Optimizing Outcomes with Enhanced Recovery

7

Julie Thacker and Nancy Morin

Key Concepts

- Enhanced recovery is the process of defining modifiable sources of perioperative stress to the surgical patient and applying standardized evidence-based interventions through all phases of care to avoid complications, facilitate faster recovery and discharge (without increasing readmission rates), and reduce hospital costs.
- Champions from surgery, anesthesia, and nursing are essential to the ERAS team, while other members for protocol creation include pharmacy, IT, nutrition, and administration.
- Key elements of patient care delivery can be broken down into five phases, each assigned to and delivered by a different team while certain elements present across phases: preoperative, perioperative, intraoperative, postoperative, and post-discharge.
- Implementation of the Enhanced Recovery Program, ERP, requires order sets, team education, and administrative help as well as databases to facilitate data collection and ensure optimal compliance and quality control.
- ERAS principles are widely applicable and have been proven safe and beneficial in emergency and IBD patients, those with diverting ostomies, and elderly patients, realizing that readiness for discharge rather than length of stay is a more accurate outcome measure.
- Moving forward, technology will assist in gathering patient recovery-centric outcome measures in addition to the traditional audit measures to further quality improvement efforts.

Intrinsic to the personality of a surgeon is the drive toward perfect outcomes. Benchmarking, quality improvement comparisons, and inherent competitiveness all allow surgeons the means to evaluate their performance. Enhanced recovery principles, by contrast, focus on intervention elements. Specifically, enhanced recovery focuses on the surgical stress imposed on unique patient populations. This chapter focuses on enhanced recovery efforts, details, challenges, and future directions in the elective colorectal surgery patient.

Enhanced Recovery, Origins, and Overview

Besides a buzz word on hospital webpages for administrators to publicize adoption of popular care maps for surgical services lines, enhanced recovery has a multi-faceted history and widely diverse definitions. To some, enhanced recovery refers to the patient-focused decrease of surgical stress described in the late 1990s and early 2000s in Scandinavia as "ERAS, enhanced recovery after surgery." To others, "ERAS" is simply an order set or protocolized perioperative care. Enhanced recovery; enhanced recovery programs, "ERP"; and enhanced recovery after surgery, "ERAS" will be used interchangeably in this chapter.

Most clearly, enhanced recovery is the application of evidence-based, perioperative medicine to the care of the surgical patient with a goal of best surgical outcomes. In this chapter we review the thoughtful development of this aspect of perioperative medicine, and, specifically, we discuss the aspects of perioperative medicine that have been defined as enhanced recovery for the colorectal surgery patient.

Building on the understanding of nutrition and stress science from the preceding decades, surgeon scientists began specifically addressing the impact of depleted or supported nutritional reserves at the time of surgical stress on surgical outcomes. After decades of individual work relating operative outcomes to perioperative metabolism, stress, and nutrition, Douglas Wilmore of Boston and Henrik Kehlet of Copenhagen reported the importance of considering the

J. Thacker (✉)
Department of Surgery, Duke University School of Medicine, Durham, NC, USA
e-mail: julie.thacker@duke.edu

N. Morin
SMDB Jewish General Hospital, McGill University, Department of Surgery, Division of Colorectal Surgery, Montreal, QC, Canada

S. R. Steele et al. (eds.), *The ASCRS Textbook of Colon and Rectal Surgery*, https://doi.org/10.1007/978-3-030-66049-9_7

patient's physiologic reactions, helpful and hurtful, to surgical stress [1–3].

Their work proposed that, with a better understanding of the physiologic stress impact of operations, surgical teams could mitigate this stress. From a background of perioperative nutrition science, these early enhanced recovery efforts began to define modifiable sources of perioperative stress. Wilmore and Kehlet identified several sources of perioperative stress that were worse with traditional perioperative care, and they hypothesized that different care plans might help patients avoid complications [4]. The complexity of physiologic interactions is shown diagrammatically in Fig. 7.1 with representative enhanced recovery interventions to combat these stresses shown in Fig. 7.2.

From modifying perioperative stress to fast-track surgery to enhanced recovery, perioperative care was being revolutionized in Europe in the early 2000s. Simultaneously, in the USA, a trend toward minimally invasive approaches to abdominopelvic operations was taking off. Observed shifts in patient care paradigms followed patient recovery curves

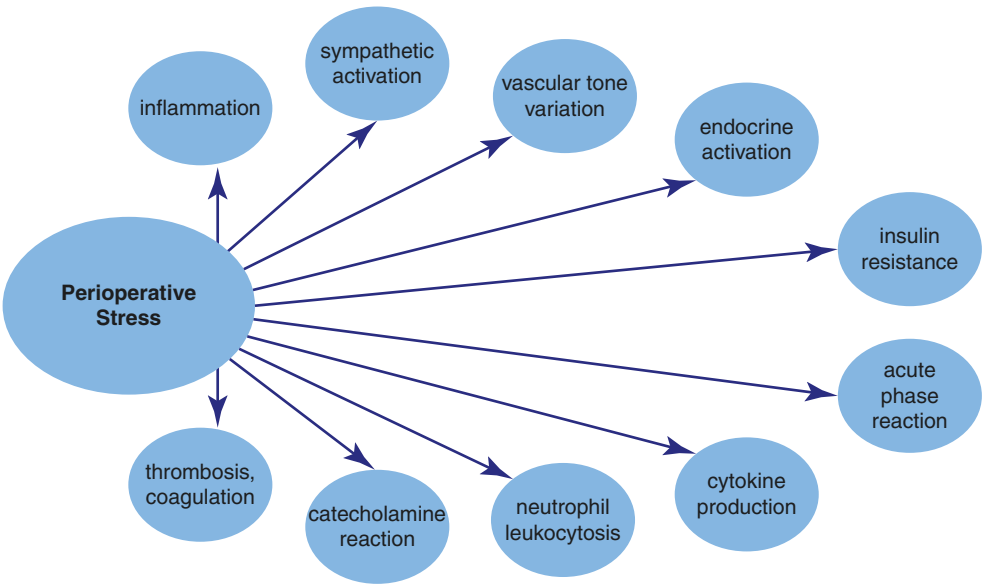

Fig. 7.1 Perioperative stress and reactions

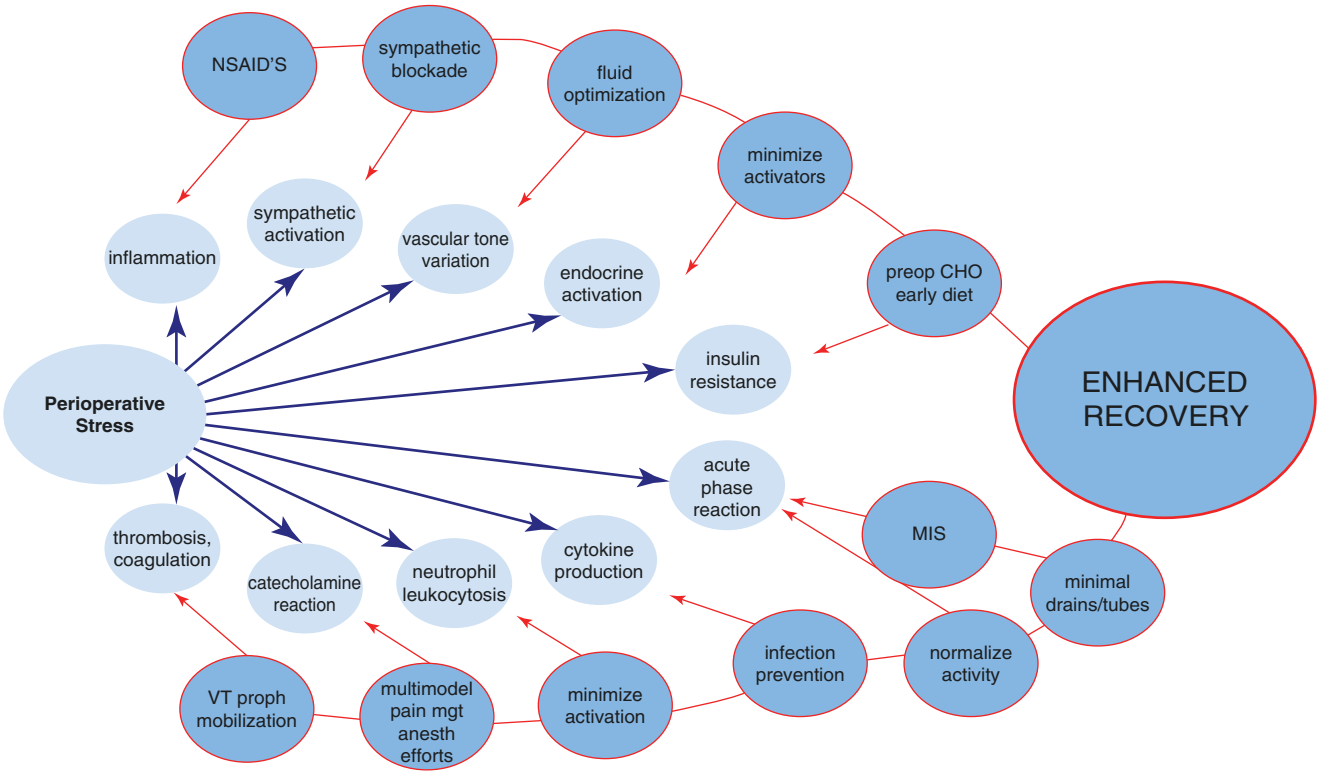

Fig. 7.2 Common ERAS elements to combat perioperative stress

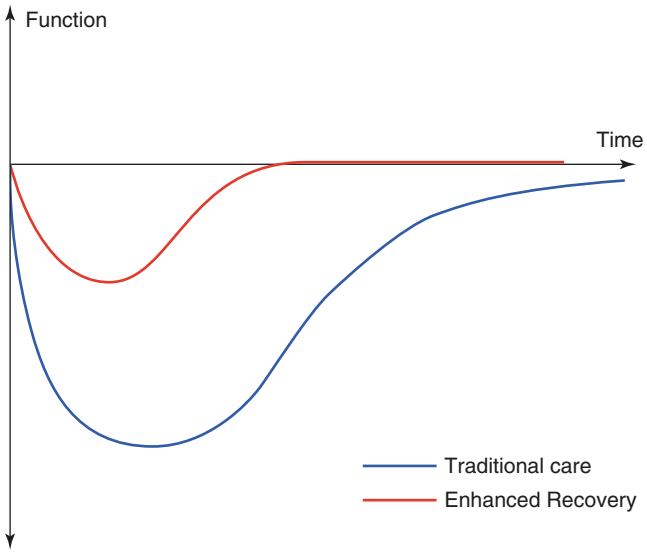

Fig. 7.3 Kehlet and Wilmore's representation of lessened perioperative stress resulting in improved recovery curve

and included earlier postoperative oral intake, earlier mobility, and earlier readiness for discharge from the hospital. Laparoscopic surgeons were responding to patients' decreased surgical stress and facilitating faster recoveries. Through critical review of laparoscopic studies and perioperative care standardization, it became obvious that allowing patients to recover more quickly worked [5]. More directly, Dr. Kehlet's parallel efforts began actively addressing perioperative care elements relative to surgical stress. He reported that an immediate diet and immediate activity, in combination with multimodal analgesia, led to quicker discharge readiness after open operations [6, 7]. He explained that the traditional care paradigms worsened surgical stress and prolonged the amount of recovery below the patient's baseline at time of operation. As demonstrated in Fig. 7.3, and as he simply described, patients did not experience the dip relative to baseline health when they had surgery on his protocol.

Specific to colorectal surgery, the two paradigm shifts collided in the early 2000s. Open operations under this new care paradigm and laparoscopic operations with inherently faster recovery were resulting in decreased narcotic need, earlier diet tolerance, and shortened hospital stays. Surgeons performing predominantly open colorectal operations in Scandinavia adopted Professor Kehlet's perioperative principles, and with the explosion of MIS equipment availability in the USA, more and more surgeons were approaching the colon laparoscopically. In 2004, the American College of Surgeons' Commission on Cancer released the non-inferiority COST trial [8], showing that laparoscopic oncologic resection for colon cancer did not have worse outcomes compared to the open approach. This led to increasing numbers of MIS colon resections in North America, particularly at academic and training centers, where academicians had been reluctant to adopt the technology without reassurance of safety in cancer. In 2005, the first publication of the "ERAS group" shared their attempt to push surgeon-driven adoption of Kehlet's protocols for open colorectal resection patients on their colorectal surgery wards. Admitting that their results were not as amazing as the very confined implementation of Kehlet's single-center and small-sample population, the ERAS group set out to apply implementation science techniques to the idea of changing the perioperative management of colorectal surgery at their centers. Subsequent development and spread of these focused change management strategies has been widely successful [9].

