

## Original article

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# Modern perioperative medicine – past, present, and future

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**Abstract:** Modern perioperative medicine has dramatically altered the care for patients undergoing major surgery. Anaesthetic and surgical practice has been directed at mitigating the surgical stress response and reducing physiological insult. The development of standardised enhanced recovery programmes combined with minimally invasive surgical techniques has led to reduction in length of stay, morbidity, costs, and improved outcomes. The enhanced recovery after surgery (ERAS) society and its national chapters provide a means for sharing best practice in this field and developing evidence based guidelines. Research has highlighted persisting challenges with compliance as well as ensuring the effectiveness and sustainability of ERAS. There is also a growing need for increasingly personalised care programmes as well as complex geriatric assessment of frailer patients. Continuous collection of outcome and process data combined with machine learning, offers a potentially powerful solution to delivering bespoke care pathways and optimising individual management. Long-term data from ERAS programmes remain scarce and further evaluation of functional recovery and quality of life is required.

**Keywords:** enhanced recovery; ERAS; perioperative medicine; surgery.

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## Introduction

The field of perioperative medicine has undergone radical change in the last 30 years witnessing major advances in anaesthetic and surgical technique. Along with this, traditional models of care have been disbanded in favour of enhanced recovery programmes in almost every surgical specialty. In this review, we have presented the evolution of modern perioperative care; we have discussed current practice, areas of contention, and future directions for advancing the field.

## Advances in perioperative care

Historically, patients knew very little of what to expect following a major surgery. Perioperative care was often characterised by prolonged fasting, aggressive bowel preparation, nasogastric decompression, bed-rest, and prolonged convalescence. A paradigm shift came during the 1990s with the work of Henrik Kehlet on the physiological stress response and organ dysfunction following surgery. He hypothesised this was a key factor in postoperative morbidity and that combined approaches to inhibit this response would improve clinical outcomes [1, 2].

Kehlet and others pioneered modern recovery – advocating multimodal analgesia and regional anaesthetic techniques [3] combined with early mobilisation and reintroduction of feeding after surgery. Utilising this approach, they reported a reduction in hospital stay for elective colectomy from 10 to 2 days [4, 5]. This heralded a new era of ‘fast track surgery’ with rapid postoperative recovery facilitated by a series of evidence based interventions delivered by a multidisciplinary team.

## Enhanced recovery after surgery

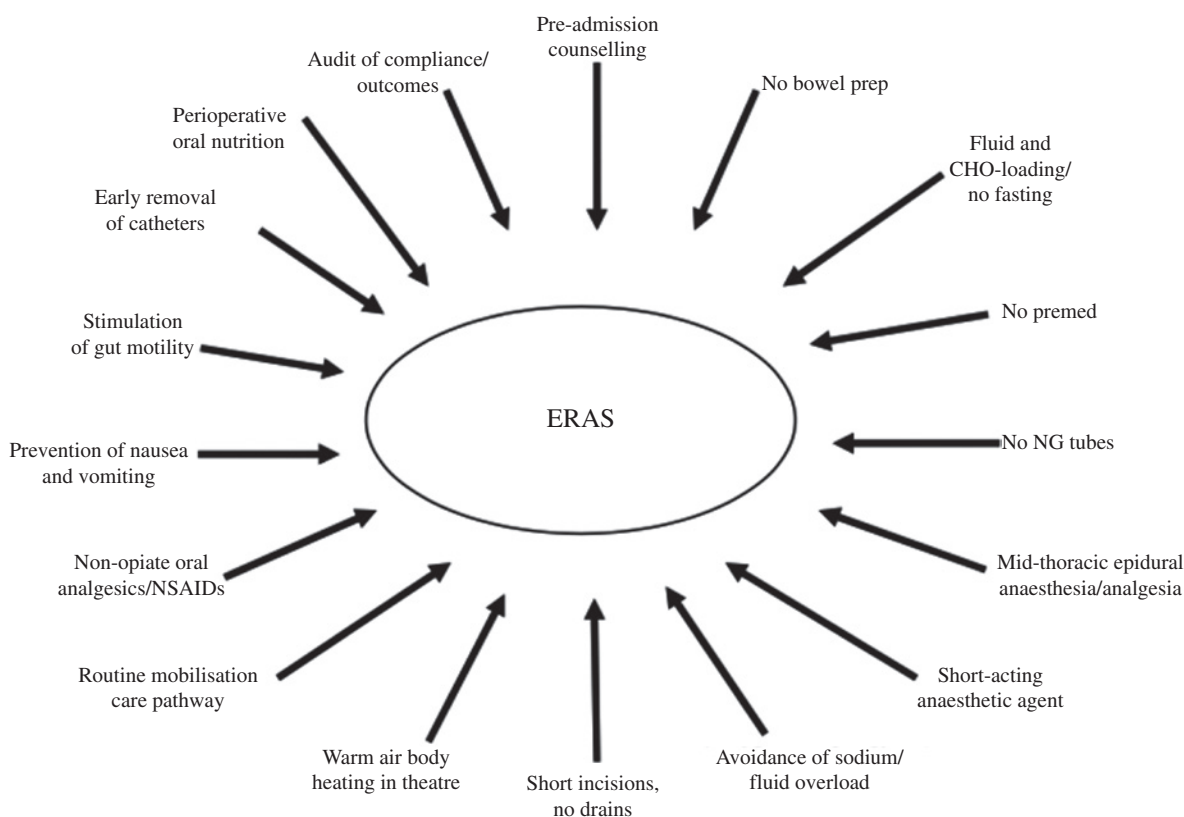
With a growing desire to reduce the morbidity and costs associated with longer hospital stay, a range of measures

