Development and Feasibility of the Early Rehabilitation Program on Postoperative Enhanced Recovery Following Minimally Invasive Esophagectomy: A Prospective Randomized Controlled Trial

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Abstract

Background: Perioperative rehabilitation management is essential to enhanced recovery after surgery. Few reports, however, focused on quantitative, detailed early activity plans for patients after esophagectomy.

Aim: The purpose of this research was to estimate the effect of the Early Rehabilitation Program (ERP) on the recovery of bowel function and physical function for patients undergoing esophagectomy.

Method: In this single-blind, 2-arm, parallel-group, randomized pilot clinical trial, patients were selected from June 2019 to February 2020 and assigned to the intervention group (IG) or the control group (CG) randomly. The participants in IG received an ERP strategy during the perioperative period, and the CG received routine care. The recovery of bowel and physical function, readiness for hospital discharge (RHD) and postoperative hospital stay were evaluated on the day of discharge.

Results: 215 cases were enrolled and randomized to the CG (n=108) or IG (n=107). There was no significant difference between the two groups in terms of demographic and clinical characteristics and baseline physical function. After the ERP intervention, the IG group presented a significantly shorter time to first flatus ($P<0.001$) and to first bowel movement postoperative ($P=0.024$), and a better physical function recovery ($P<0.001$), compared with the CG group. The analysis also showed that participants in the IG have higher scores of RHD and shorter length of postoperative stay than the CG ($P<0.05$).

Conclusion: The findings suggest that the ERP can improve bowel and physical function recovery, ameliorate patients’ RHD, and shorten postoperative hospital stay for patients undergoing MIE.

Trial registration: ClinicalTrials.gov Identifier: NCT01998230

Background

Esophageal cancer (EC) is the seventh most common cancer and the sixth most common cause of death overall on the global burden of cancer worldwide.\(^1\) In China, the latest epidemiological survey showed that around 145,700 new cases and 188,100 deaths of EC occurred in 2015, which were higher than the average level of worldwide.\(^2\) Surgery is still the standard treatment for resectable EC, which is comprised of esophagectomy with radical lymphadenectomy. Esophagectomy is also a major and complex surgery with unacceptable morbidity and mortality rates. A global review of high-volume hospitals performing esophagectomy showed overall morbidity of 59% and 30-day mortality of 2.4%.\(^3\)

Many new strategies and technologies attempted to reduce complications and promote fast recovery, such as minimally invasive esophagectomy (MIE) and the concept of enhanced recovery after surgery (ERAS). ERAS was described first in 1997 by Henrik Kehlet, which is a multimodal pathway integrating evidence-based protocols into clinical practice, and has been widely applied to reduce the surgical stress response, postoperative medical complications, hospital stay and improve recovery after major surgery.
It had been shown activity capacity was associated with postoperative complications intently,\[8\] and the key determinant in evaluating the success of ERAS is whether patient can quickly recover to an acceptable level of functional activity after surgery.\[7\] In addition, results from longitudinal studies showed that patients after esophagectomy tend to have lower levels of physical activity compared with their preoperative levels.\[9\] Therefore, it seems particularly important to do the management of perioperative rehabilitation for patients with surgery.

According to the concept of ERAS, prehabilitation includes a series of measures of increasing the initial physiological reserve and optimizing the organ function of patients before surgery, thereby fasting recovery after surgery. The prerehabilitation strategies recognized by experts currently include psychological counselling, nutritional supplementation, physical exercise and respiratory optimization. Studies showed that, as a critical part of “prehabilitation”, physical exercise program involving both aerobic and strengthening activity, had been proposed to improve outcomes, like reducing depression, anxiety, fatigue, and improving the quality of life\[10, 11\]. Respiratory optimization with deep spirometry, inspiratory muscle training, and breathing exercises also could decrease postoperative pulmonary complications.\[12\]

Besides, early ambulation in the postoperative period should be encouraged under the guidance of ERAS. Long-term bed rest after surgery wound increases the risk of complications, such as venous thromboembolism, muscle loss, insulin resistance, and pulmonary complications.\[13, 14\] Research indicated that postoperative mobilization should start on the day of surgery preferably whenever feasible, and increase the amount of activity gradually every day to achieve predetermined goals\[15\]. Hence, the provision of a quantified activity target and structured exercise approach will be more conducive to the recovery of patients.