By 2008, worldwide improvement of colorectal surgery outcomes, predominantly in length of stay and decreased wound complications, had been reported by many high-volume laparoscopic centers. Perioperative optimization strategies such as intentional fluid management and opioid stewardship began timely growth from the anesthesia literature. Parallel to the incremental changes happening around the growth of laparoscopic colorectal surgery was the successful effort of the ERAS Society, so named in 2007 [10]. With westerly drift of ideas, US and Canadian centers became aware of the principles of enhanced recovery. This spread was facilitated by the uptake of enhanced recovery in the UK. The 2008 economic recession drove the National Health Service to implement many care changes to improve service and to decrease cost. The implementation of enhanced recovery for surgery patients was mandated across the country, beginning with colorectal surgery. This effort was to save money from decreasing length of stay and complications, and the NICE program was hugely successful at its mission [11]. Enhanced Recovery Partnership Programme in the National Health Service, NHS, of the UK was the first mandated and the first truly multidisciplinary approach to the improving perioperative outcomes reported. Since 2010, the published work of major centers, predominantly shared anesthesia and surgery efforts, has skyrocketed [12–15]. North American efforts have been stimulated by the 2014 creation of American Society for Enhanced Recovery (ASER at www.enhancedrecovery.org) and the American chapter of the ERAS Society, in 2017 (Fig. 7.4).

In short and most holistically, enhanced recovery is the process of considering and implementing the best evidence for each system-patient touch from diagnosis of surgical disease to complete recovery from operative management of that disease. Currently, the best outcomes attributed to enhanced recovery work tend to start with intentional preop-

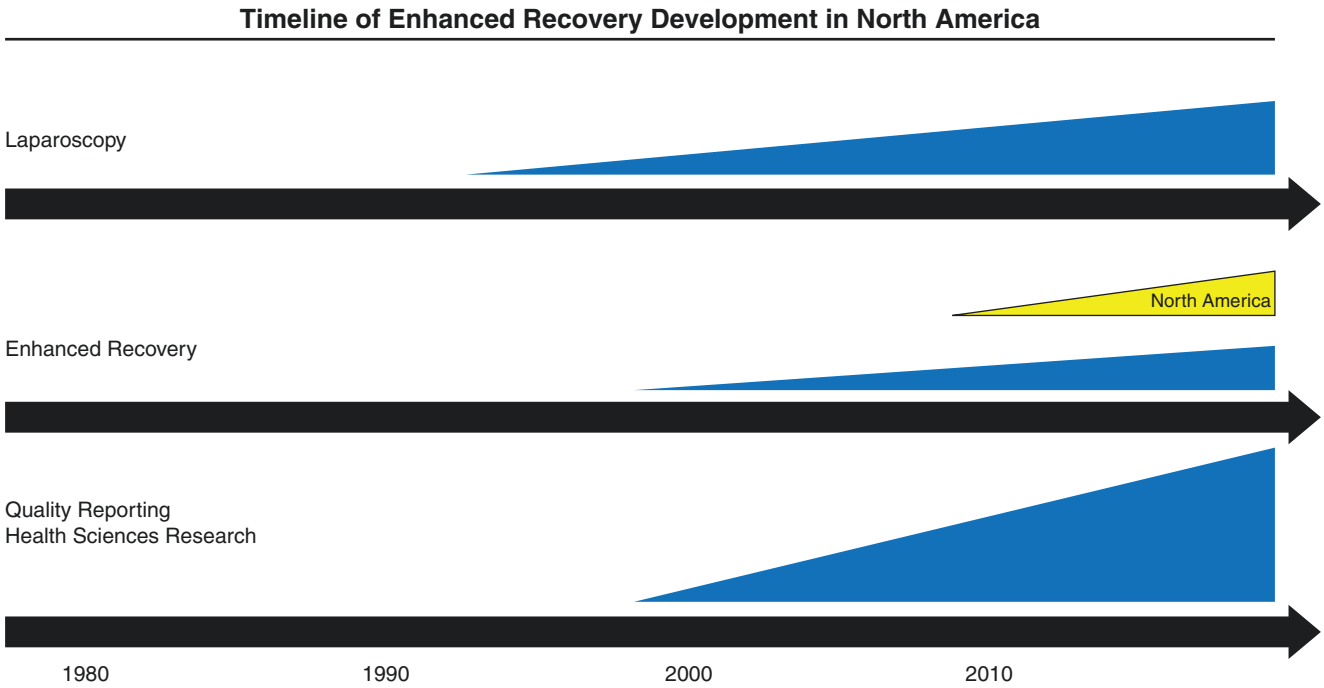

Fig. 7.4 Alignment of improvement strategies in colorectal surgery including laparoscopy, ERAS, and quality improvement research

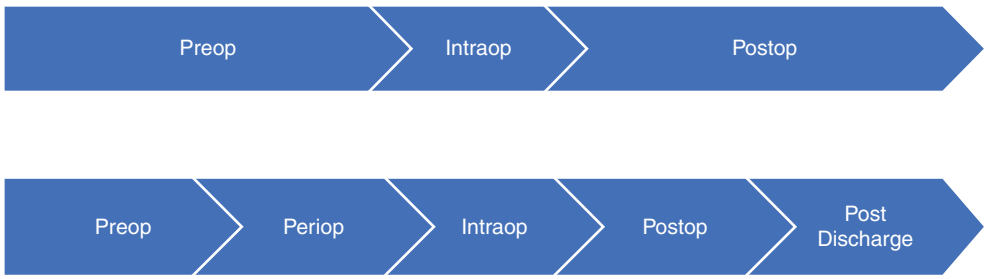

Fig. 7.5 Models of care for change management planning; three phases and five phases

erative education regarding surgical planning, followed by evidence-based management steps via preoperative anesthesia assessment, intraoperative best practices, and intentional postoperative management schemes to minimize perioperative stress and optimize outcomes. Herein, we will discuss the evidence of common care variables of enhanced recovery for colorectal operations, reported implementation schemes, and examples of improved outcomes. In addition to order sets and patient-focused care elements, enhanced recovery efforts frequently lead to continuous improvement platforms. Such platforms, via change management efforts, are tough to create and even harder to maintain. Identification of these barriers and how to break these barriers down is offered. Enhanced recovery has been attractive to administrators and payers because of economic impacts which are discussed toward the end of the chapter. Lastly, next steps and the future of enhanced recovery for colorectal patients are covered.

Enhanced Recovery Models

There are two ways to consider the care elements of most enhanced recovery models. One is to define action in a particular phase of care. Another considers the impact on physiologic stress, allowing for potentially multiple interventions along the surgical continuum.

Dividing the operative experience into phases is somewhat artificial, but it works well when creating an implementation strategy. Care delivery can be divided by time and shown as preoperative → intraoperative → postoperative. Care delivery can also be divided by location, which further defines the team members present in each phase. This five-phase care perioperative scheme is consistent with the Quality Red Book published by the American College of Surgeons (Fig. 7.5) [16].

Preoperatively, the patient is prepared for surgery with information and testing. Intraoperatively, engagement of the

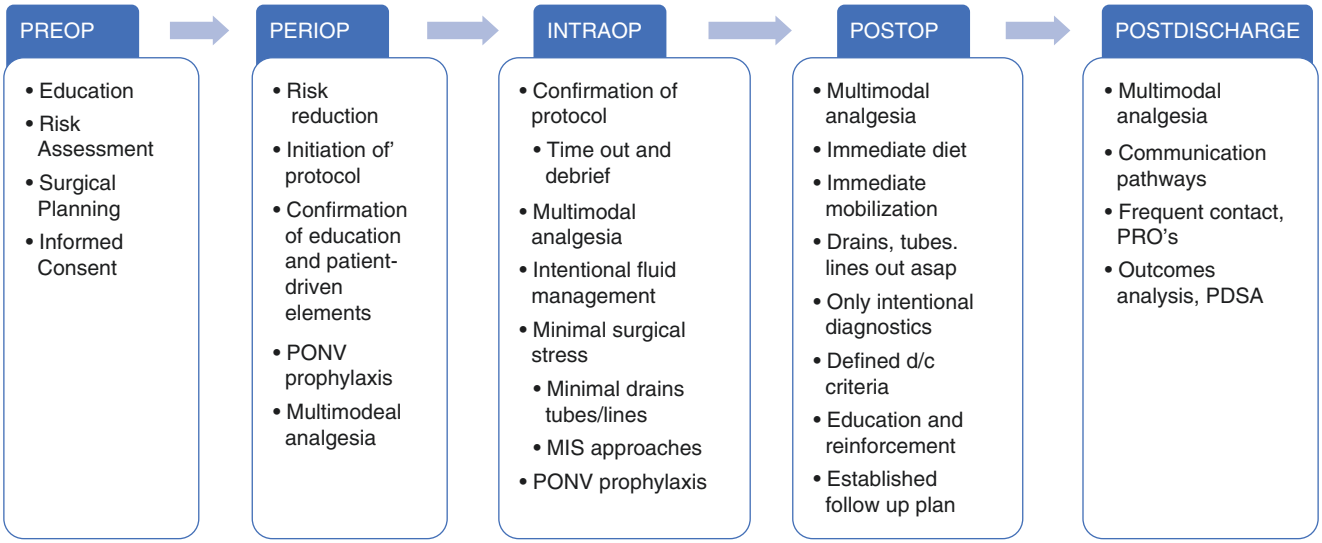

Fig. 7.6 Common enhanced recovery elements; five phases of care model

anesthesia team is key. Important elements in the operating room include intentional fluid management and minimally stressful surgical techniques. Postoperatively, the patient is guided back to baseline health, acutely in the hospital and over the weeks following an operation. Each of these phases is delivered by a different team. The patient and the surgeon are the only two players in each phase. A surgeon's understanding of who does what and when is a key first step to enhanced recovery care. Then key elements in each phase are defined from the evidence. An example of how some elements fall into phases of care is shown (Fig. 7.6).

As is obvious by the repetition of items across the phases, some interventions need to be carried out at multiple time points. Therefore, when creating a protocol, it is important to consider the principles of care and the evidence of interventions.

First Steps to Creating an Enhanced Recovery Program

To start, the ERAS team needs to define what outcomes need to be improved. Seemingly obvious, this initial step is often skipped with teams jumping into building order sets. The second step is to create an evidence library. Once outcomes of interest are defined, and the evidence is collected, the team assigns the elements of impact to phases of care and team members. The lift of implementation often includes an order set, team education, and administrative help. Pearsall et al. detail the team and facilitators nicely in a chapter on implementation in *Surgical Clinics of North America* [17]. Champions from surgery, anesthesia, and nursing are essential. Other team members for protocol creation will be from the pharmacy, IT, administration, and nutrition.

Enhanced Recovery Elements in Colorectal Surgery

This section covers elements common to most protocols for enhanced recovery of the elective colorectal surgery patient. General groupings into phases of care are used to organize the information as one would to create a protocol (Table 7.1).

Preoperative Elements of ERAS in Elective Colorectal Surgery

Education

Patient education is a key element of enhanced recovery. Setting expectations for patients at every phase of care helps to manage stress and encourage participation. Common language and instructions throughout the surgical journey allow the patient to be more relaxed and receptive to the care plan.

Information needs to be at the simplest appropriate literacy level in written, spoken, and, if possible, video versions to reach all learners. Important to every phase of enhanced recovery, the greatest educational effort may be spent at its introduction in the surgery clinic. The anesthesia assessment team, the preoperative holding team, and even the recovery room team – all of these seemingly separate teams – become part of the patient-focused care in enhanced recovery. When this philosophy is adopted, variability decreases.

