The Current and Future Role of Regional Anesthesia in Enhanced Recovery After Surgery Programs for Abdominal Surgery

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Keywords
- Regional anesthesia
- Abdominal
- Surgery
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- Laparotomy

Key points
- Improvement of surgical care and implementation of enhanced recovery after surgery (ERAS) programs might have reduced the previously described analgesic and nonanalgesic benefits of different regional anesthesia techniques.
- Regional anesthesia within the context of multimodal analgesic (MMA) regimen improves postoperative analgesia and minimizes opioid consumption and their related side effects. Opioid-related side effects are dose dependent and hinder recovery.
- Thoracic epidural analgesia (TEA) has been shown to attenuate the stress response induced by surgery and to improve gastrointestinal recovery, while decreasing cardiopulmonary complications in major abdominal (open) surgery. However, it remains unclear if the previously demonstrated benefits of TEA can be reproduced in the context of current and future ERAS programs. Alternative analgesic techniques to TEA for patients undergoing open abdominal surgery include continuous intravenous lidocaine (IVL) infusion, transversus abdominis plane (TAP) blocks, and preperitoneal continuous infusion of local anesthetic.
- For patients undergoing laparoscopic surgery, intrathecal (IT) analgesia with IT morphine, continuous IVL infusion, TAP blocks, and intraperitoneal local anesthetic (IPLA) are efficient and safe analgesic techniques commonly used in the context of an ERAS program.
- The evidence supporting the use of regional anesthesia to improve short and long-term nonanalgesic outcomes in the context of an ERAS program requires further investigation. It remains unclear if regional anesthesia techniques affect cancer outcomes.

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INTRODUCTION
In the past 2 decades, there have been major advances in regional anesthesia as a result of improved training and better technology, thus allowing regional anesthesia to become a more integrated technique of clinical anesthesia. There is general acceptance that the quality of postoperative analgesia achieved with different regional anesthesia techniques is superior to that achieved with any other nonregional techniques, and for this reason, regional anesthesia is very much in demand for different types of surgery. Epidural analgesia is the most studied regional anesthesia technique with regard to postoperative outcomes in patients undergoing abdominal surgery.

The beneficial effect of epidural analgesia on clinical outcomes as conventionally evaluated, such as mortality, morbidity, and length of hospital stay remains controversial, especially when used within the context of ERAS program.

In the past 20 years, there has been a growing interest in the ERAS programs that incorporate evidenced-based interventions with the intent to minimize surgical stress, reduce morbidity, decrease variability in perioperative care, and thereby facilitate earlier hospital discharge [1]. A major goal in the development and implementation of the ERAS program is to understand and address the factors that keep patients hospitalized after major surgery and impede their return to baseline performance and function. The evidence for their benefits in decreasing length of stay and complications has been shown to be strongest in colorectal surgery [2], but there is emerging evidence in other areas of abdominal surgery suggesting that accelerated recovery concepts are generalizable across a wide range of procedures. While most of these studies have reported traditional outcome measures such as length of hospital stay and complications, very few studies have investigated the impact of these programs on patient-centered outcomes as the primary measure. This article reviews the indications and advantages of various regional anesthesia techniques for abdominal surgery in an ERAS program. An update is also provided on the application of regional anesthesia techniques for abdominal surgery procedures. Considerations are made relative to the surgical advances in technology (robotic) and clinical practice. The literature search for this article is based on clinical works published in the past 15 years and identified using Medline and the Cochrane Library.

THE ENHANCED ROLE OF REGIONAL ANESTHESIA
There is a recognition that regional anesthesia techniques, and in particular neuraxial afferent blockade, have been shown to be associated with several recognized physiologic and clinical advantages, such as modulation of surgical stress response, improved microcirculation and tissue perfusion, decreased insulin resistance, less inhibition of diaphragmatic activity, and optimal pain relief [3,4]. These potentially beneficial effects provide the necessary conditions to facilitate the introduction of enhanced recovery pathways (ERPs). Clearly, one has to understand that these anesthetic and analgesic techniques cannot, in isolation, affect surgical outcome, but they need to capitalize on the multidisciplinary aspects of the ERAS programs to facilitate the recovery process. For
instance, TAP blocks have not been shown to affect surgical outcome unless their provision of optimal pain management is used in the context of MMA, and together with changes in organizational surgical care (early feeding and mobilization). Similarly, it can be said that the implementation of the ERAS programs will require the multidisciplinary team to identify appropriate techniques of regional anesthesia, which enhance, rather than hindering, the recovery process. For example, the use of thoracic epidural anesthesia might not be necessary for colonic surgery because this technique does not facilitate patient mobilization and early removal of bladder catheter, although the quality of pain relief might be optimal. However, it can be stated that regional anesthesia techniques, whether central or peripheral, when incorporated into MMA regimens, provide good evidence for their analgesic efficacy in ERAS protocols. The potential mechanism is based on effective quality of pain relief, reduced opioid consumption, and more importantly, opioid-related effects, leading to improved capacity to limit organ dysfunction. The result of better pain relief is earlier mobilization and oral nutrition, both elements necessary to facilitate the return to baseline functions.

