Low-frequency electrical stimulation promotes the recovery of gastrointestinal motility following gynecological laparoscopy (Review)

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Received January 31, 2022; Accepted April 5, 2022

DOI: 10.3892/mi.2022.38

Abstract. The rapid recovery of gastrointestinal transit is critical for clinical recovery following laparoscopic procedures, including gynecological laparoscopies (GLs). Rehabilitation interventions post-surgery may provide significant prevention against early post-operative gastrointestinal motility disorders and maid aid in the acceleration of post-operative recovery in patients undergoing GLs. Among others, low-frequency electrical stimulation (LFES) has been demonstrated to pronouncedly mitigate the symptoms caused by gastrointestinal motility disorders; thus, this has attracted increasing attention over the past decade. The present study aimed to present an overview of the efficacy and application of LFES in gastrointestinal motility recovery following GL procedures.

Contents

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Key words: low-frequency electrical stimulation, gastrointestinal motility, gynecological laparoscopy, more rapid recovery

1. Introduction

Laparoscopy is a minimally invasive technique with the characteristics of easy operation, a small incision, rapid healing and satisfactory efficacy. It has been widely applied to the treatment of gynecological diseases (1). Physiologically, gastrointestinal motility results from muscularis mucosa contraction, segmentation and peristalsis (rhythmic contractions) (2). The rapid recovery of gastrointestinal motility often predicts satisfactory clinical outcomes following laparoscopies, and various rehabilitation interventions have been employed to prompt and restore gastrointestinal motility post-surgery (3).

2. Factors influencing gastrointestinal motility recovery following gynecological laparoscopies

Immediate anal exhaust following gynecological laparoscopies (GLs) is almost impossible due to the absence of intestinal smooth muscle contraction. Rhythmic motion slowly occurs at 3 to 8 h post-surgery, beginning from the proximal small intestine to the rectum and colon. Post-operative exhaust often represents the recovery of gastrointestinal transit (4). However, the post-operative anal evacuation time may vary among individuals; it is usually between 24-56 h in patients receiving GLs without other specific treatments, with an average of 31 h (5). However, in >80% of this patient group, the recovery gastrointestinal transit is delayed when they develop symptoms, such as abdominal distension, and decreases in peristalsis, anal exhaust and bowel episodes (6), though their peristalsis recovery time is shorter than that of patients undergoing conventional laparotomy (7,8).

The gastrointestinal tract is more sensitive to surgical stress than other parts of the body, the recovery of which can be disrupted or even impaired by surgical trauma, post-operative pain, anesthetics and analgesics, carbon dioxide pneumoperitoneum and other factors (9), leading to severe gastrointestinal motility disorders in some patients (10,11). Specifically, surgical trauma may cause post-operative gastrointestinal dysfunction. The study conducted by Magrina demonstrated that mortality rates following injury to the bowel during laparoscopic procedures ranged from 2.5 to 5% (12). Post-operative pain leads to the transient dysfunction of the enteric nervous system, inhibiting gastrointestinal transit by the binding of abundant norepinephrine released from sympathetic postganglionic neurons to receptors on smooth muscle cells (13,14) and can also lead to intestinal paralysis (15). As regards anesthetics and analgesics, opioids are the most effective and commonly used analgesics peri-operatively; however, they can induce delayed gastric emptying and intestinal transit, resulting in fluid and electrolyte disruption. The intraoperative use of anesthetics and analgesics may also inhibit the recovery of post-operative gastrointestinal motility. Carbon dioxide pneumoperitoneum has been widely utilized in laparoscopies to create operating and viewing space (16). However, carbon dioxide insufflation into the abdomen has also been reported to disrupt tissue or organ functions, such as breathing (17), digestive (18) and urinary functions (19). Following GL procedures, a small amount of carbon dioxide can pass through the peritoneum, and can be absorbed into the circulation and converted into carbonic acid, causing hypercapnia; this triggers the release of catecholamines to activate cholinergic neurons in the enteric nervous system (20) to induce gastrointestinal symptoms, such as nausea and vomiting (21).