Preoperative Optimization

The explosion of evidence regarding preoperative optimization outreaches this chapter. There is abundant research ongoing to define readiness for operation. Subjecting patients to exercise-based challenges, evaluating interleukin levels, and reading nutritional parameters on CT scans are just a few of the areas being aggressively studied [18]. This section,

Table 7.1 Common enhanced recovery elements in elective CRS

Phase	Element	Outcomes of interest
Preoperative	Informed consent	Shared decision-making and appropriateness
	Education	Patient participation and decreased stress
	Optimization	Best management of modifiable risk factors
Perioperative	Bowel preparation	Decrease surgical site infection
	Limiting fasting	Encourage euvolemia for safe induction
	Carbohydrate load	Decrease insulin resistance and infection
	Identify/ document	Increase compliance to protocol and audit
	PONV prophylaxis	Optimize early PO tolerance and patient experience
	Multimodal analgesia	Decrease opioid-related complications
Intraoperative	VTE prophylaxis	Decrease thrombotic complications
	Antibiotic prophylaxis	Decrease infectious complications
	Multimodal analgesia	Minimize opioids during general anesthesia
	Goal-directed IVF	Optimize the right fluid relative to needs
	MIS	Decrease surgical stress and optimize recovery
	Minimize drains, tubes, and lines	Decrease foreign body reaction and complication risk without evidence of benefit
	PONV prophylaxis	Optimize early PO tolerance and patient experience
Postoperative	Multimodal activity	Minimize opioids during general anesthesia
	Immediate diet	Encourage return of bowel function, minimize catabolism
	Immediate activity	Minimize complications of inactivity
	VTE prophylaxis and teaching	Decrease thrombotic complications and begin discharge teaching
	Education	Reinforce discharge criteria and goals to minimize unnecessary length of stay and stress
Post-discharge	Multimodal analgesia	Minimize opioid complications and opioids in the community
	Continued activity	Encourage rehabilitation and muscle preservation
	VTE prophylaxis	Decrease thrombotic complications
	Close contact	Decrease stress and recognize problems early to prevent readmissions

PO Per os, *PONV* postoperative nausea and vomiting, *IVF* intravenous fluid, *VTE* venous thromboembolism, *MIS* minimally invasive surgery

though, is a brief review of well-established and feasible recommendations that should be routine in all preoperative preparation programs: smoking cessation, preoperative nutrition, and anemia and diabetes management recommendations. Since acquiring the "Strong for Surgery" program, the best guide for this preparation for surgery elements is the American College of Surgeons webpage, https://www.facs.org/quality-programs/strong-for-surgery, which includes resources for clinicians, preoperative programs, and patients.

Smoking Cessation

The association of smoking with worse operative outcomes is well established [19]. For colorectal surgeons, concerns include increased risk of anastomotic complications, impaired microcirculation, increased postoperative pulmonary complications, and special considerations in inflammatory bowel disease (IBD). Particular recommendations include taking advantage of the life-changing moment of a surgical diagnosis as motivation for patients to quit tobacco use and encouraging even 2–3 weeks of preoperative cessation as beneficial. For many patients, smoking is not their only modifiable risk factor; smoking cessation can be one goal added to increased physical activity, alcohol intake moderation, and improved blood sugar management during even a brief elective case delay. Resources available on Strong for Surgery are thorough. Having a local team with specific addiction focus and training does result in higher success of these efforts [20].

Preoperative Nutrition

The evidence that malnutrition is independently associated with worse colorectal surgery outcomes and increased costs is abundant. The problem is often underestimated, but it is substantial. Work by Wischmeyer et al. [21] produced this infographic defining the impact of inadequate preoperative nutritional status (Fig. 7.7).

However, surgeons' understanding of this has not easily translated to universally applicable recommendations for our patient population. Options to use a diseased gastrointestinal tract to improve nutrition are limited. Making nutritional preparation for CRS more challenging is the difficulty of clinically diagnosing malnutrition. A fast screening plan is proposed by the ASER and PeriOperative Quality Initiative (www.POQI.org) consensus statement by Wischmeyer et al. [21] (https://thepoqi.org/POQI-2-Manuscripts). Detailed discussion of preoperative supplements and the rare indication for parenteral preoperative repletion is available in the online resource linked above. Generally, the recommendations include protein calories, regular mineral and vitamin supplements, and evaluation for nutrient deficiencies and potential directed supplements. Practical implementation is

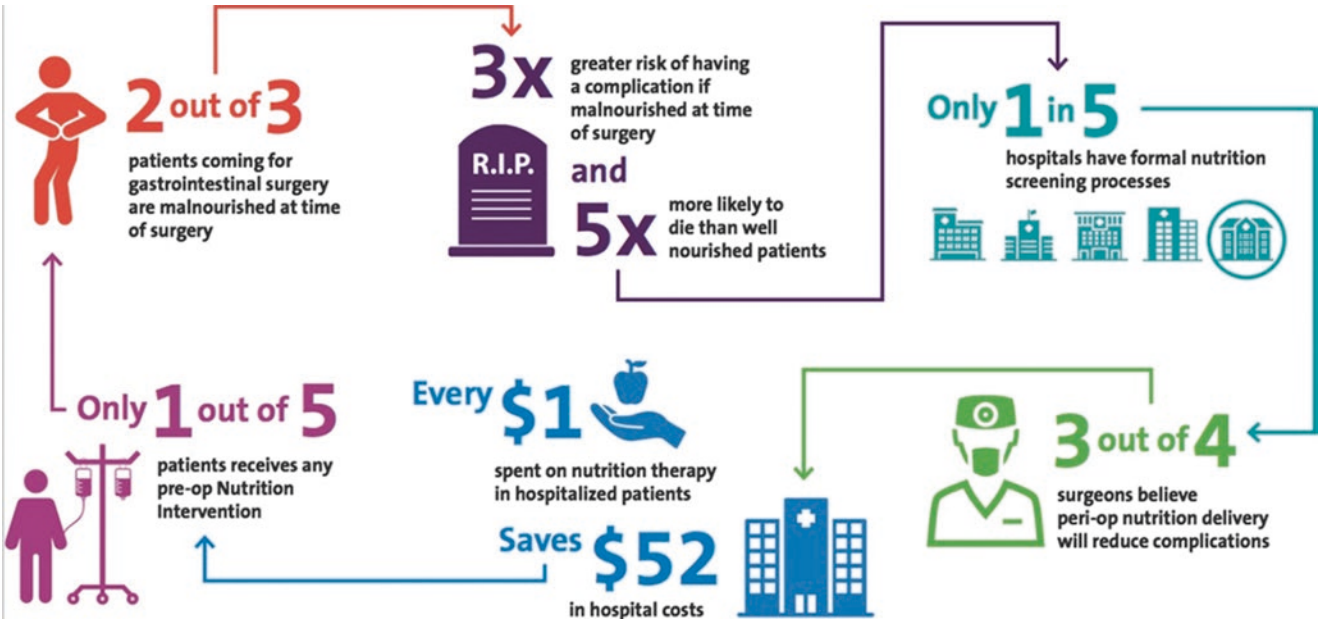

Fig. 7.7 Impact of perioperative malnutrition (Reused with permission from Ref. [21]. Copyright © Wolters Kluwer)

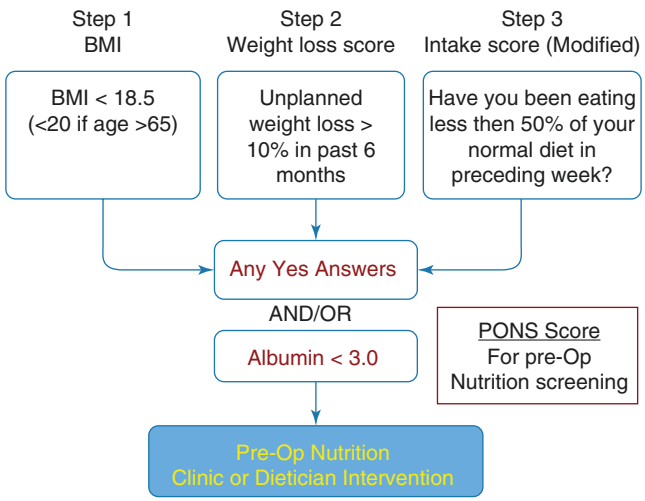

Fig. 7.8 PONS Score for preoperative nutritional assessment (Reused with permission from Ref. [21]. Copyright © Wolters Kluwer)

to wait for uptrending weight and prealbumin to ensure improvement. To minimize complications, prealbumin and other nutritional parameters should be normal before operation (Fig. 7.8).

Preoperative Anemia

Anemia is a significant and modifiable risk factor for worse outcomes from elective operations; however it is not uncommon for surgeons to feel helpless in correcting anemia in the GI surgery patient. Chronic GI losses are often the culprit of preoperative anemia in our patients, and until the operation, the source of bleeding exists. Here, we have created a practical management guide by summarizing recommendations for our patient population (Fig. 7.9) [22–24].

Perioperative Hyperglycemia

Perioperative hyperglycemia is strongly associated with increased infections, reoperations, and death; however, this increased risk is not seen in patients who are well-managed around the time of operation with insulin therapy. This is well described in a review of 11,633 patients in the Surgical Care and Outcomes Assessment Program in Washington State [25]. Good perioperative management of hyperglycemia must start with good preoperative management [26]. Kiren et al. added to our understanding that the degree of hyperglycemia is linearly associated with the severity of complication [27]. Elaborate management of diabetics and non-diabetics with elevated blood sugar in preparation and around the time of surgery has been created. However, most of the recommendations are part of algorithms for preoperative optimization before complete elective operations, such as knee replacements or ventral hernia repairs. Our population of colorectal surgery patients may be able to work on optimization for 2–4 weeks; however longer delays, referral to endocrinology, and documented improvement in HbA_{1C} are not reasonable. As per American Diabetes Association screening guidelines, the following patients meet criteria for HbA^{1C} screening: over 45 years of age; personal history of diabetes (DM1, DM2, or gestational); polycystic ovarian disease; or abnormally high fasting blood glucose. Additionally, a patient with BMI >/= 25 and anyone with inactive lifestyle; HTN; hyperlipidemia; or first-degree relative with diabetes should be tested [28]. The above evidence

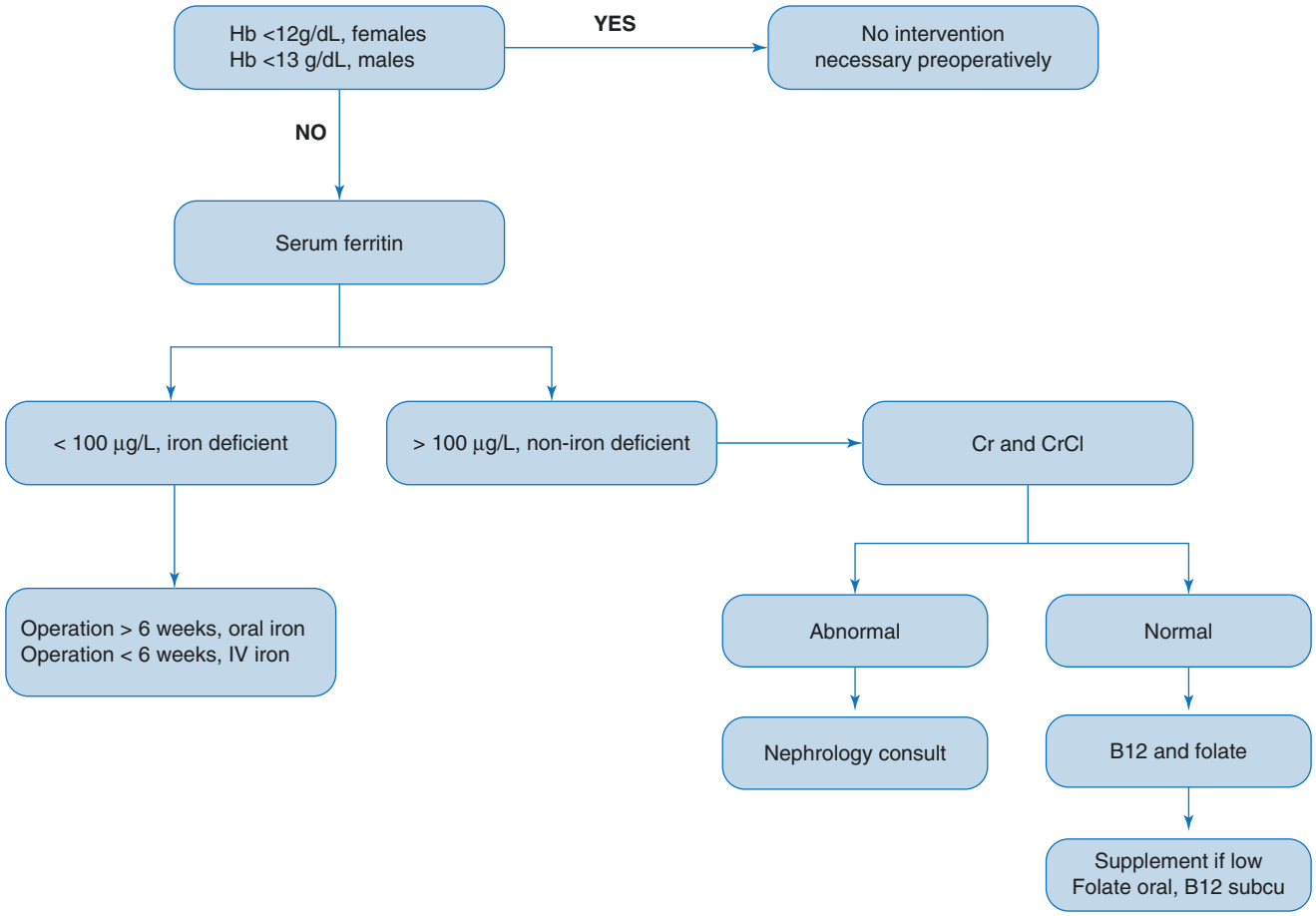

Fig. 7.9 Practical consideration of preoperative anemia in elective CRS

and recommended protocol elements are summarized in functional guide to blood sugar management in elective CRS (Fig. 7.10) [29–31].