to optimise patient performance and recovery were investigated. In 2001 Ken Fearon and Olle Ljungqvist formed the enhanced recovery after surgery (ERAS®) study group. The group sought to address the variability [6] and lack of standardisation [7] in the clinical care of patients undergoing colorectal surgery. The first ERAS® consensus protocol was published in 2005 [8]. It utilised multiple interventions derived from available research evidence to mitigate the perioperative physiological stress response and preserve anabolic homeostasis. These span the entire journey of a patient from preadmission to the preoperative, intraoperative, and the postoperative periods. The model is based on an integrated, multimodal approach with each of the elements combining in a synergistic and coordinated fashion, rather than acting in isolation (Figure 1). Critically, this protocol also stressed the multidisciplinary nature of perioperative care, the need for effective team structures and collaboration with stakeholders.

Alongside the rise of fast track and enhanced recovery programmes, the advent of minimally invasive and laparoscopic techniques has been a key development in gastrointestinal surgery. This has been the subject of much research [9–11] and has become the default approach in most centres. The growing use of laparoscopy-assisted

surgery has been complimentary to the ERAS model [12–14] which has been reflected in the subsequent updates to the colorectal guidelines [15–17].

Despite the apparent benefits of enhanced recovery programmes, their use was initially met with scepticism and resistance [18]. Issues with implementation and poor compliance with recommendations [19] has meant ERAS is yet to fulfil its full potential in many areas. Robust population data and metaanalysis supporting ERAS in colorectal surgery have only recently become available [20–22]. As the introduction of ERAS programmes has become more structured [23] and sustainable [24], the benefits have also become increasingly evident. Data now supports an overall reduction in the length of stay across a range of surgical procedures by approximately 2.5 days without an increase in hospital readmission [20–22, 25–28]. Analysis consistently demonstrates the decreased morbidity with ERAS by as much as 50%, [20–22, 25–28] equivalent to one complication being avoided for every 4.5 patients following an enhanced recovery programme [25]. This has also been associated with significant cost cutting, either through the direct reduction in complications or through more efficient utilisation of resources and availability of hospital beds [25, 28–30].



**Figure 1:** From Fearon K, Clin Nutr. 2005;24(3):466–477.

## Barriers to success

Following the foundation of the ERAS society in 2010, experts in the fields of hepatobiliary surgery [31, 32], gynaecology [33], urology [34], head and neck [35], breast reconstruction [36] and cardiothoracic surgery [37, 38] have authored guidelines and ERAS protocols, which are successfully in place in more than 25 countries worldwide. Whilst this may be regarded as a success, data collected from this expansion has revealed perhaps unsurprisingly, that protocols which are incompletely delivered or inchoate are markedly reduced in their effectiveness [19, 39, 40].

To combat this, a renewed emphasis has been placed on quality assurance with greater scrutiny in the implementation process, adherence and sustainability of ERAS. Successful implementation requires the training and education of staff members as well as effective change management strategies and good clinical leadership [19, 41, 42]. A number of training resources have been developed to accomplish this including the ERAS implementation programme and interactive audit system and more recently, a detailed consensus framework for the optimal training curriculum [43].

