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Review Article

Enhanced recovery after surgery protocols: clinical pathways focusing on anesthesiology tailored for obese patients undergoing bariatric surgery

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Abstract: The concept of enhanced recovery after surgery (ERAS) has evolved continuously over the past two decades. It originated from the practice of colorectal surgery, and the technique that was developed has been adopted by numerous surgical subspecialties. This perioperative multimodal and multidisciplinary protocol, which involves optimizing the pre, intra, and postoperative phases of clinical management, has resulted in fewer complications, lower mortality, and shorter hospitalizations. Recently, several individual ERAS components have been introduced in bariatric surgery, but ERAS protocols in the setting of bariatric surgery are still in an initial stage and have not yet been standardized. Accordingly, we propose the ERAS protocol of clinical pathways tailored for obese patients undergoing bariatric surgery considering the various perioperative stages, focusing on anesthesiology.

Keywords: ERAS, obese, bariatric surgery, anesthesiology

Introduction

Obesity has increased rapidly in many countries across the world in the past 5 decades, reaching epidemic levels [1]. According to the latest national prevalence estimates for 2015-2019 in China, 16.4% of adults were obese and 34.3% were overweight, while in children and adolescents aged 6-17 years 7.9% were obese and 11.1% were overweight, and in children younger than 6 years 3.6% were obese and 6.8% were overweight, according to the Chinese criteria [2]. Obesity represents an increasing health burden because it is associated with many concomitant diseases, such as hypertension, myocardial infarction, stroke, type 2 diabetes, fatty liver disease, obstructive sleep apnea and osteoarthritis, consequently resulting in a decline in both quality of life and life expectancy. As a result, the number of bariatric surgeries, including sleeve gastrectomy and Roux-en-Y gastric bypass, is growing rapidly in many countries [3]. For this reason, bariatric surgery has been demonstrated to be a safe and effective technology for achieving long-term weight loss, controlling various obesity-related diseases and improving life expectancy [4-6]. In addition, as the number of bariatric surgeries has increased and surgical techniques have improved, more patients with multiple comorbidities are inevitably affected. Since bariatric surgery has become the mainstream method for treating morbidly obese patients to achieve persistent weight loss and control obesity-related comorbidities, techniques to promote early recovery after bariatric surgery have become fundamental goals and emergent critical requirements.

The concept of enhanced recovery after surgery (ERAS) was first proposed by Henrik Kehlet, a Dutch gastroenterology surgeon, in 1997 [7]. ERAS consists of a series of perioperative multimodal and multidisciplinary interventions that were originally developed for elective colorectal surgery. ERAS pathways are evidence-based interventions that aim to maintain physiological function by reducing patients' physiological and psychological stress responses to surgical trauma. The goal of ERAS pathways is to reduce pain, enhance mobilization and facilitate early oral nutrition postoperatively, thus optimizing

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recovery after surgery to reduce sequelae and shorten the length of hospital stay.

Compared with nonobese patients, obese patients are more vulnerable to circulatory, respiratory and metabolic problems, which significantly increases the complexity of perioperative management. ERAS pathways have been applied in many surgical settings and have achieved favorable perioperative outcomes. The use of the ERAS protocol can decrease the incidence of complications after bariatric surgery, accelerate functional recovery and shorten the length of hospital stay. Several of the perioperative recommendations in these protocols are appropriate for the pathophysiological changes in obese patients (**Table 1**, presenting previously published data [8-10]). Although several individual ERAS components have been introduced in bariatric surgery, ERAS protocols in the setting of bariatric surgery are still in an initial stage and have not yet been standardized. Different centers carry out different types of ERAS protocols, and few studies exist with respect to the outcomes resulting from the adoption of a complete ERAS approach. Accordingly, we propose the following protocol considering the various perioperative stages focused on anesthesiology.