Although some studies of non-randomized concluded that early mobilization might hasten functional recovery after surgery, the evidence and studies on the timing and nature of mobilization are lack at present.\[7\] In addition, patients with EC are often accompany by malnutrition, frailty, pain, drainage pipes and various restrictions of treatment measures, which will further affect the rehabilitation activities of patients. Therefore, it is a particular challenge following esophagectomy to formulate early, standardized, and goal-directed mobilization plans at each day of perioperative through multidisciplinary collaboration.

The King's Theory of Goal Attainment (TGA) was proposed by Imogene M.King in 1981, a process of interaction between nurse and patient, setting goals, exploring means, and agreeing on means to achieve goals\[16, 17\]. In this study, we regard patients as the main body of rehabilitation management and focus on the feelings and communication interaction of patients. During the perioperative period, based on the King's TGA, we designed an early rehabilitation program (ERP) for patients for esophagectomy to improve communication with patients and attain the patients' preferred outcomes. The randomized controlled clinical trial has been conducted to evaluate the role of ERP in improving recovery outcomes of EC patients after surgery, and thus could provide a reference for clinical work.
Methods

Research Design

In this single-blind, 2-arm, parallel-group, randomized pilot clinical trial, patients with EC undergoing surgery were selected using convenience sampling and divided into intervention group (IG) and control group (CG) randomly by lottery. Researchers involving in the formulation and implementation of intervention programs were informed about the allocated intervention. However, research assessors, data management staff and all patients were blinded to the intervention. Furthermore, research subjects would be placed into different wards in order to avoid mutual contamination between patients. All participants in this study received written, and oral information and written informed consent was obtained from patients or their family prior to the trial. In addition, the principles of the Helsinki Declaration have been respected.

This study was approved by the Ethics Committee of the local Medical Ethics Committee(2014xjs4), and the protocol registered in the ClinicalTrials.gov (registration number: NCT01998230).

Participants

The study performed between June 2019 and February 2020 at the Department of Thoracic Surgery of Henan Cancer hospital in China. All patients with EC who had received surgery recruited by the following conditions. Eligibility criteria: histologically proven EC and selected for McKeown MIE, age ≤ 75 years, volunteer to this research and be informed consent. Exclusion criteria included previous severe lung, brain and heart organic diseases, bone and joint disorders, emergency surgery, serious postoperative complications such as anastomotic leakage, inability to perform language communication or text understanding.

Interventions

Patients in the CG received usual nursing measures after McKeown MIE, which included conventional postoperative feeding, pain management, safe and comfortable environment, wound care, diet guidance, medication care, psychological counseling, regular postoperative rehabilitation exercises etc. The pulmonary rehabilitation and physical exercise conducted by nurses according to the routine of postoperative care.

Participants in the IG received the ERP based on King's TGA and usual care. According to the treatment characteristics of patients during the perioperative period, the program designed into two main parts: pre-rehabilitation before surgery and fast rehabilitation after surgery, which includes six stages in total. The intervention implementation process was as follows:

(1) Forming a research team

The members of the ERP team included two thoracic surgeons, four nurses, one rehabilitation therapist, and respiratory therapist, and was led by a nursing manager.
(2) Comprehensive evaluation

When patients are admitted to the hospital, the research team should conduct a comprehensive examination for patients. The assessment includes: 1) disease conditions; 2) cardiopulmonary function, including cardiac ultrasound, lung function, hematological indicators, etc; 3) disease cognition, including psychological status, relationship with family, perception of disease, awareness of self-disease management, social support system, etc.

