Evaluation of Equine Cecal Motility by Ausculation, Ultrasonography and Electrointestinography after Jejunocecostomy

[1]Naoki Sasaki, DVM, Ph.D., [1]Aya Murata, DVM, [2] Inhyung LEE, DVM, Ph.D., [1]Haruo YAMADA, DVM, Ph.D.

[1]Department of Veterinary Clinical Science, Obihiro University of Agriculture & Veterinary Medicine, Inada, Obihiro, Hokkaido, 080-8555, Japan.

[2] Department of Neuroscience and Cell Biology, University of Texas Medical Branch, 301 University Boulevard, Galveston, TX 77555-1069, USA.

Correspondence to**:** Naoki Sasaki, DVM, Ph.D.

Department of Veterinary Surgery,

Obihiro University of Agriculture & Veterinary Medicine, Inada,

Obihiro-city, Hokkaido, 080-8555, Japan.

Phone:＋81-0155-49-5378

Fax:＋81-0155-49-5379

E-mail：naoki@obihiro.ac.jp

Structured abstract

Objective: Horses often suffer reduced intestinal motility after jejunocecostomy. Therefore, accurate evaluation of intestinal motility is important for the prevention, diagnosis and treatment of this condition. The purpose of this study was to evaluate intestinal motility in horses after jejunocecostomy using three different methods, i.e. auscultation, ultrasonography and electrointestinography.

Animals: Six healthy thoroughbreds were used in this study. They were subjected to jejunocecostomy.

Procedure: Bowel sounds in the right paralumbar fossa were assigned a score of 0-3 for intestinal motility evaluation by auscultation, and the number of cecal contractions during a 3-min period were counted by ultrasonography. Electrointestinography (EIG) was used to measure percutaneous potential of the cecum.

Results: We identified 3 specific postoperative periods: the period of reduced intestinal motility (postoperative day 1 to day 2), in which intestinal motility declined, the unstable period (day 3 to day 7), in which intestinal motility partially recovered, and the full recovery period (day 8 to day 31), in which intestinal motility returned to preoperative state. Careful management was found to be especially important during the period of reduced intestinal motility and the unstable period. We found that, in healthy horses that underwent jejunocecostomy, it takes approximately one month for the cecum to return to normal motility patterns observed before surgery.

Conclusion: We have shown in this study that evaluation of intestinal motility after jejunocecostomy in horses by EIG is more objective and provides more details than evaluation by auscultation or ultrasonography.

Key words: electrointestinography, horse, intestinal motility, jejunocecostomy,

postoperative ileus

1. Introduction

Many gastrointestinal lesions in horses cause acute colic that requires laparotomy for definitive diagnosis and treatment. Jejunocecostomy is performed to by pass the ileum in patients who suffer ileal impaction, strangulation, volvulus, intussusception or stenosis of the distal jejunum or ileum. However, reduced intestinal motility remains a major problem in patients with jejunocecostomy [6, 7]. Thus, it is important to accurately and continuously evaluate intestinal motility after jejunocecostomy to appropriately prevent, diagnose, and treat this condition.

Until recently, intestinal motility has been evaluated by auscultation [18, 21] and ultrasonography [5, 8, 14, 15]. However, continuous evaluation of intestinal motility with these methods is unpractical and considered to be insufficient for accuracy. On the other hand, electrointestinography (EIG), in which changes in intestinal motility are recorded continuously [25], is considered to be a more accurate and objective method for evaluating intestinal motility than either auscultation or ultrasonography. Although EIG is used to evaluate motility in the small intestine, cecum, right ventral colon and right dorsal colon [23, 24], it has never been used to investigate reduced intestinal motility after jejunocecostomy in horses.

The purpose of the present study was to evaluate intestinal motility after experimental jejunocecostomy in six healthy horses by auscultation, ultrasonography and electrointestinography.