Preoperative Fasting Period and Preoperative Carbohydrate Drink

The origins of ERAS Society guidelines date back to work on insulin resistance and the use of preoperative carbohydrate loading by Ljungqvist [32]. In animal trauma models and then in human surgical patients, his lab showed that pre-stress maltodextrin carbohydrate loading decreased postoperative insulin resistance and complications. Currently many products are available commercially and to health systems to fulfill this element. Notably, just carbohydrates, without the studied maltodextrin source, have not been shown to have the same effect. The mechanism of preoperative carbohydrate influence on postoperative insulin resistance has been described as being mediated by AMP-activated protein kinase activation [33]. With this understanding, perhaps more in-depth analysis of the best preop carb drink can be accomplished.

Preoperative carbohydrates and other liberal clear fluids should be encouraged as part of enhanced recovery perioperative preparation. The American Society of Anesthesia guidelines include preoperative clear fluid intake to continue up to 2 hours before induction of general anesthesia [34]. The challenge to institute this recommendation from over 40 years ago is a good reminder of the teamwork that must go into practice changes across phases of care.

Bowel Preparation

Bowel preparation, with antegrade laxative preparation and oral antibiotics, is recommended for operations with a planned lower bowel resection. The literature was recently reviewed, and guidelines were published by the ASCRS Practice Guidelines Committee [35]. Early ERAS Society guidelines did not endorse routine mechanical bowel preparation. However, the evidence of benefit since the earlier ERAS guidelines is robust and clear; most current enhanced recovery programs for CRS include bowel prep.

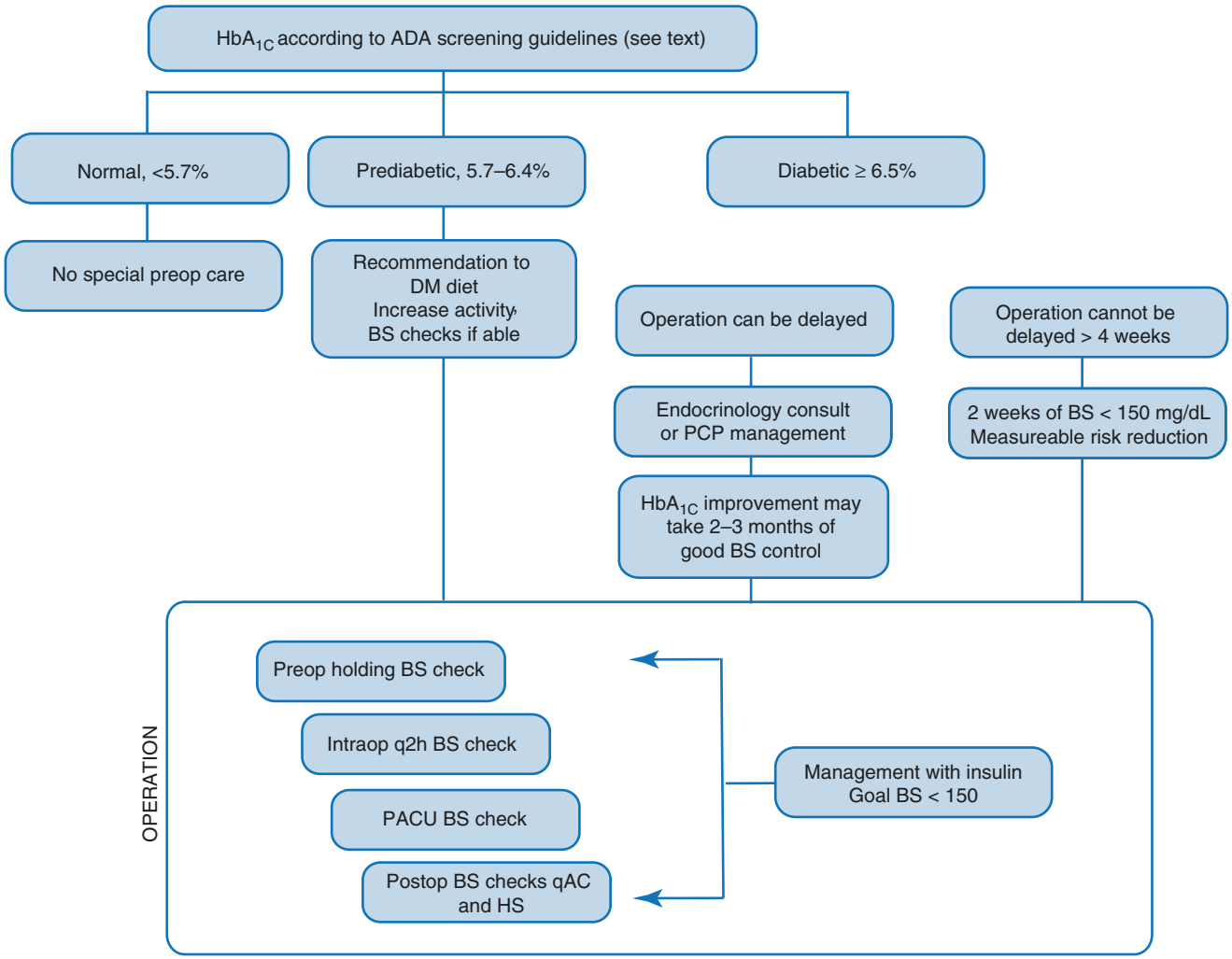

Fig. 7.10 Practical consideration of preoperative hyperglycemia in elective CRS

In-hospital Preoperative Enhanced Recovery Elements

Education and continued, constant messaging are essential for patient participation and stress reduction. At the time of admission, many elements that will continue throughout the hospitalization begin in the preoperative holding area.

Prevention of Postoperative Nausea and Vomiting (PONV)

Combatting the common complication of nausea after general anesthesia must begin in the preoperative space. The role of the surgeon is to identify patients at increased risk and to ensure pre-emptive management by anesthesia. Gan et al. updated the guidelines for the management of PONV; included is an easy cursory scale for PONV risk [36]. Each binary risk factor is 1 point if present: female, non-smoker, history of PONV, or postoperative opioids. These factors are additive, with baseline PONV risk of 10%, any one risk factor correlates to 20%, any two 40%, and any three 60%. If all four risk factors are present, there is an 80% chance of PONV. This prediction model should be applied in preoperative clinic to inform the patient and the anesthesia team before general anesthesia to consider prophylaxis in at-risk patients. Most enhanced recovery protocols include multimodal PONV prophylaxis as per anesthesia recommendations [37].

Multimodal Analgesia (MMA)

Pain receptors and the sensation of pain are mediated by several pathways. Opioids impact a patient's sensation of pain, but opioid-related complications can be minimized or completely avoided by strategies to impact different pain pathways simultaneously [38]. While it might be too stringent to aim for narcotic-free major CRS, the key to MMA is to recognize the cost of each narcotic dose. Even an exposure of as little as ten morphine equivalents has been associated with an increase incidence of postoperative ileus in CRS [39]. A scheme to summarize general MMA approaches is shown (Fig. 7.11).

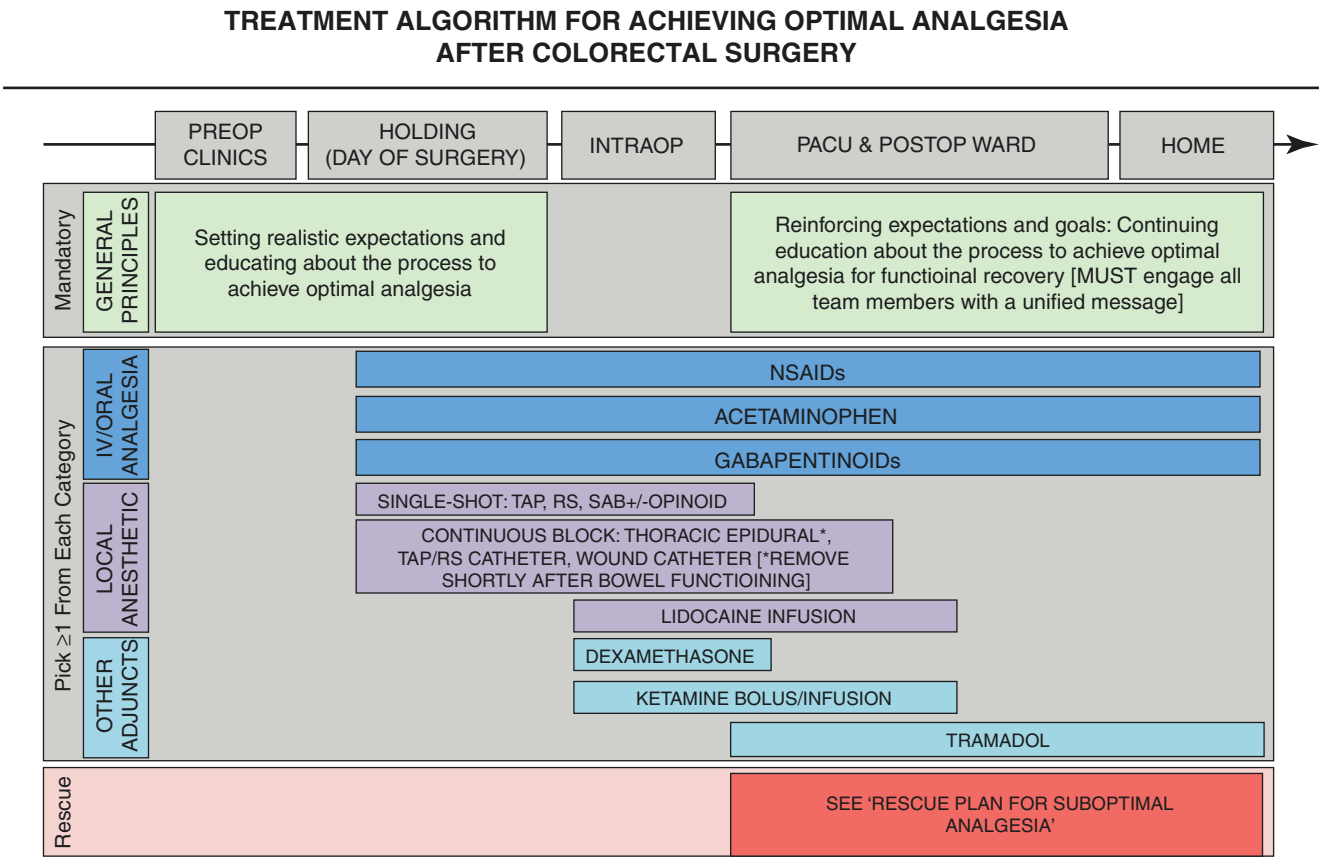

Fig. 7.11 PeriOperative Quality Initiative multimodal analgesia strategy [38]

Multimodal analgesia in enhanced recovery always raises discussion of epidural as a mandatory element. What is often missed in interpretation of earlier ERAS guidelines is the incidence of open operation. Current recommendations for open CRS still include epidural analgesia if the use is supported locally [40, 41]. If inadequate experience and oversight exists, epidurals can increase time to mobility, urinary catheter removal, and discharge. The authors offer experience of expeditiously placed, safely managed epidurals with extremely high success rates and decreased costs [12]. Many other non-catheter blocks are available and in combination with other components of MMA are more appropriate than epidural catheters for MIS cases. They may also be proven to be more appropriate for open cases.