The delayed recovery of gastrointestinal motility can significantly increase challenges in post-operative recovery and can aggravate patients' discomfort (22-25). This can occur in addition to another risk factor, intestinal dilation, that impairs wound healing and induces intestinal paralysis, nausea and vomiting, or severe complications such as arrhythmia and multiple organ dysfunction syndrome (26,27). Both of these conditions may impair the effectiveness of nursing care or rehabilitation, leading to longer hospital stays and higher medical expenditures.

3. Gastrointestinal motility recovery following gynecological laparoscopies

A consensus on the management of gastrointestinal motility disorders post-GLs has not yet been reached, and the efficacy of relevant interventions reported to date is unsatisfactory (28). In the majority of cases, commonly prescribed drugs against these symptoms only achieve limited results, alongside pronounced adverse events (29) and extra costs, which limit their application in patients undergoing GLs (30). Traditional Chinese medicine (TCM) has been shown to exert preventive and therapeutic effects on post-operative gastrointestinal motility disorders. However, the efficacy of TCM is accumulative; treatment based on syndrome differentiation and acupuncture with needle manipulation are highly demanding tasks for novices, and moxibustion may cause burns (31,32). Therefore, non-drug treatments that are easy to use, cost-effective, non-invasive and highly repeatable for distinct operators are required to promote gastrointestinal motility recovery following GLs and to improve the quality of life of patients, promote early post-operative recovery and enhance the quality of nursing care (33).

4. Low-frequency electrical stimulation

Low-frequency electrical stimulation (LFES) is a suitable non-invasive technique that delivers low-frequency pulsed currents to the muscles and nerves through skin surface electrodes (34). The device is a portable apparatus and easy to operate for novices (Fig. 1). It is placed on acupoints, in a manner similar to acupuncture, but is not inserted into the skin. Thus, LFES can also exert a therapeutic effect similar to that of acupuncture, but circumvents adverse events, such as subcutaneous hematoma, accidental needle-sticks and fainting during acupuncture treatment (35); it is therefore more acceptable for patients. This treatment has been utilized in departments of obstetrics and gynecology, cardiovascular diseases, rehabilitation, TCM and surgery (36).

Mechanisms of LFES. Bioelectricity is the basis for nerve conduction, and bioelectrical signals delineate the activity of neurons and muscle cells (37). Applying a current of designated magnitude to the organ of interest or central nerves or peripheral plexuses innervating it can stimulate muscle contractions (38), thus aiding in the restoration of peristalsis (39). Currently, the mechanisms primarily responsible for LFES treatment, although not fully explored, have been ascertained as follows: Electrical stimulation to block or enhance neuronal electrical activity to restore intestinal function; electrical stimulation on muscularis mucosae with distinct frequencies of currents to induce the contraction or relaxation of intestinal muscularis mucosae directly; long-term, chronic electrical stimulation to alter tissue structure (40,41).

LFES has exhibited marked potential in preventing post-operative ileus and gastrointestinal motility disorders (42,43), including esophageal motility disorders, gastroesophageal reflux disease, functional dyspepsia, chronic intestinal pseudo-obstruction, post-operative intestinal obstruction and irritable bowel syndrome with diarrhea or constipation (44-47). The delivery of LFES with skin electrodes placed on the sites corresponding to the gastrointestinal segment with abnormal motility patterns (48) can trigger the contractions of gastrointestinal smooth muscle cells and can thus stimulate peristalsis, gastric emptying, intestinal transit and absorption (49). Furthermore, the activation of submucosal and myenteric plexuses by LFES facilitates gastrointestinal fluid secretion, and blood and lymphatic circulation in the gastrointestinal tract post- (50). Overall, LFES promotes the early recovery of gastrointestinal function, post-operative exhaust and defecation, and also alleviates abdominal distension and pain by stimulating gastrointestinal peristalsis (51).

