magnetic field effects on these cell types have been reported.

In summary, for the magnet type, field strength and application duration used, a magnet-related reduction in skin blood perfusion was observed, with no evidence of a difference in effects due to magnet polarity. The magnet-related effect was detectable if confounding effects of the normal large variability in absolute SBF among different persons was reduced by analyzing changes in SBF between magnet-exposed and nonexposed skin.

References

Birla, G.S., Hemlin, C., 1999. Magnet Therapy. Healing Arts Press.

Brown, C.S., Ling, F.W., Wan, J.Y., Pilla, A.A., 2002. Efficacy of static magnetic field therapy in chronic pelvic pain: a double-blind pilot study. Am. J. Obstet. Gynecol. 187, 1581–1587.

Flipo, D., Fournier, M., Benquet, C., Roux, P., Le Boulaire, C., Pinsky, C., LaBella, F.S., Krzystyniak, K., 1998. Increased apoptosis, changes in intracellular Ca^{2+}, and functional alterations in lymphocytes and macrophages after in vitro exposure to static magnetic field. J. Toxicol. Environ. Health, A 54, 63–76.

Gmitrov, J., Ohkubo, C., Okano, H., 2002. Effect of 0.25 T static magnetic field on microcirculation in rabbits. Bioelectromagnetics 23, 224–229.

Ichioka, S., Minegishi, M., Iwasaka, M., Shibata, M., Nakatsuka, T., Harii, K., Kamiya, A., Ueno, S., 2000. High-intensity static magnetic fields modulate skin microcirculation and temperature in vivo. Bioelectromagnetics 21, 183–188.

Ichioka, S., Minegishi, M., Iwasaka, M., Shibata, M., Nakatsuka, T., Ando, J., Ueno, S., 2003. Skin temperature changes induced by strong static magnetic field exposure. Bioelectromagnetics 24, 380–386.

Lawrence, R., Rosch, P.J., Plowden, J., 1998. Magnet Therapy. Prima Publishing.

Man, D., Man, B., Plosker, H., 1999. The influence of permanent magnetic field therapy on wound healing in suction lipectomy patients: a double-blind study. Plast. Reconstr. Surg. 104, 2261–2266 (discussion 2267–2268).

Martel, G.F., Andrews, S.C., Roseboom, C.G., 2002. Comparison of static and placebo magnets on resting forearm blood flow in young, healthy men. J. Orthop. Sports Phys. Ther. 32, 518–524.

Mayrovitz, H.N., 1998. Assessment of human microvascular function. In: Drzewiecki, G., Li, J. (Eds.), Analysis of Cardiovascular Function. Springer, pp. 248–273.

Mayrovitz, H.N., Leedham, J.A., 2001. Laser-Doppler imaging of forearm skin: perfusion features and dependence of the biological zero on heat-induced hyperemia. Microvasc. Res. 62, 74–78.

Mayrovitz, H.N., Groseclose, E.E., Markov, M., Pilla, A.A., 2001. Effects of permanent magnets on resting skin blood perfusion in healthy persons assessed by laser Doppler flowmetry and imaging. Bioelectromagnetics 22, 494–502.

Mayrovitz, H.N., Groseclose, E.E., Sims, N., 2002. Assessment of the short-term effects of a permanent magnet on normal skin blood circulation via laser-Doppler flowmetry. Sci. Rev. Altern. Med. 6, 9–12.

Nilsson, G.E., Tenland, T., Oberg, P.A., 1980. Evaluation of a laser Doppler flowmeter for measurement of tissue blood flow. IEEE Trans. Biomed. Eng. 27, 597–604.

Null, G., 1998. Healing with Magnets. Carroll and Graf Publishers.

Ohkubo, C., Xu, S., 1997. Acute effects of static magnetic fields on cutaneous microcirculation in rabbits. In Vivo 11, 221–225.

Okano, H., Gmitrov, J., Ohkubo, C., 1999. Biphasic effects of static magnetic fields on cutaneous microcirculation in rabbits. Bioelectromagnetics 20, 161–171.

Papatheofanis, F.J., 1990. Use of calcium channel antagonists as magneto-protective agents. Radiat. Res. 122, 24–28.

Payne, B., 1997. Magnetic Healing. Lotus Press.

Philpott, W.H., Taplin, S., 1990. Biomagnetic Handbook. Enviro-Tech Products.

Rosen, A.D., 1996. Inhibition of calcium channel activation in GH3 cells by static magnetic fields. Biochim. Biophys. Acta 1282, 149–155.

Tierra, M., 1997. Biomagnetic and Herbal Therapy. Lotus Press.

Vallbona, C., Hazlewood, C.F., Jurida, G., 1997. Response of pain to static magnetic fields in postpolio patients: a double-blind pilot study. Arch. Phys. Med. Rehabil. 78, 1200–1203.

Weintraub, M.I., Wolfe, G.I., Barohn, R.A., Cole, S.P., Parry, G.J., Hayat, G., Cohen, J.A., Page, J.C., Bromberg, M.B., Schwartz, S.L., 2003. Static magnetic field therapy for symptomatic diabetic neuropathy: a randomized, double-blind, placebo-controlled trial. Arch. Phys. Med. Rehabil. 84, 736–746.

Xu, S., Okano, H., Ohkubo, C., 1998. Subchronic effects of static magnetic fields on cutaneous microcirculation in rabbits. In Vivo 12, 383–389.