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REVIEW ARTICLE/BRIEF REVIEW

Review of the enhanced recovery pathway for children: perioperative anesthetic considerations

Les programmes de récupération rapide pour les enfants: considérations anesthésiques périopératoires

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Abstract

Purpose *Enhanced recovery after surgery (ERAS) pathways have been used for two decades to improve perioperative recovery in adults. Nevertheless, little is known about their effectiveness in children. The purpose of this review was to consider pediatric ERAS pathways, review the literature concerned with their potential benefit, and compare them with adult ERAS pathways.*

Source *A PubMed literature search was performed for articles that included the terms enhanced recovery and/or fast track in the pediatric perioperative period. Pediatric patients included those from the neonatal period through teenagers and/or youths.*

Principal findings *The literature search revealed a paucity of articles about pediatric ERAS. This lack of academic investigation is likely due in part to the delayed acceptance of ERAS in the pediatric surgical arena. Several pediatric studies examined individual components of adult-based ERAS pathways, but the overall study of a comprehensive multidisciplinary ERAS protocol in pediatric patients is lacking.*

Conclusion *Although adult ERAS pathways have been successful at reducing patient morbidity, the translation, creation, and utility of instituting pediatric ERAS pathways have yet to be realized.*

Résumé

Objectif *Les programmes de récupération rapide après la chirurgie (RRAC, connus aussi sous l'acronyme ERAS) sont utilisés depuis une vingtaine d'années pour améliorer la récupération périopératoire des adultes. Nous ne connaissons toutefois que peu de choses concernant leur efficacité auprès des enfants. L'objectif de ce compte-rendu était d'examiner les programmes pédiatriques de RRAC, de passer en revue la littérature touchant à leurs avantages potentiels, et de les comparer aux programmes de RRAC destinés aux adultes.*

Source *Une recherche de la littérature a été réalisée sur PubMed afin d'identifier les articles comprenant les termes « récupération rapide » ('enhanced recovery' et/ou 'fast track') en période périopératoire pédiatrique. Les patients pédiatriques étaient définis comme étant des patients allant de la période néonatale à l'adolescence.*

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Constatations principales *La recherche de littérature a révélé très peu d'articles touchant à la RRAC pédiatrique. Cette absence de recherches académiques est probablement due en partie à l'acceptation tardive des programmes de RRAC dans le domaine de la chirurgie pédiatrique. Plusieurs études pédiatriques ont examiné des composantes individuelles des programmes de RRAC dédiés aux adultes, mais l'étude globale d'un protocole de RRAC multidisciplinaire complet auprès de patients pédiatriques n'existe pas.*

Conclusion *Bien que les programmes de RRAC appliqués chez l'adulte soient parvenus à réduire la morbidité des patients, le transfert, la création et l'utilité de la mise en œuvre de tels programmes chez l'enfant doivent encore avoir lieu.*

One of the primary goals of an enhanced recovery after surgery (ERAS) pathway is to promptly return the patient to baseline function by maintaining preoperative organ function and attenuating the neuroendocrine stress response after surgery. Many components comprise a typical enhanced recovery pathway, including avoidance of prolonged fasting and oral carbohydrate loading preoperatively, early mobilization, early enteral nutrition, and patient education. Additional anesthesia-related strategies may involve implementation of a standardized anesthetic regimen that includes regional anesthesia, multimodal opioid-sparing analgesia, antiemetic prophylaxis, intraoperative goal-directed fluid therapy, and strict thermoregulation. These components of ERAS pathways have been developed, and assessed to varying degrees, in adult patients. Although some consideration has been given to the development of pediatric ERAS protocols, there are unique challenges to the interpretation of surgical outcomes data in this patient population. Primarily, the burden of morbidity and the adverse postoperative events in pediatric surgical patients differ from those of adults and thus present challenges to determining the focus of quality improvement initiatives such as ERAS pathways. The purpose of this study was to consider the concept of pediatric ERAS and identify significant differences between the pediatric and adult populations.

Adult evidence

For the past two decades, ERAS has been implemented and assessed in the adult population. Most randomized controlled trials have focused on patients undergoing colorectal surgery. Meta-analyses consistently show that use of an ERAS pathway (*vs* conventional care) is associated with many benefits, including a decreased length of stay (LOS) by approximately two to three days, and reductions in overall perioperative morbidity and complication rates.[1,2] Nevertheless, no improvements are typically noted in mortality or readmission rates.[1,2] Similar benefits of ERAS pathways have been shown for other surgical procedures, including liver resection and pancreaticoduodenectomy.[3-5]

Enhanced recovery after surgery pathways may confer other benefits, such as improvements in the quality of recovery and patient satisfaction. In a study that compared ERAS and conventional management in patients undergoing open colon surgery, ERAS patients had faster rehabilitation, decreased hospital LOS, and better short-term quality of life (physical, emotional, cognitive, and social functioning).[6] In gynecological patients undergoing an ERAS-type pathway, patients reported higher levels of satisfaction with their care.[7,8] The financial models for ERAS protocols also may be favourable because of the reduced hospital LOS and improved surgical outcomes.[9] Finally, implementation of ERAS pathways has been associated with some unanticipated benefits, such as a decrease in surgical site infections[8] and improved five-year cancer-specific survival after colorectal cancer surgery.[10]

Pediatric experience

We performed a PubMed search for relevant articles related to enhanced recovery in the pediatric perioperative period. Search terms included "enhanced recovery", "fast track", "pediatric", "youth", "postoperative", and others (see Appendix for full list of key words searched). Age groups included the neonatal through the teen interval.