(3) Formulating program

This was a nurse-led ERP, which was guided by King’s TGA during the formulating process. Therefore, before the program is formulating, researchers need to explain the concept of ERAS and the significance of early activities to patients, and discuss pre and post-operative rehabilitation types and target amount together. The individualized practical rehabilitation target list formed with the joint participation of patients and researchers, including short-term and long-term activities. Team discussion was necessary before the program began to implement. The theoretical framework of this study carried out according to Fig. 1. Finally, the rehabilitation activity plan would be presented in tables and in stages, including the training items, content, methods, frequency, and target quantity for each stage, the sample table was shown in Table 1.
Table 1
The Implementation Strategy of ERP for patients with EC

| Time                  | Stage                  | Items and methods                                                                 | Frequency           | Target type               |
|-----------------------|------------------------|-----------------------------------------------------------------------------------|---------------------|---------------------------|
| pre-rehabilitation     | Stage 1 (before surgery) | **Stair climbing training:** The height of the ladder is 15 cm, one ladder by a step, the speed should be controlled at 20 ~ 40 ladders/minute. The specific amount of activity needs individual guidance under the rehabilitation therapist after the evaluating of the stair-climbing test. | 3 to 5 times per day; 10 minutes each time | Long-term goal |
|                       |                        | **Inspiratory muscle training (IMT):** A tapered flow resistive inspiratory loading handheld device (K3, POWER breathe) was used for inspiratory muscle training. At program commencement, participants received one face-to-face instructional session. Training commenced at 60% of maximal inspiratory pressure. The training intensity was adjusted by physiotherapist timely according to the participant-reported rate of perceived exertion. | 6 to 8 times per day; 10 minutes each time | Long-term goal |
| ERAS postoperative    | Stage 2 (the day of surgery) | **Exercise on the bed:** Participants began to perform exercise on the bed, after waking up under anesthesia and returning to the ward. The exercises included toe flexion and extension, ankle joint and knee joint movement, leg muscle isometric contraction, 20 times each. Finally, lift hips off the bed for 5 times. | 2–3 times, according to the postoperative return time to the ward | Short-term goal |
|                       | Stage 3 POD 1          | **Bedside activity:** Follow the “5-3-1 methods” of getting out of bed, sitting on the bed for 5 minutes, standing on the bed for 3 minutes, and moving the legs and feet for 1 minute. | 4 to 6 times per day (1–2 times in the morning, 3–4 times in the afternoon) | Short-term goal |
|                       |                        | **IMT**                                                                             | Same as above       | Long-term goal |
|                       | Stage 4 POD 2–3        | **Walking:** in the corridor of the ward for 5–10 minutes each time                 | 6 to 8 times per day; total target quantity: 500-1000m | Short-term goal |
|                       |                        | **IMT**                                                                             | Same as above       | Long-term goal |
| Time       | Stage          | Items and methods                                      | Frequency               | Target type          |
|------------|----------------|-------------------------------------------------------|-------------------------|----------------------|
|            | Stage 5        | Walking: in the corridor of the ward for 15–20 minutes each time | ≥ 8 times per day; total target quantity: 1000-1500m | Short-term goal      |
|            | POD 4–5        | IMT                                                   | Same as above           | Long-term goal       |
|            | Stage 6        | Walking: Walking in the corridor of the ward, for 15–20 minutes each time | ≥ 8 times per day; total target quantity: above 2000 m | Short-term goal      |
|            | POD 6 to       | IMT                                                   | Same as above           | Long-term goal       |
|            | Discharged     |                                                       |                         |                      |

POD: postoperative day.

(4) Intervention safeguards:

To ensure the effective implementation of the intervention program, we have made the following efforts:
1) A safe environment for activities: such as temperature and humidity, clean and dry ground, auxiliary equipment, and mobile monitors if necessary; 2) Adequate analgesia management: Painlessness is the prerequisite for early postoperative activities. Multimodal analgesia and individualized analgesia programs ought to use to control the patient's pain to less than 3 points (Visual analogue scoring); 3) Extubation as soon as possible: After evaluation by the research team, the urinary tube and gastric tube were generally removed on the POD 1 to facilitate activities. 4) Recording activities: A recording table of perioperative rehabilitation activities had established, so that researchers could record the times and amount of patient's daily activities, and note patient's daily activities on the bedside visual board; 5) Encouragement and adjustment: Positive encouragement should be given when the target is completed. Adjustment and update of the rehabilitation plan would be conducted based on cause analysis and solution searching by researcher and patient, when the goal is not achieved.