Multimodal analgesia is aggressively studied and re-evaluated with each new pain medicine released. The plan shown above summarized an MMA model with recommendations current to its publication. Some evidence suggests that gabapentin may be related with drowsiness and respiratory depression, and the use oral acetaminophen before placement of gastric decompression may not be as effective as intravenous acetaminophen at fascial closure. Improvement in MMA can be made about every 6–9 months to keep pace with the literature. The pain management scheme for ERAS protocols should be addressed with every interval protocol review. The perception of providers must be that MMA is effective since the implementation of an enhanced recovery protocol was associated with increased use of perioperative MMA in non-ERP patients [42].

VTE Prophylaxis and Antibiotics

Evidence for best VTE strategies and antibiotic coverage for CRS is well established in the literature and elsewhere in this text (Chap. 6). The line item is included here to remind surgeons that not everyone along the continuum of the patient's surgical journey will know these details. The appropriate preoperative antibiotic and the VTE prophylaxis timing, inpatient plan, and plan at discharge with required teaching must be visible to the entire team.

Intraoperative Enhanced Recovery Elements

Surgical outcomes are impacted by every aspect of care while the patient is in the operating room – every dose of narcotic, every liter of fluid, every tube or drain, every incision. While it is impossible to study any one intraop care element independent of the rest of the operation, general principles have been investigated. Including the anesthesiology team throughout the creation of an enhanced recovery pathway is essential for success.

Multimodal Analgesia

MMA must continue during general anesthesia. The details of medication combinations, available blocks and neuraxial approaches, as well as intraop and postop infusional choices are all subject to local formularies and anesthesiologists' talents and preferences. The anesthesia team's knowledge of ERAS and their expertise relative to narcotic-sparing management has to be garnered during the creation of any enhanced recovery pathway. Infusional lidocaine has been shown to be effective in center reports, but Cochrane review failed to find convincing evidence for recommendation [43].

Intentional Fluid Management

The evidence supporting the safest fluid management for intraoperative enhanced recovery is still evolving. There was little discussion of fluid management in the first colorectal ERAS guidelines, as this was developing in the anesthesiology literature simultaneously. Studies and opinions about this are now abundant; most are anesthesiologist designed and directed.

Specifically, trial design often includes a statement such as "an enhanced recovery pathway was in place," and a diversity of patient populations are included to ensure power. In the larger trials, from which the anesthesiology community is defining their understanding of best fluid management, surgical outcomes, such as length of stay in the hospital, readmissions, surgical complications, and ileus, are recorded. However, the postoperative fluid management is not reviewed. As has been proven, excessive or inadequate fluid management postoperative also impacts these same outcomes. The data can be difficult to interpret.

Contradiction between "restrictive and liberal" protocols can be clarified by analysis of the details. Myles et al. claimed higher incidences of acute kidney injury (AKI), in enhanced recovery protocol patients who randomized to the restrictive fluid arm of a multinational study of over 3000 [44]. Given there was no analysis of the enhanced recovery elements or preoperative fluid allowance, this study also lacked direction for perioperative fluid management. The thoughtful comments of a surgeon in Denmark who has studied perioperative fluid management since the 1990s are helpful describing the benefits of intentional fluid management and limitations of the Myles study [45]. Evidence for best fluid management is still accruing; therefore watching for studies with a defined perioperative protocol and deeper evaluation than just high-level, reported surgical outcomes is prudent. Though the Myles study showed association with AKI, a careful observational study out of Mayo failed to show increased AKI in ERAS. Their chief finding, however, was potential increase of ileus in patients receiving greater volumes of fluid on their protocol [46].

As we await further science behind patient responses to fluid and associated surgical outcomes with well-defined care protocols [47], safest and cheapest management of fluid around the time of colorectal operations has three tenets [48, 50]:

1. Liberal fluid encouraged during bowel prep and until 2 hours before induction of general anesthesia.
2. Zero-balance intraoperative fluid management based on weight.
3. Normotension and urine output should be maintained with reactive intravenous fluid until oral intake is adequate.

Minimally Invasive Surgical Approaches

Discussed previously and covered thoroughly elsewhere in this text, minimally invasive approaches decrease surgical stress and improve outcomes. These benefits are additive when combined with enhanced recovery care plans [51].

Minimal Use for Drains, Tubes, and Lines

Early in literature for enhanced recovery, the promotion of minimizing the use of intra-abdominal drains, nasogastric tubes (NGT), and central venous access lines (CVL) was promoted. These recommendations persist with evidence of no benefit to abdominal drains; harm with NGT except in obstruction; and increased infection and complication with CVL [51, 52].

Postoperative Enhanced Recovery

Aarts et al. reported a review by the iERAS group in Canada that postoperative ERAS interventions have the greatest impact on optimal recovery [53]. Confounded by the fact that postoperative elements are more successful if earlier occurring elements show high compliance, the postoperative phase is, indeed, the longest of the in-patient phases and the most impactful on outcomes.

Early Diet, Early Mobilization, and Early Oral Medications

The success of postoperative elements of enhanced recovery often demonstrates the success of earlier elements. Education leads the patient toward a low stress discharge plan. A minimally stressful operation results in faster return to regular diet and oral management of fluid needs. Well-managed, opioid-sparing analgesia is less likely to result in ileus. The elements of immediate diet and mobilization are well supported as safe and beneficial. Low residue diet is better than clear liquid diet at promoting earlier return of bowel function and earlier discharge with fewer complications [54]. However, Clough et al. showed persistent reluctance to adopt early feeding in a comparative cohort study. Lack of adoption of these well-founded elements further represents the need for evidence-based care protocol implementation, such as enhanced recovery [55].

Multimodal Analgesia

Details of MMA are discussed above. Important aspects of MMA in the postop period include rescue therapy and education. Not all patients will be well-managed with the prescribed MMA. Anxiety and pre-existing pain conditions make postop analgesia challenging. ASER-POQI 2 addressed this with the rescue plan shown in Fig. 7.12 [38].

Postoperative reiteration of the goals of MMA, medication names, and an opioid-sparing plan is essential. This message needs to be consistent from the first dose of medication in the postoperative experience, through discharge instructions, and with the clinic contacts after discharge.

Standard Discharge Criteria

An international consensus to determine readiness for discharge criteria created a simple five-item list [56]. GI function and general recovery are well assessed by solid diet tolerance, adequate liquid intake, oral pain management, and activity. Objective readiness is confirmed with ward data, such as blood pressure, heart rate, urine output, temperature, and spontaneous voiding. A rigorous and well-known enhanced recovery program demonstrated that the delays typical of discharge after a patient meets discharge criteria are minimized with standard practice. In the review at McGill, readiness for discharge and actual discharge most often were at the expected 3 days after colorectal resection [57].

Considerations in Special ERAS Populations

Enhanced Recovery in Stoma Creation and Reversal

Diverting ileostomy is a frequent source of delayed discharge and readmission. High ileostomy output and dehydration readmission rates are reported in up to 15% of these patients. Index admission length of stay among diverted patients has been shown to be prolonged significantly, mitigating the effects of laparoscopy on LOS [58], even in the context of an ERP [59]. With the expected expedited recovery on an ERAS protocol, new ileostomy patients leave the hospital sooner, leaving little time for a patient with a newly formed stoma to learn the practical skills of caring for the stoma. In fact, many studies looking at the impact of ERAS exclude patients undergoing stoma creations. This section discusses the application of ERAS to even these patients and the special considerations necessary.

A controlled randomized study [60] out of Norway investigated whether an ERAS program with a dedicated ERAS and stoma nurse specialist could reduce the length of hospital stay, readmission, and stoma-related complications, compared to standard of care pathways in patients undergoing planned stoma. Preoperative and postoperative stoma education in the context of an ERAS program was associated with a significantly shorter hospital stay with no difference in

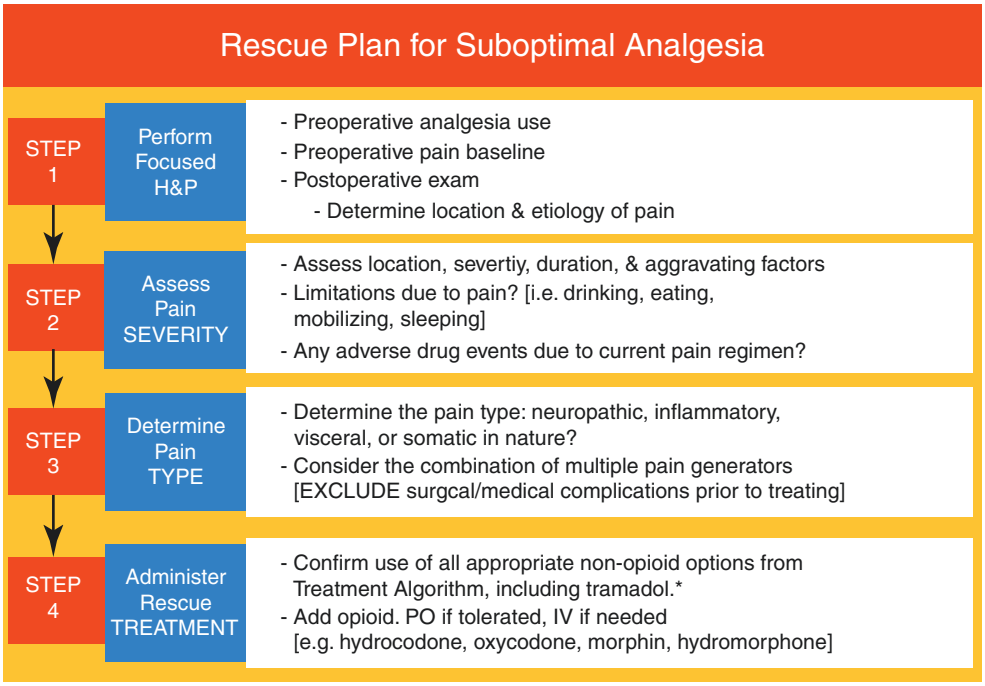

Fig. 7.12 Rescue plan in MMA breakthrough. *MMA* Multimodal analgesia [38]

readmission rate or early stoma-related complications. In a UK-based pre-/post-ERAS study of anterior resection patients with ileostomy, Younis et al. [61] showed significant reductions in average LOS (nearly half) with preoperative stoma management teaching as part of an ERP. The readmission rates in both groups were low (2.5% pre-ERP vs. 0% post-ERP), and none was due to stoma management issues. Patients were closely monitored in the community by stoma care specialist nurses and any stoma complications managed promptly in conjunction with GPs. This is in line with other studies that confirm that length of hospital stay need not to be prolonged among patients with a stoma if adequate patient education is provided [62], particularly in the context of ERAS [63, 64]. The Ontario Provincial ERAS Enterostomal Therapy Nurse Network recently published best practice guidelines for care of patients with fecal diversion [65], addressing coordinated preoperative, postoperative, as well as discharge phases of care in the community, in order to improve outcomes, decrease complications, and reduce hospital costs.

ERAS in Emergency Surgery and Trauma

ERAS is well established in elective colorectal surgery; however the feasibility and benefit of ERAS in emergency colorectal surgery has only been reviewed more recently. In 2019, Lohsiriwat et al. [66] reviewed six retrospective observational studies [67–72] on patients undergoing emergency operations managed by enhanced recovery principles. The authors concluded the following: (1) Compared to ERAS-CRS for elective cases, ERAS after emergency colorectal surgeries is associated with a longer length of stay and a higher rate of unplanned reoperation without a difference in rates of anastomotic leak or readmission. Overall compliance with ERAS protocol was lower, with comparable compliance to elective cases in the operating room. (2) Compared to emergency surgeries performed without ERAS programs, ERAS is safely applicable in emergency colorectal surgery and confers similar beneficial effects seen in the elective setting.

A recent meta-analysis of 6 ERAS protocols in 1334 total emergency abdominal surgery patients [73] confirms these findings. The authors conclude that ERAS protocols favorably resulted in reduced postoperative complications, accelerated recovery of bowel function, and shorter length of stay without increased readmission in emergency abdominal surgery patients. As in all patient populations, ERAS in emergency colorectal surgery should be guided by the concept of reducing stress responses to surgery [74].