QUALITY IMPROVEMENT AND ENHANCED RECOVERY AFTER SURGERY?

Since the original work of Kehlet [5] in the late 1990s on fast-track colorectal surgery, many perioperative therapeutic modalities, which could have an impact on perioperative outcomes, have not been consistently applied in clinical practice. It became evident that integrated, standardized, coordinated, multidisciplinary perioperative care plans that incorporated several therapeutic interventions would decrease the impact of surgical stress and improve the postoperative physiologic and functional recovery, thus leading to less complications and earlier discharge from the hospital. In 2005, a consensus guideline was published by the ERAS Society indicating the elements that modify the pathophysiology of the stress response associated with colorectal surgery [6,7]. The goal was to combine a variety of individual evidence-based elements of perioperative care, each of which may have only modest benefits when used in isolation, into a coordinated effort that can be expected to have a synergistic beneficial effect on surgical outcomes. Surgeons have focused on the development of minimally invasive techniques to improve recovery, although many other interventions, such as afferent neural blockade, nutrition, maintenance of normothermia, fluid management, and earlier mobilization, would also have the potential to enhance or delay recovery through their effect on the surgical stress response. The goal of the ERAS program has also been to challenge surgical traditions for which there is a lack of evidence such as routine preoperative fasting, bowel preparation, and the prolonged use of surgical drains and nasogastric tubes. Therefore, to implement all these elements, a collaborative approach and a consensus between perioperative care providers, surgeons, anesthesiologists, and nursing staff is required. The advantages are obvious: the variability in clinical care between practitioners is reduced and recovery is accelerated. A review of all published
randomized controlled trials (RCTs) of ERAS in colorectal surgery has clearly indicated a reduction in medical morbidity by 40% and a reduction in hospital length of stay by 2.28 days without changes in the rate of readmission [8]. There seems to be a relationship between adherence to the ERAS pathways and rate of complications: the greater the compliance to the program, the higher is the reduction of morbidity [9].

IS INTEGRATION OF REGIONAL ANESTHESIA AND ANALGESIA IN THE ENHANCED RECOVERY AFTER SURGERY PROGRAM IMPROVING OUTCOME?
The successful integration and implementation of regional anesthetic and analgesic techniques within the ERAS program requires the cooperation of multiple stakeholders, including surgeons, anesthesiologists, nursing staff, hospital administrators, and patients. This situation represents a significant paradigm shift in perioperative management, and clearly, many barriers to implementation can be encountered. Each regional anesthetic technique has to be chosen based on the specific pathway to be implemented and with the understanding that it will provide meaningful clinical value when integrated with other interventions [10]. To achieve such integration, the anesthesiologist needs to work in conjunction with the surgical team, meet regularly with the other stakeholders, audit the process of care, consult with his or her group, and discuss potential standardization of anesthesia care once the evidence for a specific intervention is evident. Additional resources, such as a pathway coordinator, may be considered, depending on the number of ERPs to be implemented. Consensus is required with all of these groups to ensure successful implementation and practice.