2. Materials and Methods

2. 1. Horses

Six healthy thoroughbreds (4 mares, 1 gelding, and 1 stallion) were used in this study. The horses mean age was 13.8±5.0 (mean±SD) years, and their mean weight was 514.5±61.2 kg. All horses were fed on an ordinary two-meal diet (0.9 kg oats, 0.3 kg bran and 3.5 kg dried grass per meal) with unrestricted water intake. Housing and care of the horses as well as the study protocol were approved by Obihiro University Institutional Animal Care and Use Committee.

2. 2. Surgical Procedure

All food was withheld for 12 hr before the surgical procedure. At 8 hr before surgery, each horse was intravenously treated with 4,000 ml of lactated Ringer's solution (Solulact, Terumo Co., Tokyo, Japan), and 2,000 ml of mineral oil (Liquid Paraffin, Kanto Chemical Co., Tokyo, Japan) given via a nasogastric tube. Immediately prior to the surgical procedure, the horse was intramuscularly treated with 20,000 IU/kg of procaine penicillin G for veterinary use (Meiji Seika Kaisha, Ltd., Tokyo, Japan) and intravenously given 1.1 mg/kg of flunixin meglumine (Banamine 5%, Dainippon

Pharmaceutical Co., Osaka, Japan).

Anesthesia: Each horse was intravenously injected with 4μg/kg of medetomidine (Domitor, 0.1%, Orion Co., Espoo, Finland) and 25-50 mg/kg of Guaifenesin (Kyoto Pharmaceutical Industries, Kyoto, Japan) was infused rapidly until the horse became ataxic. Anesthesia was then induced by intravenous injection of 0.03 mg/kg diazepam (Horizon 10mg, 0.5%, Yamanouchi Pharmaceutical Co., Ltd., Tokyo, Japan) and 2.2 mg/kg ketamine (Veterinary Ketalar 50, Sankyo Yell Yakuhin Co., Ltd., Tokyo, Japan). Next, the trachea was intubated and the horse was held on a surgical table in dorsal recumbency. Anesthesia was maintained by inhalation of halothane and oxygen. Twenty min after the beginning of anesthesia, dobutamine (Retamex, 2%, Sankyo) was intermittently administered at 1-5 μg/kg/min to maintain a mean arterial blood pressure of approximately 70 mmHg.

The surgical area was aseptically prepared and a ventral midline celiotomy was performed. The cecum was brought out through the ventral midline incision, and the apex was pulled caudad to expose the dorsal band of the cecum. Jejunocecal anastomosis was performed as previously described[22, 24]. In brief, the ileum was resected in the position proximal (approximately 50 cm) to the ileocecal junction, and the jejunum was transected in the position proximal (approximately 200 cm) to the ileocecal junction. After the mesenteric vessels were triple-ligated with polyglactin 910 size 3 metric (Vicryl, Ethicon), the mesentery and its vessels were resected, and the ileal stump was closed by Parker-Kerr suture using the same suture material[22, 24]. The long axis of the jejunum was made perpendicular to the dorsal bands of the cecum, and the jejunum was anastomosed to the cecum in an end-to-side fashion. The seromuscular layer of the jejunum on the side adjacent to the cecum was attached to the cecum in a continuous Lembert pattern using polyglactin 910 suture material. An incision was then made in the cecum alongside the suture line, and the mucosa of the jejunum and cecum were apposed in a continuous approximating suture pattern around the entire circumference. The mesentery of the jejunum was attached to the ileocecal fold and the dorsal band of the cecum. The linea alba was closed with a far-near-near-far suture pattern using polyglactin 910 The skin was closed with a simple interrupted suture pattern using nonabsorbable suture material (Ethilon Nylon Suture, Ethicon, Inc., USA).

After surgery, each horse was treated with 20,000 IU/kg of penicillin G procaine, given intramuscularly, once a day for 3 days, 1.1 mg/kg of flunixin meglumine, given intravenously, twice a day for 3 days, and 10,000 ml of lactated Ringer's solution, given intravenously, twice a day for 4 days. Additionally, 2,000 ml of mineral oil was administered to the horse via a nasogastric tube at 22, 37, and 46 hr after surgery.