Enhanced Recovery in the Elderly

ERAS pathways in the elderly are safe and effective. Bagnall et al. [75] performed a systematic review that included 16 studies involving 5965 patients who underwent colorectal surgery. Two randomized controlled trials demonstrated shorter hospital stay and fewer complications in elderly patients >65 and >70 years of age who were on an ERAS pathway compared with an age-matched group receiving standard perioperative care. There are no significant differences in morbidity and mortality between the elderly and younger patients on ERAS pathways, although older patients tended to have a longer length of stay compared to the younger patients. Only two studies in the systematic review above reported any data on adherence to the ERAS pathway: Rumstadt et al. [76] found lower compliance among patients >79 years of age (not the group of patients age 70–79 years). Feroci et al. [77] showed that patients age >75 years had poor adherence to many postoperative items. In this study, poor compliance in this age group was the greatest predictor of poor outcomes. However, two later studies [78, 79] did not show any effect of age on adherence to ERAS pathway, and they did not demonstrate a difference in morbidity or mortality. Interestingly, Baek et al. found that there was no difference among older versus younger patients in return of bowel function, diet advancement, urinary catheter removal, complications, or length of hospital stay, but there were increased rates of emergency room visits and readmission in older patients [80]. The most recent study by Owodunni et al. [81] evaluating compliance to ERAS pathway in patients age ≥ 65 years did not show any significant difference in overall compliance rates compared to younger patients. While ERAS intervention in the older patients resulted in significant decrease in length of hospital stay, a further reduction in length of stay occurred in ERAS patients undergoing laparoscopy. In all studies, the greatest benefit was seen in older patients achieving high compliance with the ERAS variables.

A recent Italian study confirmed the feasibility, safety, and benefit of a tailored ERAS program in octogenarian patients undergoing minimally invasive surgery for colorectal cancer [82]. The majority of patients met release criteria in a median of 5 days, which was significantly shorter than the actual days of dismissal (6+/−4.2). The authors commented that a consideration should be made for the very elderly for whom length of hospital stay could be a misleading outcome; readiness to discharge might be a more accurate measure. They speculate that several factors may explain the discordance between these variables including social and geographical isolation, unavailability of nursing assistance, and limitation of communication with caregivers.

Management on an ERAS pathway appears to be safe and beneficial in the elderly, though with slightly lower rates of adherence to certain aspects of the protocol and increased length of hospital stay and readmission compared to the younger patients. These differences in adherence and outcome in the elderly are likely due to their comorbidities and baseline functional status [74]. Caution must be taken to not overinterpret "lower compliance," when compliance is considered across a population. Enhanced recovery, at its best, is patient-focused. The geriatric patient on anticoagulation, who does not qualify for an epidural, is not non-compliant for that element. The patient is not eligible, and should not be considered non-compliant. However, that ineligibility may, indeed, portend a slower recovery.

Enhanced Recovery and Inflammatory Bowel Disease

Patients with inflammatory bowel disease (IBD) frequently present with malnutrition, immunosuppression, anemia, as well as intra-abdominal abscesses, fistulas, and bowel obstruction placing them at higher risk for significant postoperative morbidity. As such, patients undergoing surgery for IBD, as a group, have prolonged hospitalizations and increased readmissions and hospital costs. In addition, many IBD operations are less suitable for laparoscopy. This drives the question whether enhanced recovery would be able to achieve similar benefits in IBD patients as in patients with colorectal cancer or other benign conditions.

Ban et al. [83] investigating the American College of Surgeons National Surgical Quality Improvement Program (NSQIP) database for patients with enhanced recovery variable data undergoing elective colectomy have shown that a preoperative diagnosis of IBD is associated with prolonged length of stay and higher odds of readmissions and morbidity/mortality when compared with patients who had undergone colectomies for non-IBD diagnoses. In a single-institution ERAS retrospective analysis, Dai et al. [84] demonstrated that IBD patients had higher incidence of postoperative ileus compared to colorectal cancer patients (28.8% vs. 14.8% ($P < 0.001$), respectively). The results from these two studies do in fact question whether there is any benefit in ERAS protocols for IBD patients in the first place.

Enhanced recovery pathways do improve outcomes after bowel resection for IBD. D'Andrea et al. [85] analyzed pre-/post-ERP implementation IBD patients undergoing elective bowel resection. The ERAS group had significantly reduced rates of SSI, ileus, and anastomotic leak with a decreasing trend in the LOS, readmission, reoperation, sepsis, and wound disruption. Another pre-/post-ERAS study showed ERAS-managed IBD patients had reduced LOS and hospital costs without an associated increase in complications or readmissions. In addition, MIS was independently associated with reduced LOS, while ERP within the MIS group was associated with an even shorter LOS. Crohn's disease (CD) diagnosis was associated with a longer LOS. However, the post-ERP group still had a shorter LOS despite having a higher rate of CD. Patients with IBD undergoing major abdominal and pelvic surgery, despite being a complex patient population, benefit from the implementation of an ERP, at least with respect to LOS and in-hospital costs.

Clearly ERAS principles are widely applicable and beneficial to these unique patient populations. Increased physician and nursing training to promote widespread implementation and adherence to ERAS principles (as many as feasibly possible) can further improve the quality and cost of healthcare administered. Modified programs are appropriate for different patient populations, with the common goal of decreasing surgical stress and its effects and costs.

Economic Impact and Value of Enhanced Recovery to the Healthcare System

In the most recent systematic review and meta-analysis on cost analysis of ERPs in colorectal surgery, ERP induced mean saving costs of $3101 USD per patient [86]. It is generally accepted that ERPs reduce healthcare costs by virtue of shorter duration of hospital stay and decreased rate of complications without increasing readmission rates, as demonstrated in several systematic reviews [87–89]. These pathways achieve such cost savings by using defined evidence-based processes that are monitored to allow optimal resource management and minimal variability. Roulin et al. [90] found specific gains in medication, laboratory, and radiology costs. Standardization not only ensures that patients receive routine care items that might otherwise be forgotten, it also prevents unnecessary diagnostics without increasing the complication rate.

However, there are many limitations when examining the mechanisms of impact of ERPs on cost using these traditional audit measures [70, 91, 92]. The true costs and systemic values need to be considered. Future economic models of ERP costs need to incorporate societal costs and patient, as well as recovery-centric outcomes, in addition to the traditional audit measures. In fact, ERAS can and should fulfill what is now referred to as the "Quadruple Aim": achieving not only better patient outcomes, at a lower cost, and improved patient satisfaction but also medical, nursing, and provider satisfaction [93–96]. A recent review of the literature by Li et al. [97] confirms that the application of ERAS pathways following colorectal surgery does not lead to worse outcomes in patient satisfaction, quality of life, fatigue, and return to activities: however, no publications have assessed surgeon or care provider satisfaction with ERAS pathways.

Current Directions and the Future of ERAS

Societies and Governments Assist Implementation Across Canada and the USA

ERAS is quickly becoming the standard of care in colorectal surgery. In North America, adoption of enhanced recovery has been mostly driven by individual providers or healthcare systems, without government collaboration or incentive. At our training centers, adoption has been occurring insidiously via substantive, unfunded academic effort and inculcating trainees by incorporation of ERAS principles in training and on certification exams [98]. Nonetheless, barriers to implementation remain a challenge. Results from a Canadian qualitative study suggest that although clinicians see the value in implementing an ERAS program, lack of nursing staff, lack of financial resources, resistance to change, and poor communication and collaboration are perceived as barriers to its adoption [99]. There is no unified enhanced recovery assessment program or compensation program in the USA, but the American Society for Enhanced Recovery (ASER) promotes best practice via multidisciplinary collaboration between surgical, anesthesia, certified registered nurse anesthetists, and nursing societies. In addition, quality initiatives and protocols that arise from ASER are undertaken with an understanding of US healthcare strategies – cost structures, interactions of siloed stakeholders, and shared outcomes without shared inflow of resources [98]. In an exceptional effort to expand the implementation of ERAS pathways across the USA, a multimillion-dollar grant was awarded by the US Agency for Healthcare Research and Quality (2017–2020). The "Safety Program for Improving Surgical Care and Recovery" team plans to introduce enhanced recovery in approximately 750 US hospitals [98, 99]. Similarly, in Canada, the Canadian Patient Safety Institute's Integrated Patient Safety Action Plan for Surgical Care Safety, with support from numerous partner organizations from across the country, formed Enhanced Recovery Canada (ERC) in 2017.

Future Directions

Innovation of technology provides opportunities to overcome challenges with ERAS [100–102]. Databases facilitate core data collection, ensure optimal adherence to protocols, and reduce variability in clinical care. More robust data collection is particularly useful for ERAS clinical studies [103]. In the future, such dataset will also allow us to investigate the impact of the perioperative period on long-term patient outcomes such as cancer survival or disease recurrence in IBD [100]. Wearable sensors measure, store, and transmit large amounts of patient and environmental data and have been used to objectively and continuously monitor physical activity (an important indicator of functional recovery) within the hospital setting and at home following discharge [104–106]. To provide a complete recovery picture beyond activity tracking, smart devices will also be ready to collect patient-reported outcome data concerning other relevant aspects of postoperative recovery [107, 108]. In recent years, the role of telemedicine (TM) in postoperative care, implemented by way of smart devices with text messaging or mobile health applications, including pictures and videos, has grown. TM has demonstrated excellent clinical outcomes, a high degree of patient satisfaction, decreased driving distance and wait times, and cost savings to both the patient and healthcare systems, particularly for surveillance after ambulatory surgery [109, 110]. A prospective multicenter study in France confirmed the feasibility of home surveillance by TM after major surgery, in colorectal patients within an ERP. TM with automatic alerts led to early, timely detection of postoperative complication and less time spent answering phone calls by the surgical team and avoided ER visits. A more recent cohort study [111] looked at an active post-discharge surveillance (APDS) program as part of an ERAS protocol in colorectal patients in the USA. The program's interface is also centered on a text messaging paradigm with automatic alerts and is accessible via any smart device or desktop. It employs automated protocols (defined by the surgery team) to automatically communicate with patients not only after discharge but also before and after surgery to ensure compliance with protocol perioperatively. Patients, physicians, office staff, nurses, care coordinators, and extended care nurses are all able to communicate and coordinate care via the APDS. The study also concluded that APDS allows many postoperative issues to be resolved in an outpatient setting without ER visits or readmissions. The biggest limitation in this study was attrition bias as patients enrolled in the APDS and engaging with the program initially would stop responding. It is unclear if this was due to technical difficulties or that patients were simply overwhelmed by the frequent reminders and checks. Future studies should look further into the difficulties of TM technology. Integrating patient-centered recovery data in electronic health records [112] will provide an opportunity for recovery auditing and further database-driven research aimed at quality improvement [107].

Summary

The principles of enhanced recovery require thoughtful analysis of the perioperative literature and application of the evidence to everyday care. This process has fit the practice of colorectal surgery as we are always striving for better outcomes in our patients with known risks having operations

with known complication profiles. Our specialty encompasses a significant portion of elective operations, providing us with research opportunities and volume to merit quality improvement efforts. The change management of enhanced recovery requires the development of a team that is then in place for whatever the next, best thing is. This deliverable, from working through the implementation phase of enhanced recovery, sets up colorectal practices and their hospitals for continuous, efficient improvement. The enhanced recovery process brings as much to the surgeon and system, as it does to our patient population. The authors' hope is that we as individuals and as change management agents keep an open mind to all possible future care improvement strategies and that we encourage an open platform for continuous improvement.