(5) Precautions:

The guidance and supervision of medical staff were essential when patients begin to perform stair climbing training or get out of bed to ensure the safety. Rehabilitation activities should stop immediately, when patients suffered from arrhythmia, chest tightness, suffocation and other discomforts, and the next rehabilitation plan would decide after the evaluation and treatment by a professional doctor.

Outcomes and Sample Size
At baseline, all patients underwent a preoperative assessment on the day of admission, including sociodemographic data, medical history and comorbidities, and physical function. Subsequently, the ERP or usual nursing measures implemented until patient discharge. Research outcomes measured on the day of discharge, which usually was on the 7-9th day postoperative.

The primary endpoints were bowel function recovery (measured as the time to first flatus and bowel movement postoperative) and physical function (measured by the timed up and go test and frailty score) in both the groups. In the Timed up and go test (TUGT), time will be recorded for participants to rise from a chair, walk 3 meters, and turn around, walk back to the chair and sit down\(^{18}\). Take the test twice, and the average value used as a research result. The frailty score was developed by Fried and colleagues\(^{19}\), whose criteria comprise five components: exhaustion, unintentional weight loss, slowness, weak muscle strength, and low physical activity. For the five frailty criteria, 1 score would be given if the criterion was met. The total scores ranges between 0 and 5, and participants would be classified as robustness states (0 score), pre-frailty (1 or 2 scores), or frailty (3 or more scores)\(^{20}\).

The secondary endpoints were readiness for hospital discharge (RHD) and postoperative hospital stay in both groups. The RHD questionnaire was developed by Weiss et al in 2006\(^{21}\) and has been translated and revised into Chinese version by Taiwanese scholars\(^{22}\). This scale consists 12 items and 3 dimensions, covering physical status, adaptive ability, and expected support. The score range of each item is from 0 to 10. The overall Cronbach’s\(\alpha\) coefficient of the scale was 0.89\(^{22}\), confirming its validity.

The sample size was calculated based on the primary outcome—the time to first flatus after surgery. Previously published results\(^{23}\) showed that the mean values of time to first flatus in the IG and CG were 2.6 days and 3.4 days, and the standard deviation was 1.7 days. Group sample sizes of 72 and 72 achieve 80.08\% power to reject the null hypothesis of equal means when the population mean difference is \(\mu_1 - \mu_2 = 3.4 - 2.6 = 0.8\), with a standard deviation for both groups of 1.7 and with a significance level (alpha) of 0.05, using a two-sided two-sample equal-variance t-test by PASS 15.0 software. Allowing for 20\% attrition, we increased the sample size to 180 patients (90 participants per group) at baseline.

**Statistical analysis**

Descriptive statistics can be used for demographic and clinical characteristics at baseline. Continuous variables were presented as Means ± SD and compared using the unpaired \(t\) test. Categorical or ranked variables were presented as frequency (%), and analyzed with the \(\chi^2\). \(P<0.05\) was considered statistically significant. The statistical analysis performed using SAS 9.4 (SAS Institute Inc., Kerry, USA).

**Results**

**Participant demographics and clinical characteristics**

327 potential participants were recruited, of whom 250 (76.45\%) patients were included, and randomized into two groups randomly to receive the intervention of usual care or ERP strategy. During the research, 35
patients were excluded, and 215 patients were included in the final analyses (IG, n = 107; CG, n = 108). The detailed selection process of the participants was as shown in Fig. 2.