IDENTIFYING RELEVANT OUTCOMES BEYOND ANALGESIA
For several years, the anesthesiologist has focused his attention on improving the quality of postoperative pain relief and integrating the regional techniques with other analgesic modalities. The results have been overall positive; however, the results on morbidity have been less convincing. One would identify possible causes in the lack of integration of perioperative care and limited communication between the surgeon and the anesthesiologist, the latter preoccupied with achieving optimal analgesia and the former continuing to use surgical techniques based on either poor evidence or even lack of evidence. For example, the anesthesiologist would initiate TEA with the belief that such a modality would lead to opioid sparing, and thus less nausea and vomiting, as well as improve postoperative pulmonary function. Conversely, the surgeon would request that the nasogastric tube be introduced and kept until bowel movement is present, probably fully unaware that the routine placement of a nasogastric tube may actually delay return of bowel function and increase pulmonary complications [11]. Another example would be inadequate or poorly managed regional block, thus limiting the implementation of early mobilization and nutrition. The advent of ERAS has clearly emphasized the need to
integrate the various elements with the contribution of various stakeholders, and move away from the concept of separated interventions with little or no evidence of improving outcome. In addition, with the greater involvement of patient in the recovery process, achieved through education and participation in the decision of care, there has been a shift toward patient-centric outcome measures. Some outcomes such as length of hospital stay or rate of readmission to the hospital or poor analgesia might be of greatest interest to clinicians, whereas for patients, recovery means absence of symptoms such as nausea or vomiting, having a stoma, and the desire to perform activities as they did before surgery, to return to a state of normality, and to return to preoperative levels of independency in activities of daily living. One cannot ignore the fact that focusing on the clinical domains only and ignoring the physical, psychological, and affective domains will lead to incorrectly describing this patient as recovered from surgery. Traditional outcomes of interest to the anesthesiologists during the phase of postsurgical recovery are generally focused on biologic or physiologic processes, such as pain, respiration, and cardiovascular stability. Anesthesiologists often refer to recovery as the time required for patients to sufficiently recover from anesthesia, so that they can be safely discharged from the postanesthesia care unit (PACU) to the surgical ward. The question remains whether regional anesthesia, which focuses on providing optimal analgesia and mitigating the stress response of surgery, will have an impact beyond the immediate times of recovery. To this effect, Carli and Mayo [12] developed a causal pathway to evaluate the appropriateness of measures of surgical outcomes. In this model, any short- or long-term outcome measure must be biologically related to the intervention and should not be influenced by external factors. This feature would imply that the quality of analgesia achieved with regional blockade could influence moderate outcome measures, of physiologic and biological nature, such as mobilization, oral intake of nutrients, and activities of daily living (Fig. 1). Data on the relationship between quality of analgesia and long-term outcome measures, such as functional status and health-related quality of life, are scanty.

REGIONAL ANESTHESIA TECHNIQUES FOR ABDOMINAL SURGERY

Thoracic epidural analgesia

Analgesia

Laparotomy. TEA (T6-7 for upper abdominal incisions, T8-9 for right and left hemicolectomy, and T10-12 for rectal and pelvic surgery) remains the gold standard for postoperative pain control in patients undergoing major abdominal surgery [13]. Continuous infusion of a dilute local anesthetic and lipophilic opioids for 48 to 72 hours after surgery provides superior resting and dynamic analgesia compared with systemic opioids [14]. Furthermore, among different analgesic techniques, TEA has consistently shown preemptive analgesic properties and reduction of intraoperative opioid requirements [15]. Epidural lipophilic opioids enhance the analgesic effect of epidural local anesthetic [16], and epidural
 Morphine increases segmental analgesia [17]. Epidural adjuvants such as epidural epinephrine, 5 μg/mL, can be added to improve the quality of analgesia [18,19]. The analgesic efficacy of epidural clonidine is inconclusive, and its use has been associated with sedation and hypotension that can impair recovery [20]. TEA might be insufficient to control pain derived from surgical perianal incisions (S1-3) in patients undergoing extensive perianal-rectal surgery (eg, abdominal perianal resection). Based on the authors’ experience, a single-shot caudal anesthesia could be considered to decrease perianal and deep rectal pain and reduce opioid consumption in the first 24 hours after surgery.

_Laparoscopy._ The analgesic benefits of TEA in patients undergoing laparoscopic surgery are less evident. A recent systematic review compared the analgesic efficacy of epidural analgesia with that of systemic opioids given in the context of a MMA regimen in patients undergoing laparoscopic colorectal surgery [21]. Nonepidural analgesia techniques were found to provide satisfactory analgesia, as indicated by the average pain scores (numeric rate scores ≤4) in patients receiving epidural analgesia. These findings were also confirmed by the results of a recent RCT conducted in patients undergoing laparoscopic colorectal surgery.
surgery with an ERAS program [22]. Nevertheless, TEA might still be valuable for certain patients. For instance, after laparoscopic rectal surgery with a 9- to 10-cm Pfannenstiel-like incision to facilitate rectal dissection and through which extracorporeal anastomosis was created, postoperative pain scores in patients receiving TEA were lower in the first 48 hours compared with those in patients receiving systemic opioids and IVL infusion [23]. The decision process to establish whether TEA can be beneficial in patients undergoing laparoscopic abdominal surgery should also take into consideration the variety of currently used laparoscopic surgical approaches (eg, laparoscopic surgery vs hand-assisted laparoscopic surgery, multiple ports vs single port, intracorporeal anastomosis vs extracorporeal anastomosis). Furthermore, acknowledging individual institutional conversion rates (from laparoscopic to laparotomy) and technical epidural failure rates is also important. In fact, TEA can be beneficial in certain centers with high conversion rates, or in patients undergoing laparoscopic surgery at high risk of intraoperative conversion, whereas nonfunctioning epidurals can harm and delay recovery because they expose patients to the nonnegligible risks associated with epidural insertion without providing analgesia.