Efficacy of LFES. Electrical stimulation was first reported as a treatment by Bilgutay *et al* (52) in the 1960s, who employed intestinal electrical stimulation with a tube electrode introduced into the stomach, which markedly ameliorated post-operative intestinal obstruction. However, this procedure remains largely unrepeatable due to methodological complexity. Electrical stimulation was systematically studied in the 1970s, for example; Kelley and Code (53) proposed the electrical stimulation of the canine stomach and small intestine to alter their electromyographic patterns and motility. This technique has evolved into special gastric electrical stimulation, or Enterra® Therapy (Medtronic), in the late 1990s to boost gastric motility in gastroparesis (54). However, a later study proved its critical role in inhibiting nausea and vomiting, rather than increasing motility (55).

The electrical stimulation of acupoints refers to the application of a pulsating electrical current to acupuncture needles for acupoint stimulation. Electrical stimulation of acupoints increase gastrointestinal motility by regulating vagus nerve activation (56). It has been widely used for various

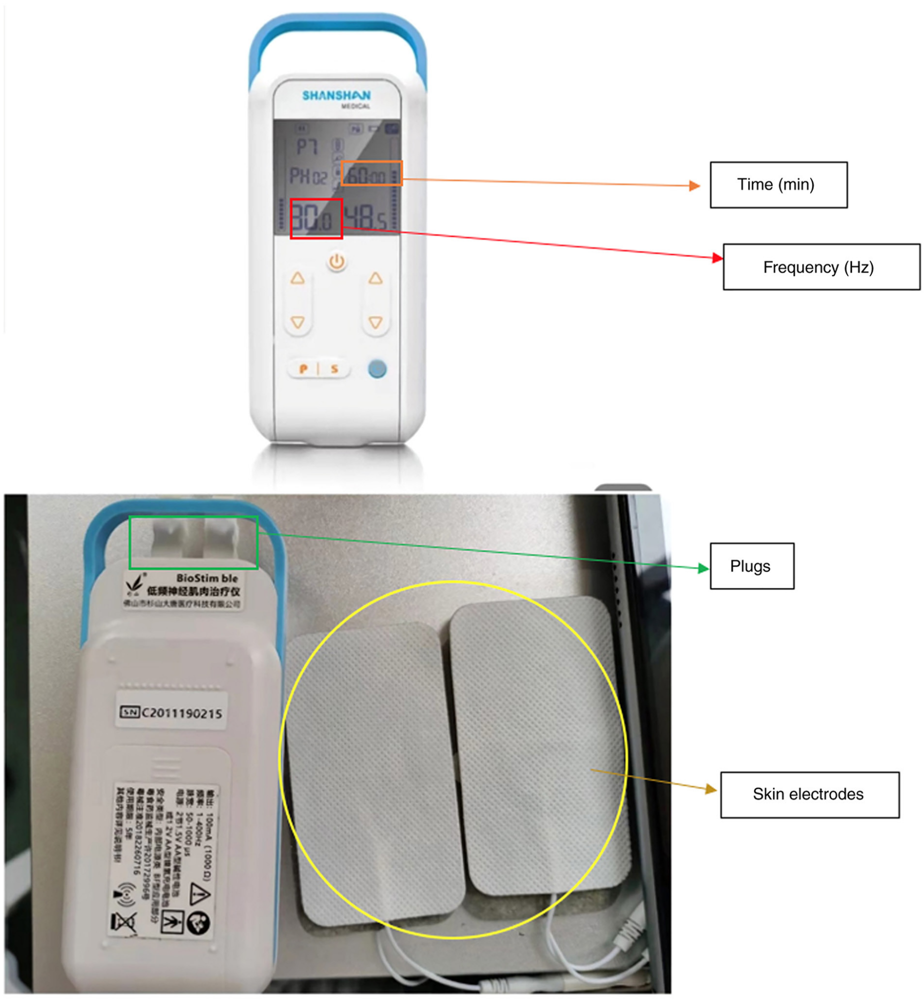

Figure 1. Low-frequency electrical stimulation device. The device is portable and easy to use.

gastrointestinal conditions in China and the West (57-59). In the study conducted by Huang *et al* (60), 64 patients undergoing laparoscopic colorectal resection were randomly divided into two groups, the control group (group A) and the electrical stimulation group (group B). Patients in the electrical stimulation group received electrical stimulation of bilateral Zusanli (ST 36) at 30 min prior to anesthesia to the end of surgery. The stimulatory effect of LFES at ST-36 on gastric motility was associated with vagal activity. The patients in the control group were not given the stimulation. The post-operative anal exhaust time in group B was significantly shorter than that of group A (60). Low-frequency electrical stimulation can promote the recovery of postoperative gastrointestinal function and reduce the pain intensity 48 h after surgery, thus satisfying the need of early postoperative analgesia (61).