Preoperative elements

Preoperative assessment and counseling

Preoperative visits to the ward have been demonstrated to relieve anxiety and improve compliance with postoperative instructions, postoperative recovery and long-term prognosis. In addition, ERAS implementation strongly depends on patient cooperation in the recovery process and a full understanding of the principles of modern perioperative care, early mobilization and discharge. However, there is little evidence on the impact of assessment or counseling prior to bariatric surgery. A questionnaire has been used to evaluate patients' views on ERAS implementation and has shown the necessity of preoperative visits by anesthetists as the most significant element of the ERAS protocol for patients [11]. Moreover, obese patients are prone to greater risks and challenges due to comorbidity rather than merely the presence of obesity. Therefore, the risk factors and severity of obesity should be assessed, and preoperative counseling should be completed during the preoperative visit. Particular attention should be given to evaluating the severity of obstructive sleep apnea (OSA) using screening scores (STOP-Bang) or diagnostic testing (polysomnography) and screening patients with particularly high risk associated with mortality. The obesity surgery mortality risk stratification score (OS-MRS) (**Table 2**) has been demonstrated to be a risk factor associated with mortality in obese patients undergoing gastric bypass surgery [12]. Patients with an OS-MRS score of 4-5 are more likely to require closer postoperative monitoring to avoid postoperative complications. These data should be recorded on the visit list to assist in the implementation of the ERAS protocol. Preoperative visits and counseling can help patients understand the importance of early mobilization and remind patients to bring their own continuous positive airway pressure (CPAP) machine into the hospital, consequently reducing anxiety and promoting compliance with the ERAS protocol.

Preoperative fasting and carbohydrate loading

In addition to the implementation of ERAS guidelines, preoperative fasting from solids for at least 6 h and clear liquids for 2 h prior to anesthesia induction are recommended for elective bariatric surgery in the absence of contraindications (e.g., bowel obstruction) [8, 9, 13]. Obese patients with diabetes should comply with this recommendation, but further research is needed if patients have additional risk factors, such as gastroparesis. There is not sufficient evidence to recommend carbohydrate drink loading in bariatric surgery.

Smoking cessation

Cessation of smoking should be encouraged at least 4-8 weeks prior to surgery to reduce postoperative complications, particularly infectious and pulmonary complications. Smoking has been associated with increased risks of short-term and long-term unfavorable outcomes, including pulmonary complications, wound infections, marginal ulcers and thromboembolic events for bariatric surgery [14-16]. However, the optimal timing or duration of smoking cessation prior to bariatric surgery remains unknown. A recent systematic review suggested that smoking within 1 year before bariatric surgery was associated with significant short-term

Table 1. Items of the ERAS guidelines for bariatric surgery and their approach focused on anesthesiology

		Preoperative	Intraoperative	Postoperative
ERAS guidelines for bariatric surgery	Items of particular interest for bariatric surgery	• Preoperative assessment and counseling • Preoperative fasting and carbohydrate loading • Smoking cessation • Supportive pharmacological intervention	• Standard intraoperative anesthesia pathway (standard anesthetic protocol with short-acting drugs and Monitoring of anesthetic depth) • Airway management and Protective ventilation strategy • Fluids/goal directed fluid therapy • Prevention of PONV	• Postoperative oxygenation • Standard postoperative multimodal analgesic regimen
		• Preoperative weight loss • glucocorticoids • Pre-habilitation and exercise	• Surgical technique, volume and training • Abdominal drainage and nasogastric decompression	• Thromboprophylaxis • Early mobilization • Early postoperative nutritional care • Supplementation of vitamins and minerals • PPI prophylaxis

The table is composed of previously published data [8-10]. ERAS, enhanced recovery after surgery; PONV, postoperative nausea and vomiting.

Table 2. Obesity surgery mortality risk stratification score (OS-MRS): (a) risk factor score; (b) risk of mortality

Risk factor	Score
(a)	
Body mass index ≥ 50 kg/m^2	1
Male gender	1
hypertension	1
known risk factors for pulmonary embolism previous thromboembolism preoperative vena cava filter hypoventilation pulmonary hypertension	1
Age ≥ 45 years	1
	Risk of mortality
(b)	
Class A: 0-1 points	0.2%
Class B: 2-3 points	1.1%
Class C: 4-5 points	2.4%

and long-term postoperative complications [17]. Despite best efforts, achieving smoking cessation seems to be difficult, especially in the long term. In compliance with practice guidelines, smoking should be stopped at least 4 weeks prior to bariatric surgery [8, 9].