Nonanalgesic outcomes

Studies investigating the impact of regional analgesia techniques on nonanalgesic outcomes have been conducted mainly in patients receiving epidural neuraxial blockade. TEA initiated before surgery and continued during the intraoperative period has been shown to reduce postoperative insulin resistance and intraoperative anesthetic requirements and to facilitate surgical operative conditions [3]. However, despite its several physiologic advantages [3,24], the impact of TEA on postoperative outcomes remains controversial [25–27]. The results of a large multicenter RCT failed to demonstrate a reduction of postoperative 30-day mortality and overall morbidity in high-risk patients [28]. In contrast, a recent meta-analysis of 9044 patients undergoing different types of major abdominal surgical procedures with general anesthesia in conjunction with epidural analgesia (4525 patients) found that the use of epidural analgesia is associated with a 40% relative reduction of mortality (3.1% vs 4.9% for general anesthesia alone; odds ratio [OR], 0.60; 95% confidence interval [CI], 0.39–0.93) [29]. Furthermore, respiratory and cardiovascular complications were reduced, the risk of deep venous thrombosis was decreased, and the recovery of gastrointestinal function was accelerated [29]. The positive effect of epidural local anesthetics on the recovery of bowel function is well proven, making TEA a particularly appealing analgesic technique in patients undergoing bowel surgery [30,31]. Similarly, the respiratory benefits of TEA compared with those of systemic opioids are well established in patients undergoing upper abdominal surgery and in patients at high risk of respiratory complications [32]. Reduction of cardiovascular morbidity in patients undergoing major abdominal surgery (excluding vascular surgery) and receiving TEA has not been consistently demonstrated [26,27]. Advancement of perioperative
care, such as the introduction of ERAS program, and development of minimally invasive surgical techniques such as laparoscopic and robotic surgery might have reduced the physiologic benefits of TEA and minimized the impact of TEA on postoperative outcomes [3,26,27].

TEA does not reduce the length of hospital stay [33]. On the contrary, because of its common side effects such as arterial hypotension, pruritus, urinary retention, and lower limb weakness [34] hospital discharge can be significantly delayed, as recently demonstrated in patients receiving TEA and undergoing laparoscopic colorectal surgery within the context of an ERAS program [22,35]. Few studies have evaluated the effects of analgesic techniques on long-term outcomes. Carli and colleagues [36] found that after open colorectal surgery, patients treated with TEA had better pain score, had less fatigue, ambulated to a greater extent, and ate more than patients treated with systemic opioids. As a result, reduction of exercise functional capacity and health-related quality of life at 3 and 6 weeks after colorectal surgery were attenuated in patients who had received postoperative TEA. With regard to oncologic outcome, retrospectives studies have initially showed that TEA might reduce cancer recurrence and improve survival [37]. However, these results have not been further confirmed in patients undergoing colorectal surgery [38,39] and the impact of TEA on oncologic outcomes remains unknown.

**Thoracic epidural analgesia: in which patients?**

- In patients undergoing open major abdominal surgery.
- In patients undergoing laparoscopic procedures in whom alternative analgesic techniques cannot be used or do not provide satisfactory analgesia.
- In patients undergoing surgical procedures at high risk of being converted to laparotomy, or in patients at high risk of pulmonary complications.

**Intrathecal analgesia**

**Analgesia**

**Laparotomy.** IT morphine (200–400 µg in patients younger than 75 years and 150 µg in patients older than 75 years) compared with systemic opioid has shown to improve postoperative resting and dynamic analgesia (2–24 hours) and reduce 24-hour morphine consumption, particularly in patients undergoing abdominal surgery (weight mean difference [WMD], −24.2 mg; 95% CI, −29.5 to −19.0) [40]. However, analgesia with IT morphine in patients undergoing upper abdominal surgery is not superior to TEA [41]. In some studies, a less-pronounced morphine-sparing effect is also observed 48 hours after surgery (WMD, −6.5 mg; 95% CI, −9.9 to −3.2). Small doses of long-acting local anesthetic (10 mg isobaric or hyperbaric bupivacaine) are usually administered together with IT morphine to potentiate intraoperative analgesia as indicated by the reduction of anesthetic and opioid requirements [40].

