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High-fat enteral nutrition controls intestinal inflammation and improves intestinal motility after peritoneal air exposure

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ABSTRACT

Background: Peritoneal air exposure is a common phenomenon in abdominal surgery, but long-term exposure could induce intestinal inflammatory responses, resulting in delayed recovery of gastrointestinal motility after surgery. High-fat enteral nutrition has been reported to ameliorate inflammation in many diseases. In the present study, we investigated whether high-fat enteral nutrition could control intestinal inflammation and improve intestinal motility after peritoneal air exposure.

Methods: Male adult rats were administrated saline, low-fat enteral nutrition, or high-fat enteral nutrition *via* gavage before and after peritoneal air exposure for 3 h. Control rats underwent anesthesia without laparotomy and received saline. Intestinal motility was assessed 24 h after surgery by charcoal transport assay; systemic inflammation was assessed by analyzing serum levels of tumor necrosis factor α, interleukin (IL)-1β, IL-6, and IL-10; and intestinal inflammation was assessed by analyzing myeloperoxidase activity and concentrations and gene expression of tumor necrosis factor α, IL-1β, IL-6, and IL-10 in the intestinal tissue.

Results: Peritoneal air exposure decreased intestinal motility significantly compared with the control group ($P < 0.05$). The systemic and intestinal inflammatory parameters were also much higher in the peritoneal air exposure groups than in the control group. Both low-fat and high-fat enteral nutrition increased intestinal motility and reduced systemic and intestinal inflammatory parameter levels to different degrees. However, high-fat enteral nutrition significantly improved the negative alterations in these biochemical parameters compared with low-fat enteral nutrition ($P < 0.05$).

Conclusions: These results suggest that high-fat enteral nutrition might be able to control intestinal inflammation and improve intestinal motility after peritoneal air exposure.

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Thus, the perioperative administration of high-fat enteral nutrition may be a promising treatment to enhance the recovery of intestinal motility after surgery.

1. Introduction

Peritoneal air exposure is a common phenomenon in abdominal surgery; however, long-term exposure can induce injury in various organs and tissues [1–3]. In particular, postoperative gastrointestinal dysmotility can impact patients' well-being after open abdominal surgery [1]. Compared with laparoscopic surgery, open abdominal surgery is known to be associated with delayed recovery of gastrointestinal motility after surgery, potentially resulting in later bowel movements and anal discharge and leading to additional postoperative complications and a longer hospital stay [4–6]. In open abdominal surgery, the peritoneal cavity is exposed to air, and the oxygen present can induce intestinal inflammation through oxidative stress injury to the exposed gut and the induction of intestinal bacteria translocation [1,3,7]. This inflammation can act further as a depressant factor and contribute to decreased gastrointestinal motility through various mechanisms, such as direct cytotoxic effects and the induction of nitric oxide and prostanoids [8]. Our previous studies have revealed that the intestinal inflammation induced by peritoneal air exposure during open abdominal surgery may be a key factor contributing to intestinal paralysis after surgery [1,9]. As such, methods to control intestinal inflammation and enhance the recovery of intestinal motility after peritoneal air exposure are popular pursuits aimed at shortening the postoperative rehabilitation course in modern surgery.

Enteral nutrition support is considered to be an important treatment during the perioperative period [10–12]. In recent decades, great progress has been made in enteral nutrition support, with various intended uses improving clinical outcomes [13]. Currently, enteral nutrition has been accepted as a preferred way of performing nutrition support because of its many advantages, including coincidence with physiology and fewer complications [11,12,14]. The therapeutic effect of enteral nutrition can be enhanced significantly when the proportion of enteral nutrition component is optimized. It has been demonstrated that high-fat enteral nutrition, which is formulated with standard enteral nutrition plus additional fat, ameliorates inflammation in many diseases and improves organ function [15–17]. However, little is known about the effect of high-fat enteral nutrition on intestinal inflammation and its further contribution to intestinal motility after peritoneal air exposure.

Therefore in the present study, based on the findings of our previous studies, we investigated whether high-fat enteral nutrition can control intestinal inflammation and improve intestinal motility after peritoneal air exposure.

2. Materials and methods

2.1. Animals

Healthy adult male Sprague–Dawley rats (weighing 210–230 g) were obtained from Jinling Hospital, Nanjing, China, and housed in our laboratory in a temperature- and humidity-controlled environment with lights maintained on a 12:12-h light–dark cycle. The rats had free access to standard rat chow and tap water. The animal use and care protocol and experimental procedures were reviewed and approved by the Institutional Animal Care and Use Committee of Jinling Hospital. The experiments were performed according to the National Institutes of Health Guide for the Care and Use of Laboratory Animals.

2.2. Animal grouping and administration

After an adaptation period for 1 wk, 24 rats were randomized into four groups ($n = 6$ in each group): a control group (CG); an exposure group with peritoneal air exposure for 3 h (EG); a low-fat enteral nutrition–treated EG group (LFG); and a high-fat enteral nutrition–treated EG group (HFG). The peritoneal air exposure was established as described in our previous studies [1–3]. Briefly, after full anesthesia with 2% pentobarbital sodium (3.5 mL/kg) [18], the rats in the EG, LFG, and HFG groups underwent laparotomy with a 3 cm midline abdominal incision, after which the wound edge was retracted to allow for maximal peritoneal air exposure for 3 h. The animals in the CG group received the same anesthesia but did not undergo any operative procedures. The rats in the LFG and HFG groups received low-fat and high-fat enteral nutrition, respectively, orally *via* gavage at 12 h (3 mL; other time points, 0.75 mL), 2 h, and 45 min before peritoneal air exposure, and at 45 min, 90 min, and 3 h after peritoneal air exposure [19,20]. The rats in the CG and EG groups received an equal volume of saline at the same six time points and by the same method as the LFG and HFG groups.

The high-fat enteral nutrition was formulated with 100 g ENSURE (Abbott Laboratories B.V., Zwolle, The Netherlands), 28 mL 50% glucose solution, and 25 g corn oil; the low-fat enteral nutrition was formulated with 100 g ENSURE and 140 mL 50% glucose solution. ENSURE contains 15.9% protein, 15.9% fat, 8.7% linoleic acid, 60.7% carbohydrate, 5% moisture, electrolytes, and multivitamins. Each nutrition dose was dissolved in saline and diluted to a final solution of 300 mL. The formulations were calculated according to the results of previous studies [19,20]. The high-fat formulation contained 50.4 energy percent (en%) fat, 8.7 en% protein, and 40.9 en% carbohydrates; the low-fat formulation was composed of 19.6 en% fat, 8.7 en% protein, and 71.7 en% carbohydrates. The high-fat enteral nutrition formulation was isocaloric and isonitrogenous to the low-fat formulation.

2.3. Determination of intestinal motility and sampling

Twenty-four hours after surgery, intestinal motility was assessed in all the rats by charcoal transport assay, as described in our previous studies [1,9]. Briefly, the rats were administered a black marker (10% charcoal suspension in 10% gum arabic, 10 mL/kg body weight) by gavage; 20 min later, they