Supportive pharmacological intervention

To reduce patients' stress responses to surgical trauma during the perioperative phase, several pharmacological interventions have been recommended before elective surgery. Although there is a lack of evidence for the use of glucocorticoids before bariatric surgery, 8 mg intravenous dexamethasone has been recommended to be administered 90 min before anesthesia induction to reduce the inflammatory response as well as postoperative nausea and vomiting (PONV) in practice guidelines [8, 9]. Statin premedication was considered to reduce mortality, systemic infection and anastomotic leakage. However, studies have shown that statin use is not associated with postoperative complications in patients undergoing noncardiac surgery or major colorectal surgery. In addition, evidence on statin use in bariatric surgery specifically is scarce. Routine preoperative administration of statins to obese patients undergoing bariatric surgery is not recommended for the prevention of complications but can be continued for patients on statins during the perioperative phase. Beta-adrenergic blockade does not reduce complications in bariatric surgery. Therefore, the routine application of beta-blockers perioperatively is not recommended in the bariatric population but can be safely continued for patients with cardiovascular events who are already on beta-blockade during the perioperative phase.

Intraoperative elements

Standard intraoperative anesthesia pathway (standard anesthetic protocol with short-acting drugs and monitoring of anesthetic depth)

Short-acting anesthetics, minimal opioid use and easily reversible agents during the operation are important choices for obese patients to improve recovery. For most anesthetics used for induction and maintenance, dosages based on total body weight (TBW) may not be appropriate because they increase the risk of overdose. However, the dosage of most anesthetics is affected by factors such as the loss of the eyelash reflex, the relief of pain or the nerve stimulator response. Based on current practice guidelines for bariatric surgery, lean body weight (LBW) and adjusted body weight (ABW) are recommended as scalars for calculating initial anesthetic dosages rather than TBW (**Table 3**) [18]. Propofol is the most commonly used anesthetic drug, and the dosage should be calculated on the basis of LBW to avoid hypotension in the induction phase and ABW in traditional Schnider and Marsh models or TBW in the Eleveld allometric model for maintenance [19]. Compared with sevoflurane, if volatile inhaled anesthetics are used for maintenance of anesthesia in bariatric surgery, desflurane can achieve tracheal extubation earlier without compromising safety [20, 21]. However, sevolurane is a bronchodilator, whereas desflurane can increase airway resistance, hypertension and tachycardia. Therefore, the decision with respect to which inhaled anesthetic to choose should be based on existing comorbidities. The clinical effect of opioids is poorly associated with plasma concentration; therefore, a dosage based on LBW is an appropriate initial titration

Table 3. Four most useful items of obese patients' weight and suggested initial dosing scalars for commonly used anesthetics for healthy obese adults [18]

Items of patients' weight	Calculation method	Suggested initial dosing scalars for commonly used anesthetics
Total body weight (TBW)	The actual weight of the patient	
Ideal body weight (IBW)	IBW (kg) = height (cm) - x (where x = 105 in females and 100 in males)	
Lean body weight (LBW)	$LBW\ (kg) = \frac{9270 \times TBW\,(kg)}{6680 + (216 \times BMI\,(kg/m^2))}$ (men) $LBW\ (kg) = \frac{9270 \times TBW\,(kg)}{8780 + (244 \times BMI\,(kg/m^2))}$ (women)	Propofol (induction) Fentanyl Rocuronium Atracurium Vecuronium Morphine Bupivacaine Lidocaine
Adjusted body weight (ABW)	ABW (kg) = IBW (kg) + 0.4 (TBW (kg) - IBW (kg))	Propofol (infusion) Alfentanil Neostigmine (maximum 5 mg) Sugammadex

point for determining the effect. Opioid-sparing anesthesia, which uses a multimodal approach such as regional anesthetic techniques, should be applied to enhance postoperative recovery. Epidural analgesia is not required in laparoscopic surgery but is effective in reducing postoperative pain. In addition, ultrasound-guided erector spinae or transversus abdominis plane block can effectively reduce pain scores and opioid consumption and thus enhance early mobilization after bariatric surgery [22]. Neuromuscular blockade (NMB) is essential for bariatric surgery. Unlike suxamethonium-associated fasciculations, which increase oxygen consumption, rocuronium can shorten the apnea time from the cessation of spontaneous breathing to controlled ventilation. Owing to the reversal effect of sugammadex, rocuronium could be considered a better choice for neuromuscular blocking than suxamethonium. The dose of sugammadex should be based on the degree of NMB and body weight to achieve rapid and complete reversal. A sugammadex dose of 1.5 mg/kg according to IBW can reverse moderate rocuronium-induced NMB in bariatric surgery [23]. Furthermore, a dose of 4 mg/kg IBW plus 35-50% can rapidly and completely reverse rocuronium-induced deep NMB in obese patients undergoing bariatric surgery [24]. The dose of sugammadex should be calculated and prepared in advance for emergency situations.