**Laparoscopy.** Similar analgesic benefits have been observed in patients undergoing laparoscopic surgery [42], even when IT morphine was compared with TEA [35,43].
Nonanalgesic outcomes

Compared with systemic opioids, the risk of pruritus and respiratory depression (although rare) is increased (OR, 7.86; 95% CI, 1.54–40.3) [40]. Postoperative urinary retention is also slightly more frequent after administration of IT morphine (OR, 2.35; 95% CI, 1.00–5.51) [40]. Furthermore, hypotension in the first 12 hours after surgery has also been observed in patients receiving IT hydromorphone (with IT bupivacaine or IT clonidine) in the context of an ERAS program with a restrictive fluid management [44]. One observational study found that IT with diamorphine and local anesthetic significantly facilitates early mobilization compared with TEA in patients undergoing colorectal surgery (1 day vs 4 days, \( P < .001 \)) [43]. Although cardiovascular and respiratory morbidities are not affected, IT morphine with local anesthetic has been shown to reduce length of hospital stay in patients undergoing open [40] and laparoscopic surgery [35,43]. In particular, IT morphine has been shown to reduce length of hospital stay by 1 day compared with patients receiving TEA and undergoing laparoscopic colorectal surgery with an ERAS program [35,43]. Furthermore, IT diamorphine with local anesthetic provided optimal analgesia for 10 patients undergoing laparoscopic colectomy that involved a 23-hour length of stay and treated with an ERAS program [45].

The impact of IT analgesia on long-term outcomes has been evaluated in one study [46]. Health-related quality of life recovered faster and time to return to daily activity (sick leave) was shorter in patients receiving spinal anesthesia with IT morphine compared with patients receiving general anesthesia after abdominal hysterectomy for benign lesions [46].

Intrathecal analgesia: in which patients?

- In patients undergoing open abdominal surgery in whom TEA is contraindicated. Caution should be used in elderly patients and in patients with chronic obstructive pulmonary disease.
- In patients undergoing laparoscopic colorectal surgery, especially in the context of an ERAS program.

Intravenous lidocaine

Analgesia

In view of its systemic analgesic and antiinflammatory properties, IVL infusion has been used as an analgesic adjuvant to improve postoperative analgesia after open and laparoscopic abdominal surgery [47–49]. The levels of common proinflammatory cytokines that promote central and peripheral sensitization such as interleukin (IL)-6, IL-1β, and IL-1 receptor antagonist are reduced by the infusion of IVL. Furthermore, IVL prevents excessive activation of inflammatory cells, by inhibiting the expression of CD11b/CD18 protein, a member of the integrin family, which has a central role in neutrophil adhesion and priming of respiratory burst [50]. Different regimens have been used in the perioperative setting [49]. A 1.5-mg/kg bolus of IVL (ideal body weight [IBW]) is commonly given within 30 minutes before surgery, and an infusion of 2 mg/kg/h (IBW) is continued until the end of surgery. The infusion can also be continued in
PACU and stopped before PACU discharge, because continuous cardiovascular monitoring is required. Local anesthetic systemic toxicity is rare.

Laparotomy. IVL as an adjuvant analgesic to systemic opioids has been shown to improve postoperative analgesia, at rest, on coughing, and during movements, and to reduce opioid consumption, mainly in the early (≤24 hours) postoperative period [48,49]. Few studies have shown a longer analgesic effect [51], but these results have not been consistently reproduced. One study compared the analgesic efficacy of IVL with TEA in patients undergoing open colorectal surgery. Pain scores were similar between the 2 groups, but the study was underpowered to conclude that IVL provides equivalent analgesia as TEA. Furthermore, the 2 groups were not equally compared, because IVL infusion was initiated before surgery and continued throughout the intraoperative and postoperative period, whereas TEA was started only within 1 hour after the end of surgery [52].

Laparoscopy. Similar analgesic benefits, but to a lesser extent, have been shown in patients undergoing laparoscopic abdominal surgery [47,53–55], when compared with systemic opioids, but not with TEA [23].