The mean (SD) age of IG was 63.09 (8.98) years, and 61.14 (10.02) years in CG. The mean (SD) operation time of IG and CG groups was 5.11 (0.63) hours and 4.97 (0.75) hours respectively. The majority of subjects were men (153/237, 71.16%), married (201/237, 93.49%), living with family (198/237, 92.09%), and middle location of tumor (115/237, 53.49%). Pathological staging was concentrated in stages I and II (170/237, 79.07%), and 20 (9.30%) participants experienced recurrent nerve paralysis, which was temporary. Demographic and clinical characteristics were similar between intervention and control groups, the analysis showed no statistically significant difference (Table 2).
Table 2
Demographic and clinical characteristics of patients with EC in the two groups

| Variable                | Intervention Group (n = 107) | Control Group (n = 108) | Statistics | P Value |
|-------------------------|-----------------------------|-------------------------|------------|---------|
| Age, y                  | 63.098.98                   | 61.1410.02              | 1.50       | 0.135   |
| Gender                  |                             |                         | 1.56       | 0.212   |
| Male                    | 72                          | 81                      |            |         |
| Female                  | 35                          | 27                      |            |         |
| Marital status          |                             |                         | 1.34       | 0.512   |
| Married                 | 98                          | 103                     |            |         |
| Divorced                | 6                           | 3                       |            |         |
| Widowed                 | 3                           | 2                       |            |         |
| Living situation        |                             |                         |            |         |
| Living alone            | 12                          | 5                       | 3.20       | 0.074   |
| Living with family      | 95                          | 103                     |            |         |
| Occupational status     |                             |                         | 3.01       | 0.08    |
| Employed                | 39                          | 52                      |            |         |
| Unemployed or Retired   | 68                          | 56                      |            |         |
| Operation time, h       | 5.110.63                    | 4.970.75                | 1.90       | 0.058   |
| Location of tumor       |                             |                         | 5.46       | 0.065   |
| Upper                   | 18                          | 16                      |            |         |
| Middle                  | 64                          | 51                      |            |         |
| Lower                   | 25                          | 41                      |            |         |
| Pathological stage      |                             |                         | 7.46       | 0.059   |
| 0                       | 3                           | 2                       |            |         |
| 1                       | 18                          | 22                      |            |         |
| 2                       | 30                          | 46                      |            |         |
| 3                       | 56                          | 38                      |            |         |
| Recurrent nerve paralysis|                             |                         | 0.62       | 0.734   |
| No                      | 94                          | 98                      |            |         |
Efficacy of effect of the ERP

The primary outcomes about bowel function recovery and physical function recovery were outlined in Tables 3 and 4 respectively. As shown in Table 3, the mean (SD) time to first flatus postoperative were 3.24 (1.11) days in IG and 4.19 (1.67) days in CG, the mean (SD) time to first bowel movement were 4.55 (2.34) days in IG and 5.38 (2.98) days in CG. Compared with the CG group, the IG group presented a significantly shorter time to first flatus ($P < 0.001$) and to first bowel movement ($P = 0.024$).

| Variable                        | Intervention Group (n = 107) | Control Group (n = 108) | Statistics | $P$ Value |
|---------------------------------|-----------------------------|-------------------------|------------|-----------|
| Yes                             | 11                          | 9                       |            |           |
| Uncertain                       | 2                           | 1                       |            |           |

Table 3
The bowel function recovery of patients with EC in the two groups

Table 4
The physical function recovery of patients with EC in the two groups

The ERP strategy was even more effective than usual care in improving physical function recovery as measured by the TUGT (s) and Frailty score. As summarized in Table 4, before the intervention (the day of admission), no significant differences in baseline physical function between the two groups were observed ($P > 0.05$). After the ERP intervention (the day of discharge), the mean (SD) time of TUGT (s) was 13.22 (4.05) in IG and 16.13 (5.42) in CG, the mean (SD) score of Frailty was 2.16 (0.75) in the IG and
3.22 (1.10) in CG, which showed physical function recovery in IG was significantly better than CG ($P<0.001$).