Incisions were sterilized and bandaged as necessary. The horses started to be watered at 13 hr after surgery and to be fed on a meal diet (0.7 kg alfalfa softened by hot water) at 37 hr after operation. Horses were returned to their normal diet 1 week after the surgical operation.

2. 3. Evaluation of Intestinal Motility

2. 3. 1 Auscultation

Auscultation was performed with a stethoscope for 3 minutes in the right paralumbar fossa, and bowel sound was assigned a score of 0-3. Score 0 indicated no borborygmi. Score 1 indicated that the period of no borborygmi was longer than the period of peristaltic sound. Score 2 indicated that the period of peristaltic sound was longer than the period of no borborygmi. Score 3 indicated constant peristaltic sound (example, normal activity).

2. 3. 2. Ultrasonography

An ultrasound system (SonoSite 180 II, SonoSite, Inc., Bothell, WA, USA) and a transducer (C15/4-2, Microconvex 2-4MHz, SonoSite, Inc., Bothell, WA, USA) were used to evaluate intestinal motility. Hair was removed from the right paralumbar fossa and an ultrasonography gel was applied. A longitudinal section of the cecum was described at the domain below the line, which connects the front edge of the right tuber coxae and the rear edge of the last rib, and the number of cecal contractions during a 3-minute period was counted. Ultrasound frequency was set at 2.5 MHz throughout the experiment.

2. 3. 3. EIG

EIG of the cecum was performed on conscious horses at rest in a stall. After hair was removed from the right paralumbar fossa, EIG electrodes were installed via surface electrodes (Vitrode M-150 Disposable Electrodes, Nihon Kohden Co., Tokyo, Japan) at three sites: the front edge of the right tuber coxae (EIG mini-amplifier), the intersection of the horizontal line extending from the tuber coxae and the rear edge of the last rib (non-inductive electrodes), and the apex of an inverted regular triangle formed by placing the other two electrodes on the other apexes (EIG-mini-amplifier). At a sampling rate of 1 Hz, the frequency was measured within a range of 1.8 to 12 cycles per min (cpm). A Digitrapper EGG System (Synectics, Stockholm, Sweden) was used to measure the percutaneous potential of the cecum. The whole system was attached to the horse trunk with a saddle, a girth, and a saddle blanket.

2. 3. 4. Schedule of intestinal motility evaluation

Auscultation and ultrasonography were carried out three times a day at 8:00, 12:00 and 17:00 for 31 days starting day 1 after surgery. Preoperative electrointestinograms were recorded for 24 hr 1 week before surgery when the horses were fed on an ordinary diet. Recording of postoperative electrointestinograms began just after recovery, continued till day 10, and thereafter was conducted on days 17, 24 and 31 for 24 hr each day.

2. 3. 5. Electrointestinograms analysis

For Electrointestinograms analysis, a running spectrum method with fast Fourier transform (FFT) analysis was used, and the maximum amplitude (μV) of the waveform in 10 min per hr was calculated. To determine the total power [(μV)2×cpm], the waveform for one min was subjected to FFT analysis, and the power for the entire frequency band was calculated [23]. Analysis was performed at the frequency band of 1,8-3 cpm, 3-6 cpm, 6-9 cpm or 9-12 cpm. We calculated the ratio of the total power of 10 min per hr in each frequency band to the total power in the entire frequency band.

2. 4. Statistical Analysis

Data are presented as the mean ± SD. One-factor analysis of variance was used to determine significant differences in each value. Significant differences between baseline and postoperative values were evaluated using post-hoc test (Fisher's Protected Least Significant Difference). The significance level was set at $p<0.05$.