Nonanalgesic outcome
IVL accelerates the recovery of bowel function and reduces the incidence of postoperative nausea and vomiting when compared with systemic opioids [47,48]. However, recovery of bowel function is similar to those of patients receiving TEA and undergoing laparoscopic colorectal resection using an ERAS program [23].

The results of 2 meta-analysis including 9 [49] and 8 RCTs [48] conducted in abdominal surgery have demonstrated that length of hospital stay is shortened by less than 1 day in patients receiving IVL. Nevertheless, these results need to be further validated, because most studies included were not performed in the context of an ERAS program. IVL has also been shown to reduce postoperative fatigue after colorectal surgery [47] and enhances functional exercise capacity after laparoscopic prostatectomy [53].

Finally, it has been suggested that IVL has antitumor properties because in vitro IVL demethylates DNA of specific breast cancer cell lines at clinically relevant concentrations and in a dose-dependent manner [56]. The clinical relevance of this finding remains to be determined.

Intravenous lidocaine: in which patients?
- In patients undergoing open abdominal surgery in whom neuraxial blockade is contraindicated.
- In patients undergoing laparoscopic abdominal surgery, especially in the context of an ERAS program.

Abdominal truncal blocks: transversus abdominis plane block and rectus sheath block
Analgesia
Abdominal truncal blocks, such as TAP blocks and rectus sheath (RS) blocks, have been used to control somatic surgical pain originating from the skin,
muscles, and parietal peritoneum of the abdominal wall. TAP blocks have been described several years ago to provide analgesia of the abdominal wall. Using as landmarks the borders of the lumbar triangle of Petit, local anesthetics (15–20 mL of long-acting local anesthetic per side) were injected in the fascial plane between the internal oblique and transversus abdominis muscles with the aim of blocking the anterior rami of the thoracic-lumbar nerves T7-L1 [57]. A blind double-pop posterior technique was originally used, but today TAP blocks are mainly performed under ultrasound guidance. Despite the original cadaveric dye and volunteer radiological (MRI) contrast study by McDonnell and colleagues [57] that demonstrated that dermatomal spread following single-injection TAP block performed blindly at the level of the triangle of Petit was between T7 and L1, clinical studies were not able to reproduce these findings. On the contrary, dermatomal spread of local anesthetic after ultrasound-guided single-injection lateral TAP blocks is on an average limited to 1 to 3 dermatomes [58–60], and it does not always follow a dermatomal distribution [61]. For these reasons, posterior [57], lateral [62], subcostal [59], and lateral to medial [63] TAP block approaches, alone or in combination, have been described to provide analgesia in different anatomic distributions of the anterolateral abdominal wall. TAP blocks can also be performed by surgeons either directly from the abdominal cavity before closing the abdominal wall [64,65], or under laparoscopic visualization [66–70]. Optimal timing, local anesthetic dosing, and volumes remain unknown [71].

RS blocks are useful to control pain arising mainly from periumbilical incision. Although a blind double-pop technique was also originally described, currently, local anesthetics (10 mL of long-acting local anesthetic per side) are injected under ultrasound guidance between the rectus abdominis muscle and its posterior fascia to block the 9th 10th, and 11th intercostal nerves. Limited evidence is available to establish the analgesic efficacy of RS block and the impact on nonanalgesic outcomes in patients undergoing abdominal surgery.

**Laparotomy.** Single-shot ultrasound-guided TAP blocks as adjuvant analgesics to systemic opioids have been shown to reduce postoperative pain scores and opioid consumption, mainly in the first 24 hours after surgery [72–74]. These analgesic benefits persist up to 48 hours after surgery if TAP blocks are performed using a landmark-based posterior approach, but not when using an ultrasound-guided lateral approach [62]. Analgesia can be also prolonged up to 48 to 72 hours by inserting multiorifice catheters in the TAP and either continuously infusing or intermittently bolusing local anesthetics [75–77]. The analgesic efficacy of TAP block in patients has also been compared with that of patients receiving TEA while undergoing upper abdominal surgery. Pain scores in the first 72 hours, at rest and on coughing, in the TEA group were not higher than the pain scores in the continuous subcostal TAP block group [78]. However, TAP failure rates were high (30% vs a 22% technical...
failure rate for TEA), and 45% of the TAP catheters had to be replaced in the postoperative period, raising concerns about the stability of TAP catheters.