References

1. Kehlet H, Nikki P, Jäättelä A, Takki S. Plasma catecholamine concentrations during surgery in unsupplemented glucocorticoid-treated patients. Br J Anaesth. 1974;46(1):73–7.
2. Wilmore DW. Alterations in protein, carbohydrate, and fat metabolism in injured and septic patients. J Am Coll Nutr. 1983;2(1):3–13.
3. Kehlet H, Wilmore DW. Multimodal strategies to improve surgical outcome. Am J Surg. 2002;183(6):630–41.
4. Kehlet H, Wilmore DW. Evidence-based surgical care and the evolution of fast-track surgery. Ann Surg. 2008;248(2):189–98.
5. Wexner SD. Standardized perioperative care protocols and reduced lengths of stay after colon surgery. J Am Coll Surg. 1998ay;186(5):589–93.
6. Kehlet H, Mogensen T. Hospital stay of 2 days after open sigmoidectomy with a multimodal rehabilitation programme. Br J Surg. 1999;86(2):227–30.
7. Basse L, Jakobsen D, Billesbølle P, Werner M, Kehlet H. A clinical pathway to accelerate recovery after colonic resection. Ann Surg. 2000;232(1):51–7.
8. Clinical Outcomes of Surgical Therapy Study Group, Nelson H, Sargent DJ, Wieand HS, Fleshman J, Anvari M, Stryker SJ, Beart RW Jr, Hellinger M, Flanagan R Jr, Peters W, Ota D. A comparison of laparoscopically assisted and open colectomy for colon cancer. N Engl J Med. 2004;350(20):2050–9.
9. Nygren J, Hausel J, Kehlet H, Revhaug A, Lassen K, Dejong C, Andersen J, von Meyenfeldt M, Ljungqvist O, Fearon KC. A comparison in five European Centres of case mix, clinical management and outcomes following either conventional or fast-track perioperative care in colorectal surgery. Clin Nutr. 2005;24(3):455–61.
10. Ljungqvist O, Young-Fadok T, Demartines N. The history of enhanced recovery after surgery and the ERAS society. J Laparoendosc Adv Surg Tech. 2017;27(9):860–2.
11. NHS Institute, Elective Care & Diagnostics Branch. Enhanced Recovery Partnership Programme Project Report. http://www.dh.gov.uk/publications. Mar 2011.
12. Miller TE, Thacker JK, White WD, Mantyh C, Migaly J, Jin J, Roche AM, Eisenstein EL, Edwards R, Anstrom KJ, Moon RE, Gan TJ, Enhanced Recovery Study Group. Reduced length of hospital stay in colorectal surgery after implementation of an enhanced recovery protocol. Anesth Analg. 2014;118(5):1052–61.
13. Neville A, Lee L, Antonescu I, Mayo NE, Vassiliou MC, Fried GM, Feldman LS. Systematic review of outcomes used to evaluate enhanced recovery after surgery. Br J Surg. 2014;101(3):159–70.
14. Napolitano MA, Skancke M, Walters J, Michel L, Randall JA, Brody FJ, Duncan JE. Outcomes and trends in colorectal surgery in U.S. Veterans: a 10-year experience at a Tertiary Veterans Affairs Medical Center. J Laparoendosc Adv Surg Tech A. 2020;30(4):378–82.
15. Eskicioglu C, Forbes SS, Aarts MA, Okrainec A, McLeod RS. Enhanced recovery after surgery (ERAS) programs for patients having colorectal surgery: a meta-analysis of randomized trials. J Gastrointest Surg. 2009;13(12):2321–9.
16. Hoyt D, Ko C, editors. Optimal resources for surgical quality and safety. 1st ed: American College of Surgeons; 2017. ISBN-13: 978-0996826242.
17. Pearsall EA, McLeod RS. Enhanced recovery after surgery: implementation strategies, barriers and facilitators. Surg Clin North Am. 2018;98(6):1201–10.
18. Levy N, Grocott MPW, Lobo DN. Restoration of function: the holy grail of peri-operative care. Anaesthesia. 2020;75(Suppl. 1):e14–7.
19. Sharma A, Deeb A, Ianuzzi J, Rickles A, Monson J, Nad FF. Tobacco smoking and postoperative outcomes after colorectal surgery. Ann Surg. 2013;258(2):296–300.
20. Taylor H, Karahalios A, Bramley D. Long-term effectiveness of the preoperative smoking cessation programme at Western Health. ANZ J Surg. 2017;87(9):677–81.
21. Wischmeyer PE, Carli F, Evans DC, Guilbert S, Kozar R, Pryor A, Thiele RH, Everett S, Grocott M, Gan TJ, Shaw AD, JKM T, Miller TE, Hedrick TL, MD ME, Mythen MG, Bergamaschi R, Gupta R, Holubar SD, Senagore AJ, Abola RE, Bennett-Guerrero E, Kent ML, Feldman LS, Fiore JF Jr, Perioperative Quality Initiative (POQI) 2 Workgroup. American Society for Enhanced Recovery and Perioperative Quality Initiative Joint Consensus Statement on Nutrition Screening and Therapy Within a Surgical Enhanced Recovery Pathway. Anesth Analg. 2018;126(6):1883–95.
22. Shander A, Knight K, Thurer R, Adamson J, Spence R. Prevalence and outcomes of anemia in surgery: a systematic review of the literature. Am J Med. 2004;116 Suppl 7A:58S–69S.2.
23. Beattie WS, Karkouti K, Wijeysundera DN, Tait G. Risk associated with preoperative anemia in noncardiac surgery: a single-center cohort study. Anesthesiology. 2009;110(3):574–81.
24. Warner MA, Shore-Lesserson L, Shander A, Patel SY, Perelman SI, Guinn NR. Perioperative anemia: prevention, diagnosis, and management throughout the spectrum of perioperative care. Anesth Analg. 2020;130(5):1364–80.
25. Kwon S, Thompson R, Dellinger P, Yanez D, Farrohki E, Flum D. Importance of perioperative glycemic control in general surgery: a report from the Surgical Care and Outcomes Assessment Program. Ann Surg. 2013;257(1):8–14.
26. Chen EB, Nooromid MJ, Helenowski IB, Soper NJ, Halverson AL. The relationship of preoperative versus postoperative hyperglycemia on clinical outcomes after elective colorectal surgery. Surgery. 2019;166(4):655–62.
27. Kiran RP, Turina M, Hammel J, Fazio V. The clinical significance of an elevated postoperative glucose value in nondiabetic patients after colorectal surgery: evidence for the need for tight glucose control? Ann Surg. 2013;258(4):599–604.
28. American Diabetes Association. Classification and diagnosis of diabetes: standards of Medical Care in Diabetes. Diabetes Care. 2018;41(Suppl 1):S13–27.
29. Colibaseanu DT, Osagiede O, McCoy RG, Spaulding AC, Habermann EB, Naessens JM, Perry MF, White LJ, Cima RR. Proactive protocol-based management of hyperglycemia and diabetes in colorectal surgery patients. Endocr Pract. 2018;24(12):1073–85.
30. Setji T, Hopkins T, Jimenez M, Manning E, Shaughnessy M, Schroeder R, Mendoza-Lattes S, Spratt S, Westover J, Aronson S, on behalf of the Duke Perioperative Enhancement Team

(POET). Rationalization, development, and implementation of a preoperative diabetes optimization program designed to improve perioperative outcomes and reduce cost. Diabetes Spectr. 2017;30(3):217–23.
31. Evans C, Lee J, Ruhlman M. Optimal glucose management in the perioperative period. Surg Clin N Am. 2015;95(2):337–54.
32. Ljungqvist O, Thorell A, Gutniak M, Häggmark T, Efendic S. Glucose infusion instead of preoperative fasting reduces postoperative insulin resistance. J Am Coll Surg. 1994;178(4):329–36.
33. Shi M, Hu Z, Yang D, Cai Q, Zhu Z. Preoperative oral carbohydrate reduces postoperative insulin resistance by activating AMP-activated protein kinase after colorectal surgery. Dig Surg. 2020;10:1–8.
34. Practice Guidelines for Preoperative Fasting and the Use of Pharmacologic Agents to Reduce the Risk of Pulmonary Aspiration: Application to Healthy Patients Undergoing Elective Procedures: An Updated Report by the American Society of Anesthesiologists Task Force on Preoperative Fasting and the Use of Pharmacologic Agents to Reduce the Risk of Pulmonary Aspiration. Anesthesiology. 2017;126(3):376–93.
35. Migaly J, Bafford A, Francone T, Gaertner W, Eskicioglu C, Bordeianou L, Feingold D, Steele S. The American Society of Colon and Rectal Surgeons Clinical Practice Guidelines for the Use of Bowel Preparation in Elective Colon and Rectal Surgery. Dis Colon Rectum. 2019;62(1):3–8.
36. Gan TJ, Diemunsch P, Habib AS, Kovac A, Kranke P, Meyer TA, Watcha M, Chung F, Angus S, Apfel CC, Bergese SD, Candiotti KA, Chan MT, Davis PJ, Hooper VD, Lagoo-Deenadayalan S, Myles P, Nezat G, Philip BK, Tramèr MR, Society for Ambulatory Anesthesia. Consensus guidelines for the management of postoperative nausea and vomiting. Anesth Analg. 2014;118(1):85–113.
37. Tateosian V, Champagne K, Gan TJ. What is new in the battle against postoperative nausea and vomiting? Clin Anesth. 2018;32(2):137–48.
38. Scott MJ, McEvoy MD, Gordon DB, Grant SA, Thacker JKM, Wu CL, Gan TJ, Mythen MG, Shaw AD, Miller TE, Perioperative Quality Initiative (POQI) I Workgroup. American Society for Enhanced Recovery (ASER) and Perioperative Quality Initiative (POQI) Joint Consensus Statement on Optimal Analgesia within an Enhanced Recovery Pathway for Colorectal Surgery: Part 2-From PACU to the Transition Home. Perioper Med (Lond). 2017;6:–7.
39. Barletta JF, Asgeirsson T, Senagore AJ. Influence of intravenous opioid dose on postoperative ileus. Ann Pharmacother. 2011;45(7–8):916–23.
40. Kooij F, Schlack W, Preckel B, Hollmann M. Does regional analgesia for major surgery improve outcome? Focus on epidural analgesia. Anesth Analg. 2014;119(3):740–4.
41. Pöpping DM, Elia N, Van Aken HK, Marret E, Schug SA, Kranke P, Wenk M, Tramèr MR. Impact of epidural analgesia on mortality and morbidity after surgery: systematic review and meta-analysis of randomized controlled trials. Ann Surg. 2014;259(6):1056–67.
42. Allen BFS, Jablonski PM, McEvoy MD, Ehrenfeld JM, Shi H, King AB, Wanderer JP. Implementation of an Enhanced Recovery Protocol (ERP) is associated with an increase in the perioperative use of non-opioid multimodal analgesia for non-ERP patients. J Clin Anesth. 2020;62:109694.
43. Weibel S, Jelting Y, Pace NL, Helf A, Eberhart LH, Hahnenkamp K, Hollmann MW, Poepping DM, Schnabel A, Kranke P. Continuous intravenous perioperative lidocaine infusion for postoperative pain and recovery in adults. Cochrane Database Syst Rev. 2018;6:CD009642.
44. Myles PS, Bellomo R, Corcoran T, Forbes A, Peyton P, Story D, Christophi C, Leslie K, McGuinness S, Parke R, Serpell J, Chan MTV, Painter T, McCluskey S, Minto G, Wallace S, Australian and New Zealand College of Anaesthetists Clinical Trials Network and the Australian and New Zealand Intensive Care Society Clinical Trials Group. Restrictive versus liberal fluid therapy for major abdominal surgery. N Engl J Med. 2018;378(24):2263–74.
45. Brandstrup B. Finding the right balance. N Engl J Med. 2018;378:2335–6.
46. Grass F, Lovely JK, Crippa J, Hübner M, Mathis KL, Larson DW. Potential association between perioperative fluid management and occurrence of postoperative ileus. Dis Colon Rectum. 2020;63(1):68–74.
47. Brandstrup B, Beier-Holgersen R, Iversen LH, Starup CB, Wentzel LN, Lindorff-Larsen K, Petersen TC, Tønnesen H. The influence of perioperative fluid therapy on N-terminal-pro-brain natriuretic peptide and the Association with Heart and Lung Complications in Patients Undergoing Colorectal Surgery: Secondary Results of a Clinical Randomized Assessor-blinded Multicenter Trial. Ann Surg. 2020;272(6):941–9.
48. Tolstrup J, Brandstrup B. Clinical assessment of fluid balance is incomplete for colorectal surgical patients. Scand J Surg. 2015;104(3):161–8.
49. Voldby AW, Brandstrup B. Fluid therapy in the perioperative setting-a clinical review. J Intensive Care. 2016;4:27.
50. Vlug MS, Bartels SA, Wind J, Ubbink DT, Hollmann MW, Bemelman WA, Collaborative LAFA Study Group. Which fast track elements predict early recovery after colon cancer surgery? Color Dis. 2012;14(8):1001–8.
51. Nelson R, Edwards S, Tse B. Prophylactic nasogastric decompression after abdominal surgery. Cochrane Database Syst Rev. 2007;3:CD004929.
52. Podda M, Di Saverio S, Davies RJ, Atzeni J, Balestra F, Virdis F, Reccia I, Jayant K, Agresta F, Pisanu A. Prophylactic intra-abdominal drainage following colorectal anastomoses. A systematic review and meta-analysis of randomized controlled trials. Am J Surg. 2020;219(1):164–74.
53. Aarts MA, Rotstein OD, Pearsall EA, Victor JC, Okrainec A, McKenzie M, McCluskey SA, Conn LG, RS ML, iERAS group. Postoperative ERAS interventions have the greatest impact on optimal recovery: experience with implementation of ERAS across multiple hospitals. Ann Surg. 2018;267(6):992–7.
54. Lau C, Phillips E, Bresee C, Fleshner P. Early use of low residue diet is superior to clear liquid diet after elective colorectal surgery: a randomized controlled trial. Ann Surg. 2014;260(4):641–7. discussion 647-9
55. Chough I, Zaghiyan K, Ovsepyan G, Fleshner P. Practice changes in postoperative feeding after elective colorectal surgery: from prospective randomized study to everyday practice. Am Surg. 2018;84(10):1675–8.
56. Fiore JF Jr, Bialocerkowski A, Browning L, Faragher IG, Denehy L. Criteria to determine readiness for hospital discharge following colorectal surgery: an international consensus using the Delphi technique. Dis Colon Rectum. 2012;55(4):416–23.
57. Balvardi S, Pecorelli N, Castelino T, Niculiseanu P, Liberman AS, Charlebois P, Stein B, Carli F, Mayo NE, Feldman LS, Fiore JF Jr. Measuring in-hospital recovery after colorectal surgery within a well-established enhanced recovery pathway: a comparison between hospital length of stay and time to readiness for discharge. Dis Colon Rectum. 2018;61(7):854–60.
58. Cartmell MT, Jones OM, Moran BJ, Cecil TD. A defunctioning stoma significantly prolongs the length of stay in laparoscopic colorectal resection. Surg Endosc. 2008;22(12):2643–7.
59. Munk-Madsen P, Eriksen JR, Kehlet H, Gogenur I. Why still in hospital after laparoscopic colorectal surgery within an enhanced recovery programme? Color Dis. 2019;21(12):1438–44.
60. Forsmo HM, Pfeffer F, Rasdal A, Sintonen H, Korner H, Erichsen C. Pre- and postoperative stoma education and guidance within an enhanced recovery after surgery (ERAS) programme reduces