After the ERP intervention, except the dimension of expected support, the total scores of RHD ($P<0.001$), physical status ($P<0.001$) and adaptive ability ($P=0.001$) were significantly higher in IG than that in the CG, as showed in Table 5. Likewise, compared with the CG, patients in the IG presented a significantly shorter in the time of postoperative stay (9.083.48d vs. 12.144.05, respectively, $t=-5.94$, $P<0.001$).

| Dimensions of RHD | Intervention Group ($n = 107$) | Control Group ($n = 108$) | Statistics | $P$ Value |
|-------------------|---------------------------------|---------------------------|------------|-----------|
| Physical status   | 8.481.45                        | 7.571.82                  | 4.06       | <0.001    |
| Adaptive ability  | 8.821.50                        | 8.012.05                  | 3.31       | 0.001     |
| Expected support  | 9.052.85                        | 8.352.70                  | 1.85       | 0.066     |
| Total             | 8.921.42                        | 7.861.79                  | 4.81       | <0.001    |

**Discussion**

Esophagectomy has identified as a particularly complex surgical procedure due to documented high levels of perioperative morbidity and mortality$^{[24]}$. Advances in perioperative management concepts and medical technology had been proposed to reduce surgical risk and perioperative morbidity and mortality, thus improving surgical short- and long-term outcomes.$^{[25–27]}$ According to the components of ERAS guidelines, early and structured mobilization is an essential factor to accelerate recovery, and there is a strong relationship between physical activity and quality of life generally.$^{[28]}$ Ambulate early not only prevents complications associated with bed rest and maintain muscle function, but also empowers patients to play an active role in their rehabilitation from surgery.$^{[7]}$ Therefore, an early and goal-directed mobilization plan should formulate by the involvement of the chest physiotherapist for EC patients on each day of perioperative.

Cardiopulmonary fitness and physical functioning are key determinants of fitness for major thoracic surgery.$^{[29]}$ One strength of our study is preoperative rehabilitation, which was involved in ERP intervention for esophageal cancer after surgery and included stair climbing training and inspiratory muscle training by a tapered flow resistive inspiratory loading handheld device. "Pre-rehabilitation before the operation can accelerate recovery after operation", this is the philosophy of our team in the implementation of ERAS. Previous research showed that preoperative moderate intensity activity was associated with a lower risk of postoperative complications following oesophagectomy and therefore may have therapeutic potential.$^{[30]}$ One scoping review$^{[31]}$ provided an overview of the available evidence of possible beneficial effects of preoperative exercise therapy in surgery, which showed that the
preoperative exercise programs could increase in exercise capacity and physical fitness, preserve pulmonary function, reduce the incidence of postoperative complications, and decrease the length of hospital stay. Although, some studies\[^7\] suggested that the preoperative rehabilitation program requires at least 4 weeks, there is limited data for esophagectomy about the general consensus or clear practical guidance currently regarding exercise methods and exercise time norms.

This randomized clinical trial provided evidence that ERP, involving pre-rehabilitation and early postoperative activity, was effective in promoting recovery of bowel function and physical function in patients undergoing esophagectomy. TUGT test is a common method to observe patient's balance motor function and daily activities, and is an important index to evaluate patient's prognosis.\[^32\] Although the physical fitness of EC patients was affected to a certain extent due to the operation, analysis of this study showed that the time of TUGT in the IG (13.22±4.05) was significantly shorter than the CG (16.13±5.42) when discharged after the intervention of ERP. The frailty scores was range from 1 to 4, there were significant statistical differences between the two groups. Something worth noting is that 32.09% of patients are in a frailty state (three or more scores) and 56.28% are in a pre-frailty state (one or two scores) after esophagectomy, which should require adequate attention from medical staffs.

RHD is a self-perception of patients about whether they are ready to be discharged, it is related to medical satisfaction and safety after discharge closely. Studies\[^33,34\] have shown that the higher RHD, the stronger ability to cope with health challenges after discharge. In this study, the RHD of patients after esophagectomy was at a medium level. Given that physical recovery is closely related to the patient's self-feeling and self-care ability in life when discharged from hospital, the improvement of RHD from patients was hypothesized as a potential secondary benefit of this program. Furthermore, ERP strategy was beneficial to enhance the level of RHD as well as shorten the postoperative hospital stay. Surprisingly, in this subanalysis, the findings showed that the postoperative hospital stay was approximately 3 days shorter in the ERP group (9.08±3.48d) than the usual care group (12.14±4.05d). One systematic review from 26 studies showed that early enteral nutrition could promote intestinal function recovery and shorten the time of postoperative hospital stay for patients undergoing gastrointestinal surgery.\[^35\] This reduced postoperative hospital stay was likely the result of the early flatus and bowel movement after surgery, which will shorten the fasting time of patients, and achieve the purpose of early oral intake, nutrition improvement, and fast postoperative recovery.