Greater compliance with ERAS programmes is directly associated with decreased complication rates and improved outcomes in a ‘dose dependent’ manner [39, 44, 45]. Repeated audit and feedback of centre-specific outcome and process data is therefore a vital means of ensuring the quality and sustainability of ERAS. The ERAS interactive audit system was developed to help centres monitor adherence to ERAS, to enable benchmarking between institutions and to confirm the legitimacy of ERAS out of the trial setting. The system holds an international database, which has become a valuable tool for research as well as directing the improvement and development of ERAS [46, 47].

## National societies

The ERAS Society (UK) was formed in 2009, following a national initiative (Enhanced Recovery Partnership Programme, ERPP) [48] for the spread and adoption of ERAS principles for key procedures across four specialties (colorectal, gynaecology, urology, orthopaedics). A Delphi study with healthcare staff involved in the ERPP showed consensus for a continued means for future networking and information sharing [49]. ERAS UK have run annual conferences since 2010, with each event held in different regions of the UK, involving local healthcare professionals and have seen an expanding membership across all

surgical specialties. Networking opportunities at these national conferences result in new research collaborations [50] and enable groups to share pathways, protocols, and documentation.

ERAS UK have also explored other ways to enable information sharing with online resources available on their website ([www.erasuk.net](http://www.erasuk.net)), a closed Facebook group for discussion ([www.facebook.com/groups/erasuk](http://www.facebook.com/groups/erasuk)) and a more secure forum with a searchable document library ([www.khub.net/group/enhanced-recovery-after-surgery-society-uk](http://www.khub.net/group/enhanced-recovery-after-surgery-society-uk)). Direct interaction with ERAS UK members, plus social media discussions on Facebook and Twitter (@ERASsocietyUK) ensure that the society continues to evolve and spread awareness of this multimodal model of care.

## Disparity and debate

There are several areas of continuing debate in perioperative care, for example the usage of mechanical bowel preparation (MBP). European ERAS guidelines do not currently recommend routine use of bowel preparation for colonic resection [16, 51]. However, recent systematic reviews suggest that MBP combined with oral antibiotic therapy may be effective in reducing surgical site infection and other postoperative complications [52–54]. This analysis has been well received by American consensus groups who advocate this as the preferred preparation for elective colonic surgery [55].

Other areas of controversy include intraoperative fluid therapy, which has been an important component of ERAS from its inception. Balancing fluid therapy to achieve adequate splanchnic perfusion whilst avoiding oedema, paralytic ileus, and fluid overload remains challenging. This is particularly true amongst high-risk patients such as those with limited physiologic reserve, severe cardiopulmonary disease, renal impairment, or patients undergoing extensive surgery [56]. Early trials suggested that goal directed fluid therapy (GDFT), which makes use of advanced monitoring systems and fluid boluses to achieve a targeted cardiac output, may confer an advantage over traditional care. However, contemporary studies comparing GDFT to enhanced recovery patients receiving evidence-based fluid management in the form of preoperative euvoemia and neutral fluid balance have shown no significant difference [56–58]. The relative equipoise in the literature has again lead to geographic disparity with American societies recommending GDFT as standard [55, 59] and the European ERAS community reserving GDFT for high risk patients only [17].

## Evolution

ERAS challenged all the dogmas of conventional perioperative care, but it needs to continue to evolve, or else risk becoming dogmatic itself. ERAS must be responsive to the latest research evidence as well as novel surgical approaches and technologies. Enhanced recovery programmes have already begun to influence the care of emergency general surgery [60, 61] and paediatric patients [62]. The use of robotic surgery [63, 64], trans anal [65], and other minimally invasive techniques is likely to alter the surgical insult and patient recovery as surgical experience with these procedures grow.

Research within ERAS is also evolving with on-going work to investigate ways of enhancing the success of ERAS. Studies to predict which patients are likely to deviate from the expected perioperative course has been of interest as it may allow remedial action to be taken to avert this [66]. Recent studies suggest that compliance is worst in the immediate postoperative period following colorectal surgery and may be most indicative of early complication or impaired functional recovery [67, 68]. Whilst this is a potential area for significant improvement, it remains unclear whether ‘non-compliance’ in these instances was due to a perioperative complication or whether a complication resulted from poor compliance [69]. More structured reporting of outcomes is likely to assist with this enquiry as well as answering research questions into the benefit of specific ERAS components [70].

