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Scientific paper

Effects of a static magnetic field on wound healing: results in experimental rat colon anastomoses

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Abstract

Background: Research has shown that pulsed electromagnetic fields (EMFs) promote wound healing in experimental colonic anastomosis; however, the effects of static EMFs in this setting have not been investigated to date.
Methods: Fifty male Wistar rats were used. Ten served as controls for mechanical strength testing, and the other 40 underwent descending colon resection and anastomosis. Twenty of these 40 animals (M group) had NeFeB magnets placed in contact with the anastomosis site (magnetic field strength at the site 390 to 420 G). The other 20 animals (sham [S] group) had nonmagnetized NeFeB bars of the same dimensions and weight implanted. Half of the animals in each group were killed and assessed for healing parameters on postoperative day 3 (M3 and S3 groups) and the other half on postoperative day 7 (M7 and S7 groups). Four types of assessment were done: gross healing, mechanical strength, hydroxyproline deposition, and histopathology.
Results: There were no differences between the M and S animals with respect to gross healing parameters. The mechanical strength was also not different between groups (23.8 ± 12.7 and 24.7 ± 9.6 mm Hg for M3 and S3, respectively; $P = .863$ and 91.3 ± 65.4 and 94.8 ± 55.9 mm Hg for M7 and S7, respectively; $P = .902$). Similarly, hydroxyproline deposition was not different between groups on postoperative day 3 or day 7. On postoperative day 3, the M group had significantly higher scores than the S group for fibroblast infiltration (2.4 ± 0.7 vs 1.4 ± 0.7, respectively; $P = .008$) and capillary formation (2.5 ± 0.7 vs 0.9 ± 0.4, respectively; $P < .001$). However, these effects were reversed and did not endure by day 7.
Conclusions: The study results suggest that static EMF has no effect on experimental colonic wound healing in the rat.

Keywords: Anastomosis; Bursting pressure; Colon; Gastrointestinal; Hydroxyproline; NeFeB magnet; Static electromagnetic field; Wound healing

The effects that electromagnetic fields (EMFs) have on biologic systems have been researched for centuries. Scientific study has focused on 2 main types of these fields: pulsed and static. Some of the findings indicate that low-frequency pulsed electromagnetic fields (PEMFs) may have adverse effects on cellular metabolism and may also cause malignant transformation [1]. However, other work has demonstrated that PEMFs have a beneficial impact on bone healing in rats [2]. Static magnetic fields (SMFs) have also been shown to promote bone healing under experimental conditions [3], and in humans these fields have had positive effects on dermal healing as well [4]. Research has shown that PEMFs increase the strength of colonic anastomoses in rats [5], but no study to date has examined how SMFs affect colonic wound healing. In this experimental study, we assessed how the SMF generated by a permanent NeFeB magnet affects colonic wound healing in rats.

Methods

The Baskent University Research Board and Ethics Committee approved the study. A total of 50 male 4- to 5-month-

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old Wistar albino rats were used. The animals were acclimatized to the laboratory conditions for 1 week before the experiments and were fed standard rat chow and given free access to water throughout the study period. To prevent interaction between magnets, each rat was housed individually in a plastic cage on a wooden bench with a gap of at least 30 cm between cages.

Power analysis

The sample size was determined based on previous bursting pressure (BP) measurements done in our laboratory under similar conditions using the same rat species [6]. Calculations were done using an online source (http://calculators.stat.ucla.edu/powercalc/normal/n-2-equal/). For bivariate comparisons, normal BP was accepted as 180 mm Hg (SD 20 mm Hg) on postoperative day 7 [6]. At a significance level of .05 and a power of .90, the calculated sample size necessary to detect a 20% change (approximately 35 mm Hg) from normal BP was 8. To account for animals that might have to be removed from the study, we decided that 10 animals/study arm would be suitable.