3. Results

Mean bowel sound score on day 1 and day 2 after surgery was significantly lower than that before surgery (0.1±0.3 and 1.1±0.3 on day 1 and 2, respectively vs. 3.0±0.0 on day 0, $p<0.01$, Fig. 1a). Although mean bowel sound score increased from postoperative day 3 to postoperative day 7, it remained significantly lower than that before surgery ($p<0.01$). Mean bowel sound score from postoperative day 8 to postoperative day 31 further increased with complete recovery to preoperative score by day 17 after surgery.

Mean number of cecal contractions detected during a 3-min period by ultrasonography on day 1 and day 2 after surgery was significantly lower than that detected before surgery (3.1±6.6 and 3.1±5.4 on days 1 and 2, respectively vs. 15.0±1.7 on day 0, $p<0.01$, Fig. 1b). Although the number of cecal contractions recorded from postoperative day 3 to postoperative day 24 increased, it remained significantly lower than that before surgery ($p< 0.05$: days 17and 24). The number of cecal contractions recorded on day 31 after surgery was not significantly different from that recorded before surgery (Fig.1b). Therefore, recovery of normal intestinal motility required at least one month after surgery.

Mean maximum amplitude of EIG waveform on day 1 and day 2 after surgery was significantly lower than that recorded before surgery (154.9±45.4μV and 110.5±59.7μV on day 1 and 2, respectively vs. 323.7±76.4μV on day 0, $p< 0.01$, Fig.1c). Although mean maximum amplitude of EIG waveform recorded from postoperative day 3 to postoperative day 10 increased, it remained significantly lower than that before surgery ($p<0.01$). From postoperative day 10 to postoperative day 31 mean maximum amplitude of EIG waveform continued to increase with complete recovery to preoperative value by postoperative day 17.

Analysis at the frequency band at 1,8-3 cpm showed that the ratio of total power to total power in the entire frequency band on postoperative day 1 was significantly lower than that before surgery (20.5±7.2% vs. 26.6±5.1%, $p<0.05$, Fig. 4). However on postoperative day 2, this ratio increased to preoperative level. At 3-6 cpm, the ratio of total power in each frequency band after surgery was similar to that before surgery (52.5±3.4 %). At 6-9 cpm, the ratio on day 2, 4 and 9 after surgery (20.4±5.1% ($p<0.05$), 21.5±3.8% ($p<0.01$), and 20.4±3.0% ($p<0.05$), respectively) was significantly higher than that before surgery (16.7±2.2 %). At 9-12 cpm, the ratio on day 3 after surgery (6.6±3.7%, $p<0.05$) was significantly higher than the preoperative ratio (4.2±0.7%).

4. Discussion

Our aim in the present study was to evaluate intestinal motility after experimental jejunocecostomy in 6 healthy horses by auscultation, ultrasonography and electrointestinography (EIG). We found that intestinal motility after jejunocecostomy can be evaluated more objectively and in greater detail by EIG with maximum amplitude and frequency than by auscultation or ultrasonography. In our experiments, three specific postoperative periods were identified the period of reduced intestinal motility (postoperative day 1 to day 2), in which intestinal motility declined as compared to before surgery; the unstable period (postoperative day 3 to day 7), in which intestinal motility partially recovered, and the full recovery period (day 8 to day 31), in which intestinal motility returned to preoperative state.

The period of reduced intestinal motility and the unstable period identified in this study are consistent with postoperative periods reported in other studies [9, 12, 13, 20]. Therefore, we believe that careful postoperative management, such as continuous monitoring of intestinal motility, early diagnosis of complications, and appropriate use of gastrointestinal prokinetic agents, is particularly important during these two periods. On the other hand, during the full recovery period, no significant difference between pre- and post-operative intestinal motility was observed as indicated by auscultation, ultrasonography and EIG on day 8, 31 and 17, respectively. Thus, the day at which intestinal motility returned to preoperative frequency varied according to the evaluation method. This discrepancy is due to the fact that auscultation detects migrating sound of ingesta, while ultrasonography detects intestinal contractions, and EIG ascertains contractility of smooth muscle[3]. In addition, the recovery process in each case was not the same. We therefore believe that intestinal motility can be evaluated more appropriately, and in details, using EIG as well as auscultation and ultrasonography.