Deconstructing ERAS protocols by analysing the effectiveness of specific items may seem counterintuitive given the evidence base is required to justify each component. Efforts to simplify and streamline protocols are primarily borne from a desire to improve compliance, but may also represent a response to criticism that ERAS has become overcomplicated and unwieldy [71]. Debate has also arisen as to whether early tolerance of oral intake and early mobilisation should be considered as markers of adherence or as markers of recovery [69].

## Personalised perioperative care

What is increasingly clear in perioperative medicine is that one size does not fit all. The individual stress response to surgery remains highly variable without a means to measure or predict this currently. The increasing complexity of patients’ medical needs combined with heterogeneity in service infrastructure, operative, and patient factors are driving a need for more personalised care programs. This is particularly true in the context of an aging global

population and the rising number of elderly and comorbid patients undergoing surgery. The increasing prevalence of frailty and geriatric syndromes amongst this patient group places them at increased risk of adverse outcome following surgery including medical complications, prolonged hospitalisation, institutionalisation, and readmission as well as short and long-term mortality [72].

Although series have demonstrated that ERAS is safe and beneficial in caring for elderly surgical patients [73], a number of studies support the use of multidomain comprehensive geriatric assessment (CGA) to identify and manage older patients who are at the risk of elective surgery [74–76]. Several centres have successfully combined this with embedded liaison services to deliver geriatrician lead, evidence based, collaborative models of care throughout the perioperative period [77, 78]. These teams contribute to preoperative assessment and medical optimisation, counselling and shared decision making, inpatient review and rehabilitation as well as proactive discharge planning. The role of perioperative geriatricians has become well established in patients undergoing emergency surgery for hip fracture, but is likely to extend to frail and elderly patients undergoing major surgery in vascular and general surgery as well. Jugdeep Dhesi and others have demonstrated significant reductions in complication rates, length of stay, and likelihood of discharge to dependent care settings with CGA methods [75, 77, 78]. In order to meet the needs of these patients personalised, holistic care programs are required necessitating closer collaboration between perioperative geriatricians, anaesthetists, and surgeons.

## Future directions in perioperative care

The growing complexity of perioperative care and the need for increasingly personalised and bespoke pathways has stimulated interest in digital technological solutions and automated care processes. Digital technology is likely to have a major role in shaping the future of perioperative care and a number of advances relevant to enhanced recovery programmes have been investigated. These include apps directed at lifestyle modification and preoperative optimisation, objective nociceptive measurements, portable non-invasive sensors calibrated to recognise postoperative cardiopulmonary complications, and activity trackers to monitor postoperative ambulatory recovery [79].

An exciting frontier in medical technology is in combining big data analytics with artificial intelligence in order to guide patient management. Artificial neural

networks and machine learning programmes have exhibited superior performance to conventional prediction models in diagnosing acute appendicitis [80], selecting patients for surgery [81], predicting quality of life after breast cancer surgery [82] and long term mortality following surgery for hepatocellular carcinoma [83]. A centre in New Jersey, USA implemented a machine-learning algorithm in the emergency department, intensive care unit, and hospital wards to identify patients with sepsis earlier. They were able to reduce the sepsis-related in-hospital mortality rate by 60% and sepsis-related 30-day readmission rate by 50% [84]. Similar models have also been applied retrospectively to colorectal ERAS patients using multi-layered perception neural networks to calculate the individual prehabilitation windows as well as the probability of delayed discharge and readmission [85, 86].