length of hospital stay in colorectal surgery. Int J Surg. 2016;36(Pt A):121–6.
61. Younis J, Salerno G, Fanto D, Hadjipavlou M, Chellar D, Trickett JP. Focused preoperative patient stoma education, prior to ileostomy formation after anterior resection, contributes to a reduction in delayed discharge within the enhanced recovery programme. Int J Color Dis. 2012;27(1):43–7.
62. Chaudhri S, Brown L, Hassan I, Horgan AF. Preoperative intensive, community-based vs. traditional stoma education: a randomized, controlled trial. Dis Colon Rectum. 2005;48(3):504–9.
63. Hughes MJ, Cunningham W, Yalamarthi S. The effect of preoperative stoma training for patients undergoing colorectal surgery in an enhanced recovery programme. Ann R Coll Surg Engl. 2019:1–5.
64. Hignett S, Parmar CD, Lewis W, Makin CA, Walsh CJ. Ileostomy formation does not prolong hospital length of stay after open anterior resection when performed within an enhanced recovery programme. Color Dis. 2011;13(10):1180–3.
65. Miller D, Pearsall E, Johnston D, Frecea M, McKenzie M. Executive summary: enhanced recovery after surgery: best practice guideline for care of patients with a fecal diversion. J Wound Ostomy Continence Nurs. 2017;44(1):74–7.
66. Lohsiriwat V, Jitmungngan R. Enhanced recovery after surgery in emergency colorectal surgery: review of literature and current practices. World J Gastrointest Surg. 2019;11(2):41–52.
67. Lohsiriwat V. Enhanced recovery after surgery vs conventional care in emergency colorectal surgery. World J Gastroenterol. 2014;20(38):13950–5.
68. Wisely JC, Barclay KL. Effects of an Enhanced Recovery After Surgery programme on emergency surgical patients. ANZ J Surg. 2016;86(11):883–8.
69. Shida D, Tagawa K, Inada K, et al. Modified enhanced recovery after surgery (ERAS) protocols for patients with obstructive colorectal cancer. BMC Surg. 2017;17(1):18.
70. Shang Y, Guo C, Zhang D. Modified enhanced recovery after surgery protocols are beneficial for postoperative recovery for patients undergoing emergency surgery for obstructive colorectal cancer: a propensity score matching analysis. Medicine (Baltimore). 2018;97(39):e12348.
71. Verheijen PM, Vd Ven AW, Davids PH, Vd Wall BJ, Pronk A. Feasibility of enhanced recovery programme in various patient groups. Int J Color Dis. 2012;27(4):507–11.
72. Roulin D, Blanc C, Muradbegovic M, Hahnloser D, Demartines N, Hubner M. Enhanced recovery pathway for urgent colectomy. World J Surg. 2014;38(8):2153–9.
73. Hajibandeh S, Hajibandeh S, Bill V, Satyadas T. Meta-analysis of Enhanced Recovery After Surgery (ERAS) protocols in emergency abdominal surgery. World J Surg. 2020;
74. Lee GC, Hodin RA. Applying enhanced recovery pathways to unique patient populations. Clin Colon Rectal Surg. 2019;32(2):134–7.
75. Bagnall NM, Malietzis G, Kennedy RH, Athanasiou T, Faiz O, Darzi A. A systematic review of enhanced recovery care after colorectal surgery in elderly patients. Color Dis. 2014;16(12):947–56.
76. Rumstadt B, Guenther N, Wendling P, et al. Multimodal perioperative rehabilitation for colonic surgery in the elderly. World J Surg. 2009;33(8):1757–63.
77. Feroci F, Lenzi E, Baraghini M, et al. Fast-track surgery in real life: how patient factors influence outcomes and compliance with an enhanced recovery clinical pathway after colorectal surgery. Surg Laparosc Endosc Percutan Tech. 2013;23(3):259–65.
78. Forsmo HM, Erichsen C, Rasdal A, Korner H, Pfeffer F. Enhanced Recovery After Colorectal Surgery (ERAS) in elderly patients is feasible and achieves similar results as in younger patients. Gerontol Geriatr Med. 2017;3:2333721417706299.
79. Slieker J, Frauche P, Jurt J, et al. Enhanced recovery ERAS for elderly: a safe and beneficial pathway in colorectal surgery. Int J Color Dis. 2017;32(2):215–21.
80. Baek SJ, Kim SH, Kim SY, Shin JW, Kwak JM, Kim J. The safety of a "fast-track" program after laparoscopic colorectal surgery is comparable in older patients as in younger patients. Surg Endosc. 2013;27(4):1225–32.
81. Owodunni OP, Hampton J, Bettick D, et al. High compliance to an enhanced recovery pathway for patients >/=65 years undergoing major small and large intestinal surgery is associated with improved postoperative outcomes. Ann Surg. 2019;270(6):1117–23.
82. Depalma N, Cassini D, Grieco M, et al. Feasibility of a tailored ERAS programme in octogenarian patients undergoing minimally invasive surgery for colorectal cancer. Aging Clin Exp Res. 2020;32(2):265–73.
83. Ban KA, Berian JR, Ko CY. Does implementation of enhanced recovery after surgery (ERAS) protocols in colorectal surgery improve patient outcomes? Clin Colon Rectal Surg. 2019;32(2):109–13.
84. Dai X, Ge X, Yang J, et al. Increased incidence of prolonged ileus after colectomy for inflammatory bowel diseases under ERAS protocol: a cohort analysis. J Surg Res. 2017;212:86–93.
85. D'Andrea AP, Khetan P, Miller R, Sylla P, Divino CM. Outcomes after bowel resection for inflammatory bowel disease in the era of surgical care bundles and enhanced recovery. J Gastrointest Surg. 2020;24(1):123–31.
86. Joliat GR, Hubner M, Roulin D, Demartines N. Cost analysis of enhanced recovery programs in colorectal, pancreatic, and hepatic surgery: a systematic review. World J Surg. 2019;
87. Lee L, Li C, Landry T, et al. A systematic review of economic evaluations of enhanced recovery pathways for colorectal surgery. Ann Surg. 2014;259(4):670–6.
88. Lemanu DP, Singh PP, Stowers MD, Hill AG. A systematic review to assess cost effectiveness of enhanced recovery after surgery programmes in colorectal surgery. Color Dis. 2014;16(5):338–46.
89. Greco M, Capretti G, Beretta L, Gemma M, Pecorelli N, Braga M. Enhanced recovery program in colorectal surgery: a meta-analysis of randomized controlled trials. World J Surg. 2014;38(6):1531–41.
90. Roulin D, Donadini A, Gander S, et al. Cost-effectiveness of the implementation of an enhanced recovery protocol for colorectal surgery. Br J Surg. 2013;100(8):1108–14.
91. Lee L, Feldman LS. Enhanced recovery after surgery: economic impact and value. Surg Clin North Am. 2018;98(6):1137–48.
92. Stone AB, Grant MC, Wu CL, Wick EC. Enhanced recovery after surgery for colorectal surgery: a review of the economic implications. Clin Colon Rectal Surg. 2019;32(2):129–33.
93. Joliat GR, Ljungqvist O, Wasylak T, Peters O, Demartines N. Beyond surgery: clinical and economic impact of Enhanced Recovery After Surgery programs. BMC Health Serv Res. 2018;18(1):1008.
94. Sikka R, Morath JM, Leape L. The Quadruple Aim: care, health, cost and meaning in work. BMJ Qual Saf. 2015;24(10):608–10.
95. Khan S, Wilson T, Ahmed J, Owais A, MacFie J. Quality of life and patient satisfaction with enhanced recovery protocols. Color Dis. 2010;12(12):1175–82.
96. Hughes M, Coolsen MM, Aahlin EK, et al. Attitudes of patients and care providers to enhanced recovery after surgery programs after major abdominal surgery. J Surg Res. 2015;193(1):102–10.
97. Li D, Jensen CC. Patient satisfaction and quality of life with enhanced recovery protocols. Clin Colon Rectal Surg. 2019;32(2):138–44.
98. Thacker J. Overview of enhanced recovery after surgery: the evolution and adoption of enhanced recovery after surgery in North America. Surg Clin North Am. 2018;98(6):1109–17.

99. Pearsall EA, Meghji Z, Pitzul KB, et al. A qualitative study to understand the barriers and enablers in implementing an enhanced recovery after surgery program. Ann Surg. 2015;261(1):92–6.
100. Abeles A, Kwasnicki RM, Darzi A. Enhanced recovery after surgery: current research insights and future direction. World J Gastrointest Surg. 2017;9(2):37–45.
101. Tanious MK, Ljungqvist O, Urman RD. Enhanced recovery after surgery: history, evolution, guidelines, and future directions. Int Anesthesiol Clin. 2017;55(4):1–11.
102. Joshi GP, Kehlet H. Enhanced recovery pathways: looking into the future. Anesth Analg. 2019;128(1):5–7.
103. Currie A, Soop M, Demartines N, Fearon K, Kennedy R, Ljungqvist O. Enhanced recovery after surgery interactive audit system: 10 years' experience with an international web-based clinical and research perioperative care database. Clin Colon Rectal Surg. 2019;32(1):75–81.
104. Aziz O, Atallah L, Lo B, et al. Ear-worn body sensor network device: an objective tool for functional postoperative home recovery monitoring. J Am Med Inform Assoc. 2011;18(2):156–9.
105. Dobkin BH, Dorsch A. The promise of mHealth: daily activity monitoring and outcome assessments by wearable sensors. Neurorehabil Neural Repair. 2011;25(9):788–98.
106. Appelboom G, Camacho E, Abraham ME, et al. Smart wearable body sensors for patient self-assessment and monitoring. Arch Public Health. 2014;72(1):28.
107. Alam R, Figueiredo SM, Balvardi S, et al. Development of a patient-reported outcome measure of recovery after abdominal surgery: a hypothesized conceptual framework. Surg Endosc. 2018;32(12):4874–85.
108. Fiore JF Jr, Feldman LS. Tracking postoperative recovery-making a case for smartphone technology. JAMA Surg. 2019;28:28.
109. Williams AM, Bhatti UF, Alam HB, Nikolian VC. The role of telemedicine in postoperative care. mHealth. 2018;4:11.
110. Asiri A, AlBishi S, AlMadani W, ElMetwally A, Househ M. The use of telemedicine in surgical care: a systematic review. Acta Inform Med. 2018;26(3):201–6.
111. Borsuk DJ, AL-Khamis A, Geiser AJ, et al. S128: active post discharge surveillance program as a part of Enhanced Recovery After Surgery protocol decreases emergency department visits and readmissions in colorectal patients. Surg Endosc. 2019;33(11):3816–27.
112. Mandel JC, Kreda DA, Mandl KD, Kohane IS, Ramoni RB. SMART on FHIR: a standards-based, interoperable apps platform for electronic health records. J Am Med Inform Assoc. 2016;23(5):899–908.