Generally, decline in intestinal motility causes intestinal distention and system dehydration [4, 10, 27]. This may cause, in serious cases, decline in the circulatory system that can lead to death. Ileus, which is characterized by functional impairment of the aboral transit of intestinal content, is considered to be a consequence of intestinal ischemia and distention, peritonitis, electrolyte imbalance, endotoxemia, anesthesia, or surgical trauma to the intestine. In addition, we believed that interception of myenteric and submucosal plexus, and blood flow at the site of anastomosis causes intestinal motility disorders after jejunocecostomy. As intestinal motility is thought to be controlled primarily by the enteric nervous system in the myenteric and submucosal plexus and secondarily by the extrinsic nervous system [7, 29], reduced intestinal motility is believed to be caused by interception of the submucosal plexus. It is known that intestinal motility in the small intestine and cecum is controlled by different pacemakers [11, 16, 17, 19, 22]. The small intestine has an interdigestive migrating motor complex (IMMC) that is generated from the pacemaker at the gastro-duodenal junction, propagates aborally to the end of the ileum, and is generated again at the gastro-duodenal junction [26, 28]. Therefore, it is believed that disorders of the IMMC at the anastomotic site occur after resection of the ileum and anastomosis of the jejunum to the cecum. As there are fewer vessels in the ileum than in the jejunum, jejunocecostomy is generally recommended over ileocecostomy to secure blood supply at the anastomotic site [12]. In addition, it is believed that after ileocecostomy blood supply to the remaining ileum is inadequate leading to intestinal motility disorders in the ileocecal junction.

From our results in the present study, it is clear that complete recovery of normal intestinal motility after jejunocecostomy requires approximately one month. This period is necessary to reconstruct the nervous network and blood supply, and reestablish cooperative functions of intestinal motility at the anastomotic site. Therefore, we believe that EIG, which can be performed continuously for 24 hr, is more suitable than auscultation or ultrasonography for evaluation of intestinal motility. As EIG power is related to its frequency[3], it was possible in the present study to determine intestinal smooth muscles contractility more objectively and appropriately by measuring EIG maximum amplitude. Furthermore, it was possible to continuously evaluate periodic intestinal motility.

In EIG, the ratio of total power in each frequency band is evaluated[3]. In humans, the frequency band is classified as low frequency (0.5-2 cpm), dominant frequency (2-4 cpm), high frequency (4-9 cpm), or arrhythmia[3]. In patients with infantile hypertrophic pyloric stenosis, an increase in the high frequency band is an indication of hyperperistalsis of the stomach, and an increase in the low frequency band is an indication of transient paresis of the stomach[1]. In the present study, the ratio of frequency band showed a significant decrease at 1.8-3 cpm on day 1 after surgery, a significant increase at 6-9 cpm on days 2 and 4 after surgery, and a significant increase at 9- 12 cpm on day 3 after surgery. This indicates that hyperperistalsis may have occurred between day 2 to 4 after surgery. Assuming 1.8-6 cpm and 6-12 cpm as the low frequency band and the high frequency band, respectively, a significant decrease in the low frequency band and a significant increase in the high frequency band were observed from day 2 to day 4 after surgery. This change in the ratio of frequency indicates tonus in intestinal motility consistent with the postoperative unstable periods described in this study. Therefore, it is likely that changes in the ratio of frequency band indicate abnormality of intestinal motility. Applying EIG to horses as used in humans[2] will allow early diagnose of postoperative complications, such as reduced intestinal motility and postoperative ileus in horses.