Laparoscopy. Reduction of opioid consumption and pain scores in the early postoperative period (<24 hours) was observed in patients receiving single-shot TAP blocks compared with patients receiving systemic opioids alone [79]. These analgesic benefits are dose dependent and more pronounced if TAP blocks are performed before surgery [79]. TAP blocks also provide superior analgesia at 24 and 48 hours after laparoscopic colorectal surgery than wound infiltration with local anesthetic [80]. Similar analgesic advantages have also been observed in the context of MMA in patients treated with an ERAS program [66–68]. A recent RCT showed that the analgesic efficacy of 4-quadrant TAP blocks (subcostal and lateral on each side), followed by bilateral posterior continuous TAP block, was not inferior to continuous TEA after laparoscopic colorectal surgery. However, 13% of the patients that received TEA and 7% of patients who received TAP blocks required patient-controlled analgesia with intravenous morphine because of inadequate analgesia. Moreover, systemic opioid consumption was not reported in either group [78].

Nonanalgesic outcomes
In view of its opioid-sparing properties, some studies have reported a reduction of some opioid-related side effects such as nausea, vomiting, and sedation when TAP blocks were used [65, 73, 81], but these results have not been consistently reproduced especially in the context of an ERAS program. Urinary catheters were removed significantly earlier (28 hours) in patients receiving continuous bilateral TAP block than in patients receiving TEA [78].

TAP blocks do not shorten the length of hospital stay [66–68] but may facilitate early discharge after laparoscopic colorectal surgery within an ERAS pathway [69]. In fact, bilateral single-shot TAP block, as part of MMA with intravenous acetaminophen and nonsteroidal antiinflammatory agents, within the context of an ERAS program, has been used to comfortably discharge 35 patients 23 hours after laparoscopic colorectal surgery [69].

Transversus abdominis plane block: in which patients?
• In patients undergoing open abdominal surgery in whom neuraxial blockade is contraindicated.
• In patients undergoing laparoscopic colorectal surgery, especially in the context of an ERAS program.

Continuous wound infusion of local anesthetic
Analgesia
Laparotomy. Continuous wound infusion (CWI) of local anesthetic as adjuvant to systemic opioids after open abdominal surgery has shown to improve postoperative analgesia and reduce opioid consumption [82, 83]. Subfascial catheters (in particular catheters placed between the transversalis fascia and the closed parietal peritoneum) seem to provide better analgesia than suprafascial catheters [84]. Two recent RCTs have compared the analgesic efficacy of
CWI of local anesthetic with that of TEA, but the results are contrasting [85,86]. Inconclusive results were also found by a meta-analysis including 9 RCTs comparing CWI of local anesthetic with epidural analgesia because the heterogeneity of the included studies was high [87]. Anatomic abnormalities of the abdominal wall, for example, because of previous abdominal surgeries, might limit the insertion of preperitoneal catheters.

**Laparoscopy.** A recent feasibility study has compared the analgesic efficacy of CWI of local anesthetic with TEA after laparoscopic colorectal surgery. Postoperative pain intensity was similar among patients receiving TEA and CWI of local anesthetic [88].

**Nonanalgesic outcomes**

Limited and contrasting evidence is available to establish the impact of CWI of local anesthetic on nonanalgesic outcomes [84–87,89,90].

**Continuous wound infiltration of local anesthetic: in which patients?**

- In patients undergoing open abdominal surgery in whom neuraxial blockade is contraindicated.

**Instillation of intraperitoneal local anesthetic**

**Analgesia**

Instillation of IPLA into the abdominal cavity was first described for open procedures and later adopted for laparoscopic surgery.

**Laparotomy.** Local anesthetics are usually administered in the abdominal cavity at the anatomic site where surgical dissection occurs. Intra-abdominal catheters can be also left in situ, and local anesthetic is infused in the postoperative period. The dose, volume, and type of local anesthetic used varies significantly [91]. A meta-analysis including 8 RCTs (abdominal and gynecologic surgery) comparing IPLA with no IPLA or placebo found a reduction of pain scores but not of opioid consumption in patients receiving IPLA [91]. Subsequently, in an RCT, the same research group compared TEA combined with IPLA (bolus plus local anesthetic infusion through intra-abdominal catheters) with TEA alone in patients undergoing open colectomy within a context of an ERAS program. Pain scores and systemic opioid use were found to be reduced in patients treated with the addition of IPLA [92].

**Laparoscopy.** IPLA instilled or nebulized through the trocars has shown to reduce pain scores, shoulder pain, and opioid consumption after laparoscopic gastrostomies [93]. Similar benefits were observed after laparoscopic cholecystectomies but not after other types of laparoscopic abdominal and gynecologic procedures [94].