The bispectral index (BIS) is essential for monitoring the depth of anesthesia to avoid intraoperative awareness and adjusting the amount of administered anesthetic, especially when the total of intravenous anesthetic techniques is applied [25, 26].

Airway management and protective ventilation strategy

Obesity is associated with difficult intubation as well as difficult mask ventilation. Airway complications occur mainly because of a lack of recognition of the challenges of airway management and preparation for potential airway problems in obese patients. Endotracheal intubation remains the primary technique of airway management in obese patients undergoing bariatric surgery. Furthermore, maintaining adequate oxygenation and ventilation throughout every step of airway management in anesthetized patients is important. During the phase of anesthesia induction, patients should be positioned in the recommended ramped position to improve lung mechanics and assist oxygenation as well as ventilation, consequently maximizing the safe duration of apnea. Patients are then adequately preoxygenated with 100% oxygen until the end-tidal oxygen concentration reaches 0.87. Videolaryngoscopy may improve the glottic view, allow fast tracheal intubation, and improve the success rate of intubation, particularly in the setting of a pre-

dicted or known difficult airway [27-29]. In addition, a strategy for airway management in morbidly obese patients, in which sevoflurane is inhaled under anesthesia with spontaneous breathing, is used to insert a supraglottic airway device (SAD), and then intravenous anesthetics are administered for tracheal intubation via the SAD, which may be feasible and safe [30].

Obese patients are more prone to developing postoperative pulmonary complications (PPCs). Therefore, intraoperative protective ventilation should be applied to every obese patient undergoing bariatric surgery to avoid the development of PPCs. With respect to protective ventilation strategies, pressure-controlled ventilation (PCV) and volume-controlled ventilation (VCV) can both be used for obese patients undergoing bariatric surgery. Compared with an intraoperative mechanical ventilation strategy with a low level of positive end-expiratory pressure (PEEP) (4 cm H_2O) among obese patients under general anesthesia, a strategy with a high level of PEEP (12 cm H_2O) did not reduce PPCs [31]. The guidelines and studies suggest that low tidal volumes (6-8 mL/kg predicted weight body) with individualized PEEP and alveolar recruitment maneuvers (30 cm H_2O for 30 seconds) may result in favorable outcomes [32, 33].

Fluids/goal-directed fluid therapy

Intraoperative fluid management should focus on maintaining euvolemia and optimizing tissue perfusion and oxygenation. It is not necessary for obese patients undergoing bariatric surgery to receive extra fluid therapy. Goal-directed fluid therapy to avoid fluid overload, which is associated with decreased fluid administration and PONV or hospital stay, may be the most effective strategy to improve outcomes [34, 35]. It is recommended for obese patients with high-risk complications, such as congestive heart failure. Regarding the type of fluid, there is a paucity of RCT studies comparing crystalloid with colloid fluid administration in bariatric surgery.

Prevention of postoperative nausea and vomiting (PONV)

Obese patients who undergo bariatric surgery are more prone to PONV because these patients are frequently female and nonsmokers and receive opioid analgesia during surgery. All of these factors are risk factors for PONV, and surgery resulting in a reduction in gastric size may further contribute to PONV. Recent guidelines recommend a multimodal approach, including avoidance of volatile anesthetics and fluid overload, total intravenous anesthesia (TIVA) with propofol, minimization of intra- and postoperative opioid administration and prophylactic pharmacological application [9]. Compared with volatile opioid anesthesia, opioid-free total intravenous anesthesia could reduce the rate and severity of PONV [36, 37], but the superiority of TIVA was shown in another study [38]. Additional research specific to obese patients undergoing bariatric surgery is needed to validate the value of TIVA. Prophylactic approaches using multiagent pharmacotherapy (dexamethasone combined with one or more agents from other classes, such as antihistamines, anticholinergics, 5-hydroxytryptamine receptor antagonists, butyrophenones and neurokinin-1 receptor antagonists), may be effective in reducing the risk of PONV [39].