In conclusion, we evaluated in this study intestinal motility in horses after jejunocecostomy using three different methods, i.e. auscultation, ultrasonography and electrointestinography. We identified 3 specific postoperative periods: the period of reduced intestinal motility (postoperative day 1 to day 2), in which intestinal motility declined, the unstable period (day 3 to day 7), in which intestinal motility partially recovered, and the full recovery period (day 8 to day 31), in which intestinal motility returned to preoperative state. It is therefore believed that careful management, such as early diagnosis and appropriate use of gastrointestinal motility enhancers, is important especially during the period of reduced intestinal motility and the unstable period as it takes approximately one month for the body to reconstruct the nervous network and blood supply, and reestablish cooperative functions of intestinal motility at the anastomotic site. We have shown in this study that evaluation of intestinal motility after jejunocecostomy in horses by EIG is more objective and provides more details than evaluation by auscultation or ultrasonography.

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Figures legends

Fig 1

Changes in intestinal motility evaluated by auscultation, ultrasonography and electrointestinography. Fig.1a: Changes in auscultation score after jejunocecostomy. Score 0 : no borborygmi, score 1: the period of no borborygmi was longer than the period of peristaltic sound, Score 2: the period of peristaltic sound was longer than the period of no borborygmi, and Score 3: constant peristaltic sound (for example, normal activity). Data are expressed as the mean ±standard deviation (SD). (ｎ=6) ＊＊:p<0.01 ＊:p<0.05 mention that this is ‘statistically different from baseline. Fig.1b: Changes in the number of cecal contractions during a 3-minute period after jejunocecostomy. 3c: Changes in EIG maximum amplitude after jejunocecostomy.

Fig. 2

Changes in the ratio of the total power in each frequency band to the total power in EIG after jejunocecostomy. Data are expressed as the mean ±SD. (ｎ=6) ＊＊:p<0.01 ＊:p<0.05