Over the past 20 years, electrical stimulation has been shown to be effective in normalizing gastric dysrhythmia, accelerating gastric emptying and improving nausea and vomiting (62). Clinical data from previous studies describe gastrointestinal motility following electrical stimulation. Zhang *et al* (63) performed ST36-LFES in 42 patients prior to abdominal surgery and found that symptoms associated with post-operative gastrointestinal motility disorders were markedly ameliorated, probably by increasing vagal activity and inhibiting sympathetic activity.

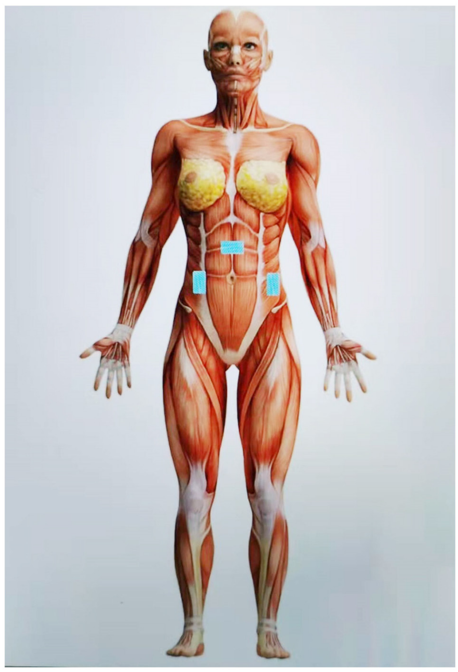

Figure 2. Placement of the electrodes of the low-frequency electrical stimulation device. Skin electrodes are placed on the abdominal sites corresponding to the ascending, transverse, or descending colon (blue squares) at a frequency of 30 Hz.

Early LFES on the gastrointestinal tract post-GLs can restore autonomic nerve function, boost local blood circulation and accelerate the recovery of gastrointestinal motility to forestall abdominal distension and pain. This is achieved by simply placing skin electrodes on the abdominal sites corresponding to the ascending, transverse, or descending colon and employing a frequency of 30 Hz (Fig. 2). It is a more convenient and efficient tool for routine nursing care compared with transcutaneous electrical acupoint stimulation and electrical pulse stimulation, without locating acupoints or adjusting for stimulation frequency during the treatment. It has been universally accepted by patients due to its safety and cost-effectiveness, without affecting other therapies administered simultaneously or limiting daily life activities.

5. Conclusion and future perspectives

LFES promotes gastrointestinal motility post-GLs probably through elevating plasma ghrelin and motilin and parasympathetic activity. It is a non-invasive and non-pharmacological intervention recommended for early nursing care or rehabilitation post-surgery. Nonetheless, future clinical studies on adults, particularly placebo-controlled studies, are required to validate its efficacy and safety. A database for electrophysiological properties in patients undergoing LFES treatment is conducive to offering sufficient data for bioinformatics or clinical studies and establishing guidelines of LFES for the management of gynecological diseases.

Acknowledgements

Not applicable.

Funding

The present study was funded by the Research Center for Medical and Health Science and Technology Development of the National Health Commission (grant no. HDSL202004003).

Availability of data and materials

Not applicable.

Authors' contributions

YW conceived and the study and drafted the manuscript. XT, LvG and LiG critically reviewed the manuscript. All authors have read and approved the final version to be published. Data authentication is not applicable.

Ethics approval and consent to participate

Not applicable.

Patient consent for publication

Not applicable.

Competing interests

The authors declare that they have no competing interests.

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