Postoperative elements

Postoperative oxygenation

Obesity is associated with a greater risk of perioperative atelectasis and hypoxemia due to increased work involving breathing and oxygen consumption. Furthermore, obese patients present with complications from OSA, which is associated with an increased risk of postoperative hypoventilation and cardiopulmonary complications [40, 41]. Therefore, patients without OSA or with mild-to-moderate OSA can be monitored slightly longer in the post-anesthesia care unit (PACU) and supplemented with oxygen prophylactically in a head-elevated position and then direct them toward the surgical ward. When a patient is prepared to be discharged from the PACU, standardized discharge criteria and satisfactory clinical evaluation can be applied to ensure that the patient has stable vital signs, particularly a sufficient respiratory depth and rate. Patients with obesity hypoventilation syndrome or severe OSA are at increased risk of respiratory adverse events. Postoperative CPAP or bilevel positive airway pressure/noninvasive ventilation (BiPAP/NIV)

should be used in the immediate postoperative period, especially for patients with OSA on home CPAP therapy. Finally, co-administration of opioids with sedative agents for postoperative analgesia is recommended to reduce episodes of apnea [41].

Standard postoperative multimodal analgesic regimen

Effective postoperative analgesia in morbidly obese patients undergoing bariatric surgery is an important component of the ERAS strategy, as pain control facilitates early postoperative mobilization and recovery. Although opioid analgesic agents are commonly used for relieving postoperative pain, their use is associated with adverse respiratory events in morbidly obese patients, especially those with OSA. Typically, multiple nonopioid analgesic drugs and techniques are used to reduce opioid-related adverse events.

Nonsteroidal anti-inflammatory drugs (NSAIDs)

NSAIDs are the foundation of multimodal analgesia programs because they control postoperative pain and reduce opioid requirements as well as opioid-related side effects. Studies investigating the use of NSAIDs for postoperative analgesia in the bariatric population are limited. A retrospective study revealed that NSAID administration for obese patients undergoing bariatric surgery is associated with better postoperative analgesia as well as shorter PACU stays without postoperative complications such as anastomosis leakage and bleeding [42]. However, NSAIDs are avoided in colorectal surgery because their use delays anastomosis healing and increases the risk of anastomotic ulcers/leaks [10]. As a consequence, the decision regarding NSAID use for the bariatric population is contentious, and further studies are warranted to investigate its feasibility.

Dexmedetomidine

Dexmedetomidine is a highly selective α_2 receptor agonist with sedative, anxiolytic and analgesic properties. Its use may be associated with a decrease in postoperative opioid requirements and pain scores and improvement in the quality of recovery during bariatric surgery [43]. Some studies have shown that an intravenous infusion of dexmedetomidine during laparoscopic bariatric surgery can reduce the overall morphine requirements and provide the same level of analgesic effect as morphine, with better hemodynamic properties [44, 45]. Therefore, the use of dexmedetomidine contributes to postoperative analgesia for morbidly obese patients undergoing bariatric surgery.

Lidocaine

Intraoperative intravenous lidocaine (bolus 1.5 mg/kg followed by a maintenance dose of 2 mg/kg/hr) during bariatric surgery prolonged the time to first opioid infusion and improved patients' postoperative quality of recovery [46-48]. However, owing to the limited number of trials, further studies are warranted to confirm the appropriate dose of perioperative intravenous lidocaine for morbidly obese patients undergoing bariatric surgery.

Transversus abdominis plane (TAP)

The transversus abdominis plane (TAP) may be an effective analgesic mode because it relieves pain, reduces opioid use and shortens the time to mobilization [49]. In addition, patients who received TAP blocks before bariatric surgery required fewer opioid agents than patients who received TAP blocks at the end of surgery [50]. Therefore, the TAP at the optimal time should be considered in multimodal analgesia in the ERAS pathway for the bariatric population.

In conclusion, the components of this protocol resemble those of the previously published ERAS pathway for bariatric surgery. All anesthesiology elements included a preoperative assessment, intraoperative management (standard intraoperative anesthesia pathway, fluid/goal-directed fluid therapy, and prevention of PONV), and postoperative analgesia. All the components of the ERAS protocols described above and emphasized in the blue box of **Table 1** can improve obese patients' outcomes. Our pathway provides more details on individual anesthetic drugs, airway management and analgesic regimens, some of which are not entirely covered in published protocols. The ERAS approach has been shown to reduce postoperative complications and improve recovery. It is likely that the application of ERAS protocols will benefit obese patients. Therefore, ERAS protocols should not be limited to the bar-

iatric population but rather should be adopted for this purpose because many approaches appear tailored to potential pathophysiological changes. To design and execute a successful ERAS protocol, multidisciplinary collaboration is essential to reach an agreement on the key process during various phases of the perioperative period. Anesthesiologists will continue to play a role in perioperative management.

Disclosure of conflict of interest

None.

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