● : 1.8-3 cycles per min (cpm) ▲: 3-6 cpm ■: 6-9 cpm ○: 9-12 cpm

Fig. 3

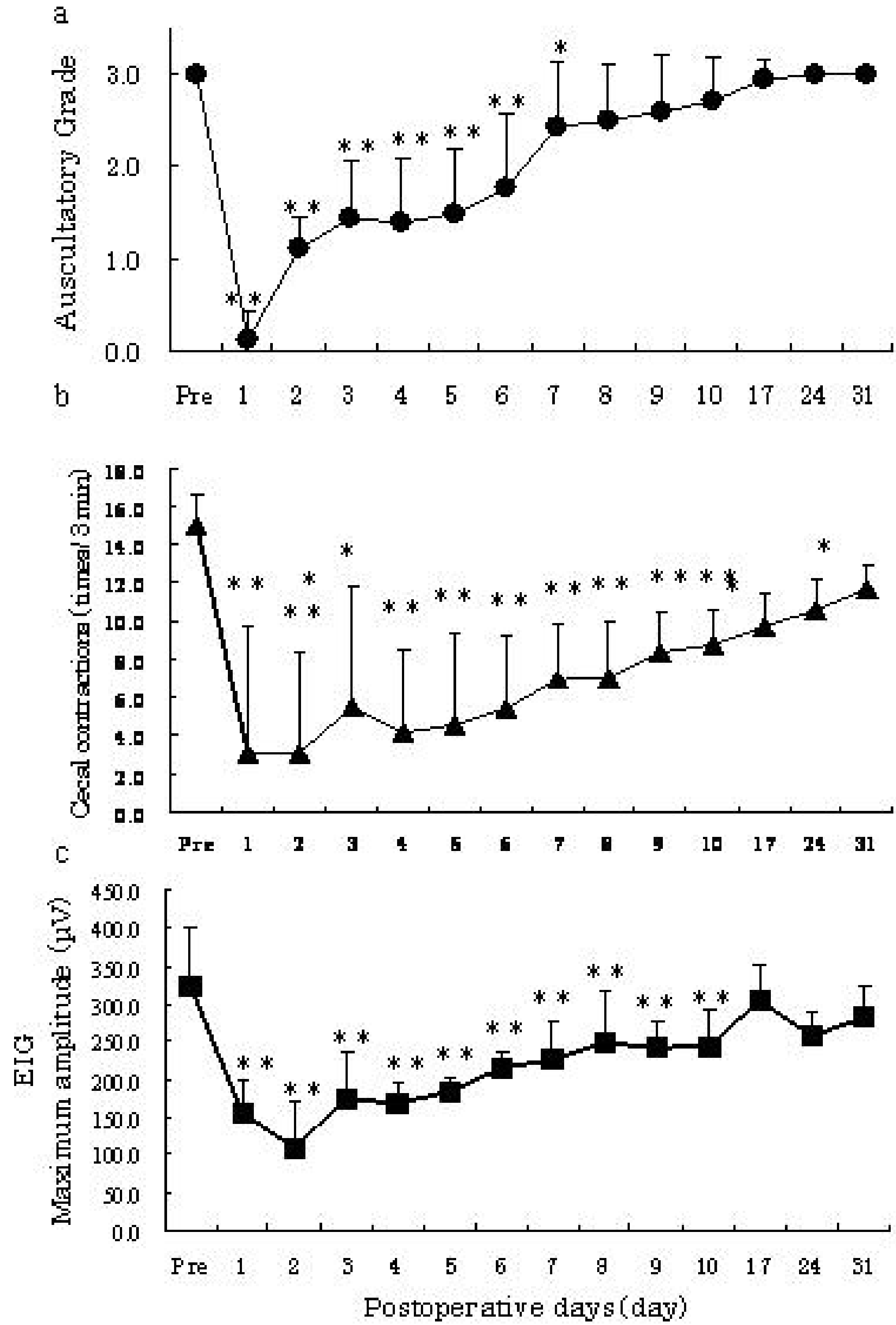
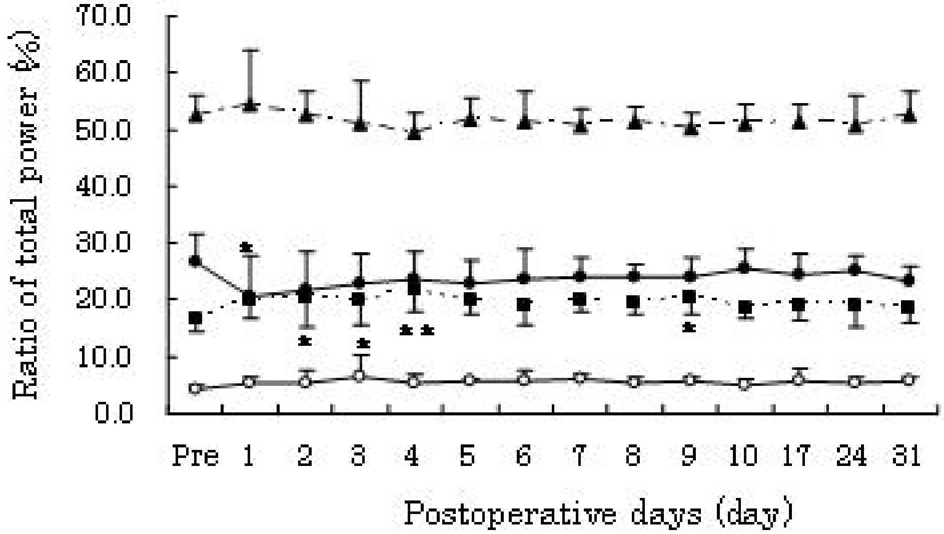

a
Auscultatory Grade
b
Cecal contractions (times/3 min)
c
EIG
Maximum amplitude (μV)
Pre 1 2 3 4 5 6 7 8 9 10 17 24 31
Postoperative days (day)

Fig. 4



Ratio of total power (%)
70.0
60.0
50.0
40.0
30.0
20.0
10.0
0.0
Pre 1 2 3 4 5 6 7 8 9 10 17 24 31
Postoperative days (day)