Study groups and procedures

Ten animals served as the control (C) group. Each was killed after the acclimatization period, and only BP measurements were done in this group. The other 40 animals were randomly assigned to 1 of 2 main groups, the SMF (M) group or the sham (S) group, and all underwent colonic resection and anastomosis. During the operation, each rat in the M group had an NeFeB magnet (see product details later) placed in the left side of the peritoneal cavity with the long axis of the magnet parallel to the colon. The north-seeking pole was positioned cranially, and the magnet was placed such that the middle of the bar was in contact with the anastomosis site. To prevent inadvertent displacement, the bars were fixed to the retroperitoneal muscles by placing a 2/0 silk suture in a groove that the manufacturer had made at each pole of the bar. To investigate early and late healing at the anastomosis site, half of the M group was killed by lethal anesthetic overdose on postoperative day 3 (M3 group; n = 10), and the other half was killed on postoperative day 7 (M7 group; n = 10). Each rat in the sham group had a same-sized NeFeB bar with no magnetic properties fixed in place as described for the M group. Half of the sham group was killed on day 3 (S3 group, n = 10), and the other half was killed on day 7 (S7 group; n = 10).

Anastomosis

All of the animals were fasted overnight before surgery. Anesthesia was achieved with intraperitoneal injection of 10 mg/kg xylazine (Rompun; Bayer, Istanbul, Turkey) and 60 mg/kg ketamine hydrochloride (Ketalar; Parke-Davis, Istanbul, Turkey). The surgical procedures were performed using clean but nonsterile instruments. In each operation, a 4-cm midline incision was made, and a 5-mm segment of the descending colon was resected approximately 3 cm above the peritoneal reflection. This resected specimen was preserved at −30 °C for later determination of the hydroxyproline (OHP) concentration in normal colon tissue. The free ends of the colon inside the abdomen were anastomosed with a single layer of interrupted inverting 7/0 polypropylene sutures (Prolene; Ethicon, Scotland, United Kingdom) placed 1 mm apart. The fascia and skin layers were closed separately with running 4/0 silk sutures (Mersilk; Ethicon). Each animal was given free access to chow and water the morning after the procedure. For postoperative analgesia, beginning the day after the surgery, .02 mg/kg fentanyl citrate (Fentanyl; Abbott, Chicago, Illinois) was administered subcutaneously twice daily for 3 days.

Static magnetic field

Each magnetized and nonmagnetized NeFeB bar weighed 9.2 g and measured 25 × 10 × 5 mm (Magnet Sales and Service Limited, Wiltshire, UK). As noted above, the manufacturer had carved 2 1-mm circumferential grooves in each bar, and each of these was located 5 mm from one of the poles. A gaussmeter with a transverse probe (Magnet Sales and Service Limited) was used to measure the magnetic strength of the 40 bars before each was placed in the peritoneal cavity. The 20 magnetized bars had a magnetic field strength of approximately 4000 Gauss (G) at each pole, and the magnetic strength in the middle of the bar (at the middle the magnetic vector is parallel to the long axis of the bar and colon), where the bar came into contact with the anastomosis site, was 390 to 420 G. The same measurements were made in the 20 nonmagnetized bars. The range of magnetic strength in these bars was 1 to 8 G, and this was similar to the background magnetic density measured in the laboratory (1 to 2 G).

Assessment of anastomosis

After each rat in the M and S groups was killed, 4 types of evaluations were done as follows.

Gross healing

The abdomen was reopened, and the abdominal structures and the anastomosis site were evaluated for adhesion and abscess formation as described by previous investigators [7]. The following grading system was used to evaluate adhesions: 0 = no adhesions; 1+ = minimal adhesions (ie, mainly between the omentum and the anastomosis site); 2+ = moderate adhesions (ie, between the anastomosis site and the omentum or between the site and a loop of small bowel or the abdominal wall); and 3+ = severe and extensive adhesions (ie, between the anastomosis site and several loops of small bowel and the abdominal wall). Abscess formation was recorded as present or absent. The colon was