Maximizing the patient's subjective initiative in disease management during the perioperative rehabilitation process is very important. The King's TGA emphasizes effective communication and interaction between health professionals and patients, which is consistent with the classification systems suggested by the North American Nursing Diagnoses Association (NANDA).\[^16\] This research used this theory as a framework to develop a detailed rehabilitation plan and set short-term and long-term goals together with patients. For example, on the first day after surgery, we encourage patients to engage in bedside activities following by “5-3-1 methods” with a definite short-term goal, 1–2 times in the morning and 3–4 times in the afternoon. Besides, a professional multidisciplinary team was established to make
individual, evidence-based and stepwise adaptation of the rehabilitation program according to patients' actual status, physical efficacy and clinical symptoms.

**Limitations**

Some limitations also should be mentioned in our research. First, due to the limited preoperative time, the time of preoperative rehabilitation in this study is relatively short (approximately 7–10 days), which may not be able to fully offer the possibility for improving fitness. Therefore, novel strategies such as maximizing physical function during short-term training, or using the occasion of neoadjuvant to exercise before surgery, need to be explored. Second, the sample size and variation were limited because the objects came from a single center. Future studies should recruit participants from multi-centers to achieve a larger sample size and more variation, and further verify the effectiveness of the ERP. Third, in this study research staff were aware of the interventions and randomization results. Despite all efforts to maintain blinding, we could not implement a double-blind method owing to the nature of the interventional research. These circumstances may have led to the overestimation of the effect of the ERP. Fourth, due to the limitations of research conditions, we could not evaluate patients' electrophysiological indicators to reflect the improvement of physical function, which is an important research field of rehabilitation medicine.

**Conclusions**

In conclusion, the present study showed that the ERP, which was a nurse-led, contained six staged procedure, and guided by King's TGA, was practical and feasible in accelerating bowel and physical function recovery for EC patients after MIE. Besides, in the context of ERAS, the ERP can also improve patient’s RHD and shorten the postoperative hospital stay, which may enhance patient’s medical experience and hospital operation efficiency. Clinical nurses play a key role in patient’s perioperative recovery, the results of this research motivate nurses to formulate quantitative, detailed and individualized early activity plans for patients combining nursing theory with clinical practice.

**Abbreviations**

ERP: Early Rehabilitation Program; IG: Intervention Group; CG: Control Group; RHD: Readiness for Hospital Discharge; EC: Esophageal Cancer; MIE: Minimally Invasive Esophagectomy; ERAS: Enhanced Recovery After Surgery; TGA: Theory of Goal Attainment; TUGT: Timed Up And Go Test; NANDA: North American Nursing Diagnoses Association

**Declarations**

All authors disclose no conflicts of interest.

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Availability of data and materials

The datasets used and/or analysed during the current study are available from the corresponding author on reasonable request.

Authors’ Contributions

Concept and design: XX.X, FN.Y, XB.L. Drafting of the manuscript: FN.Y, YZ.M. Critical revision of the manuscript for important intellectual content: FN.Y, HB.S, XB.L. Statistical analysis: XF.C, AY.S. Administrative, technical, or material support: LJ.L, LM.Z. Supervision: XB.L. All authors have read and approved the manuscript.

Ethics approval and consent to participate

All patients signed an informed consent form prior to participation in the study. This study was approved by the Ethics Committee of the local Medical Ethics Committee(2014xjs4), and the protocol registered in the ClinicalTrials.gov (registration number: NCT01998230).

Competing interests

The authors declare that they have no competing interests regarding the publication of this paper.

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