**Nonanalgesic outcomes**

Reduction of systemic cytokines, cortisol, and glucose levels after IPLA has been observed as a result of intraperitoneal deafferentation [91,92]. Bowel
function also seems to recover faster, but only some data are available [91,92]. Instillation of IPLA in addition to TEA has also shown to improve early surgical recovery after open colectomy in the context of an ERAS program [92].

**Intraperitoneal local anesthetic: in which patients?**
- In patients undergoing open and laparoscopic abdominal surgery

**Multimodal analgesia**

As surgical pain is complex, multiple analgesic strategies with different mechanisms of actions, including regional anesthesia techniques, synergistically reduce postoperative pain, systemic opioid consumption, and side effects. Opioid-related side effects are dose dependent and significantly affect surgical recovery [95], especially in the context of an ERAS program. For instance, the achievement of common ERAS milestones such as early nutrition, avoidance of nasogastric tube, and early removal of urinary catheters can be clearly impeded if patients vomit, are feeling bloated, are feeling drowsy and sedated, and cannot spontaneously urinate. Several medications are common used. Acetaminophen (per os or intravenously), in conjunction with nonsteroidal antiinflammatory drugs (NSAIDs) or cyclooxygenase 2 inhibitors, are common multimodal strategies that have shown to improve postoperative analgesia and reduce opioid consumption [96,97]. NSAIDs have also shown to reduce postoperative opioid-related side effects [96]. However, concerns have been raised about the risk of anastomotic leakage associated with the perioperative use of NSAIDs [98,99]. Ketamine has also demonstrated opioid-sparing properties and the ability to improve the quality of postoperative analgesia. However, its role in the context of an ERAS program remains to be determined [100]. The role of gabapentinoids as multimodal analgesic agents remains unknown, as well as the perioperative regimen (timing and dosage) associated with optimal outcomes [101]. Local anesthetic wound infiltration with liposomal bupivacaine has shown promising results after open [102] and laparoscopic [103] surgery but clearly requires validation in both efficacy-based RCTs and effectiveness-outcomes-based research.

**Multimodal analgesia: in which patients?**
- In every patient undergoing abdominal surgery.

**SUMMARY**

This article has highlighted the most common regional anesthetic techniques used in abdominal surgery and the important role of regional anesthesia in contributing to ERAS programs. Several modalities should be implemented, taking into consideration the different types of surgical procedures, the perioperative pathways, and the individual needs of patients (Fig. 2). The adoption of regional anesthesia and analgesia techniques requires leadership and commitment from the anesthesia community in implementing the multimodal program and auditing the results. The high quality of training in regional...
anesthesia and the advances in technology represent a great opportunity for formulating new questions and assessing novel techniques that need to be integrated in the present and future clinical practice. Much research in regional anesthesia is directed toward assessment and refinement of block techniques with less focus on impact of these novel approaches on patient outcomes, which is the key to enhanced recovery, thus shifting from a physician-centric model to a patient-centric model. Based on the understanding that the practice of anesthesia is integrated into perioperative medicine, there is a strong movement to push for anesthesiologists as leaders of surgical homes; this cannot happen if the anesthesiologist continues to remain a passive observer in front of the continuing evolution of perioperative medicine and is isolated in the operating room while surgical innovations (robotic and endoscopic techniques [104]) are introduced in clinical practice. There is a need for the anesthesiologist to participate in what has become a new paradigm, advancing the cause for enhanced patient recovery, while minimizing perioperative complications safely and decreasing associated health care costs. This demand implies that the notion of recovery goes beyond the provision of good analgesia and a proficient technique, in the sense that the analgesic intervention needs to be chosen for a specific procedure and according to the needs of accelerating the recovery process previously discussed and agreed upon with the perioperative team.

Fig. 2. Regional anesthesia, including different techniques, as individual ERAS element. CHO, carbohydrate; CWI, continuous wound infusion; IPLA, intraperitoneal local anesthetic; IT, intrathecal; IVL, intravenous lidocaine; LA, local anesthetic; NG, nasogastric; NSAIDs, nonsteroidal antiinflammatory drugs; premed, premedication; prep, preparation; TAP, transversus abdominis plane; TEA, thoracic epidural analgesia. (Adapted from Fearon KC, Ljungqvist O, Von Meyenfeldt M, et al. Enhanced recovery after surgery: a consensus review of clinical care for patients undergoing colonic resection. Clin Nutr 2005;24(3):466–77; with permission.)
References