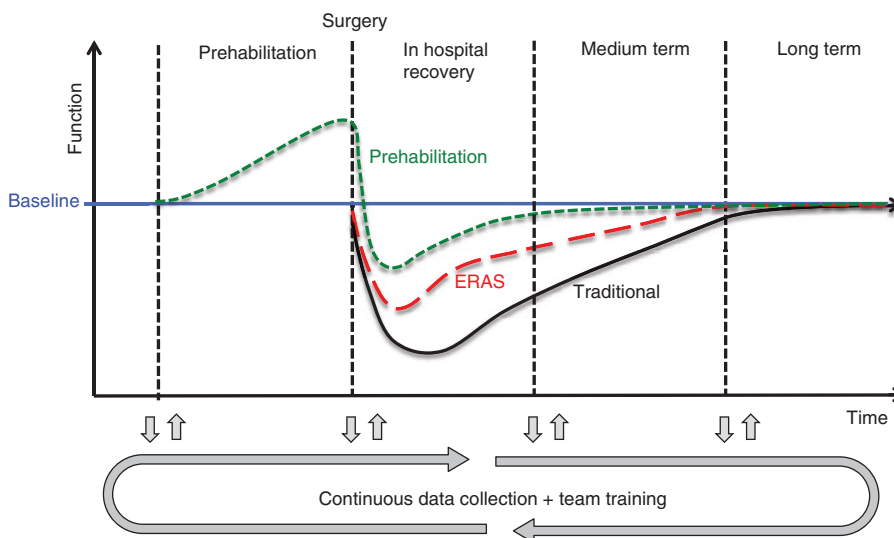
This may well revolutionise care of the surgical patient within the next 20 years. We envisage a system whereby data from electronic health records combined with metrics prospectively measured throughout the perioperative period are harvested by machine-learning programmes. This continuously updates the optimum care pathway with targeted adaptations or adjustments for an individual patient as well as the local population in an automated fashion (Figure 2).

There is cause for great optimism about the future of perioperative medicine. There has been greater consensus and collaboration on issues such as nutrition [87], anaemia [88], as well as procedure-specific pain management [89]. Prehabilitation – which is reviewed by Gerrit Slooter in this edition of the journal, is a particularly promising means of reducing perioperative morbidity. It

is worth highlighting however, whilst enhanced recovery programmes have dramatically altered surgical practice, this has been a relatively recent change and there is a distinct lack of data regarding their long-term outcomes [90]. ERAS research to date has almost exclusively focused on length of stay, readmission rate and 30-day morbidity and mortality. However, these measures fail to reflect the complex, multidimensional process of recovery after surgery. To better understand and influence the recovery continuum more detailed assessment of physical, nociceptive, emotive, functional and cognitive performance at multiple time points are required [91].

Studies examining patient satisfaction and health related quality of life with ERAS have so far found no significant difference when compared to conventional care. Some evidence supports a reduction in postoperative fatigue [92] and earlier return to activities with ERAS however, a small number of studies have reported slightly higher pain scores with ERAS in the early postoperative period [93]. Although this difference disappeared with time, this is clearly an area for potential improvement as dissatisfaction associated with postoperative pain can persist long after the index surgery [94].

A limited number of reports have now been published examining medium to long-term survival, which reveals both an overall and cancer-specific survival advantage with ERAS [95–97]. It is likely that this effect is due to direct reduction in complications and in preventing delay to commencing adjuvant chemotherapy. This finding may also result from minimising the surgical stress response placed on the immune system and the complex ways in which this modulates tumour biology.



**Figure 2:** Model of the effect of prehabilitation and ERAS on functional recovery.

Crucially these studies have reasserted the importance of adherence to ERAS protocols which was strongly associated with survival independent of cancer stage and postoperative complications [45, 96, 97].

From a global perspective there is still considerable progress required in perioperative care. In 2015 the Lancet commission on global surgery highlighted the alarming deficit in essential, life-saving surgical and anaesthesia care in low and middle income countries [98]. The report estimated that 5 billion people lack access to safe, affordable surgical, and anaesthesia care when needed. Achieving the commissions aims has been aided by commitments from the world health organisation [99] and most recently from the world bank group [100]. Application of ERAS principles may also have a role in supporting the optimal growth and development of surgical systems as they are scaled-up within National Surgery Plans [101]. However, a broad interdisciplinary focus is still urgently required to address the health system requirements for patients with surgical conditions worldwide [102].

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#### Author Contributions

Harry F Dean: Writing – original draft; Fiona Carter: Writing – original draft; Nader K. Francis: Supervision; Writing – review & editing.

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## Reviewer Assessment

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# Modern perioperative medicine – past, present, and future

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## Editor Comments to Original Submission

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<b>Recommendation Term:</b>	<b>Accept</b>
<b>Overall Reviewer Manuscript Rating:</b>	<b>95</b>

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This is an excellent review of the topic showing great knowledge of the past and future development of perioperative medicine!