We identified two evidence-based reviews of pediatric ERAS pathways. Shinnick *et al.*[11] published a systematic review of one retrospective and four prospective cohort studies that encompassed 502 children ages 2.3 months to 18 yr and included elements of enhanced recovery programs (e.g., preoperative counseling, minimized perioperative fasting, standardized anesthetic protocol, and avoidance of postoperative nasogastric tube). These were all nonrandomized studies that included a variety of procedures. The studies were not well controlled and incorporated fewer than six interventions (compared with over 20 interventions in most adult ERAS pathways). Based on these investigations, it is impossible to precisely identify changes that should be made to current clinical practice. Nevertheless, the systematic review indicated that pediatric ERAS pathways in appropriate surgical

populations may reduce hospital LOS and perioperative opioid use.[11]

In the second evidence-based review we identified, Pearson and Hall[12] examined nine studies (1,269 patients) that consisted of three case control studies, one retrospective review, and five prospective implementations. Enhanced recovery after surgical interventions included postoperative feeding and mobilization protocols, opioid-sparing analgesia, and limited postoperative use of nasogastric tubes and urinary catheters. Enhanced recovery after surgery pathway implementation was associated with reduced hospital LOS (6/7 studies), reduced time to oral feeding (3/3 studies), and earlier return of bowel function (2/3 studies).

Based on the relatively substantial literature related to adult surgical patients and a modicum of evidence from pediatric-related articles, instituting pediatric enhanced recovery protocols seems reasonable. The data suggest that pediatric ERAS pathways have the potential to improve clinical outcomes by shortening the hospital LOS, decreasing perioperative opioid consumption, increasing patient and parent satisfaction, and possibly decreasing perioperative morbidity. Nonetheless, it is essential to identify and understand some key differences between the pediatric and adult populations so that the pediatric pathways can be appropriately tailored.

In general, infants and children who undergo surgery experience lower rates of morbidity and mortality than do adults.[13] It is difficult to compare pediatric and adult surgical patients, however, as they have very different spectrums of underlying comorbidities and functional status. Moreover, these populations differ in the type and proportional volume of surgical procedures they undergo. The heterogeneity in the age and stage of physiologic or neurologic development in pediatric patients further hinders direct comparison. Many of these issues, which underlie the reasons why it is so difficult to extrapolate pediatric surgical outcomes from adult platforms, were considered during the initial development of the American College of Surgeons National Surgical Quality Improvement Pediatric Program (NSQIP-P).[14]

Bearing in mind differences in patient characteristics, co-morbidities, and surgical procedures, one must consider how current adult ERAS principles can be adapted to children. Preoperatively, pediatric evidence supports age-appropriate education, avoidance of prolonged fasting, carbohydrate loading, standardized bowel preparation, antibiotic prophylaxis, and nonopioid pain adjuncts. Intraoperatively, nonopioid pain adjuncts are used in combination with regional techniques to reduce perioperative narcotic administration and pain scores. Postoperatively, avoidance of Foley catheters and nasogastric tubes facilitates early mobilization and early oral nutrition. Thromboembolism prophylaxis and goal-directed fluid therapy are not supported by the pediatric literature and are not routinely included in pediatric enhanced recovery pathways. The currently available pediatric literature that supports the implementation, or exclusion, of adult ERAS principles into pediatric practice is discussed below and summarized in the Table.

Education

Adult preoperative educational programs were begun in the 1960s, and pediatric preoperative educational programs followed in the mid to late 1970s. Early preoperative educational programs were based on the assumption that they would decrease patient anxiety. Initially, it was assumed that providing preoperative information would be straightforward; however, it proved to be quite challenging in children. The educational content, method of delivery, and timing in relation to the surgical procedure may vary from institution to institution and among individual providers. Regardless of these variables, the educational material should be specific, accurate, and age appropriate.

In 2009, a survey indicated that children want specific procedural information, including pain expectations, and an opportunity to ask questions.[15] Some effective methods to convey the information include peer modeling, which provides an opportunity for children to learn social skills or information from peers during an activity, and written information with illustrations.[16-18] Medical play—allowing children to play with commonly used medical equipment such as stethoscopes, hats, gloves, masks, or blood pressure cuffs—in the preschool age group and written information alone are insufficient.[19] The prescriptive model offered by Blount *et al.*[20] recommends providing children with the pertinent information before scheduling the procedure and minimizing new information on the day of (or during) the procedure. Optimal timing of information delivery is essential to help decrease anxiety and negative fantasizing. Children over the age of six should receive information more than five days in advance, whereas younger children should receive information closer to the time of the procedure.[21,22] Because parental anxiety on the day of surgery is linked to increased child anxiety, it is important to include parents in the preoperative educational process.[23,24]

Fluid management

Fluid management, in the context of enhanced recovery after surgery pathways, is often described as a continuum through the pre-, intra-, and postoperative phases of care.[25] The avoidance of prolonged fasting and oral carbohydrate

Table Adaptation of standard ERAS principles to children based on the current evidence

Adult ERAS principles	Adaptability to pediatric patients	Supporting evidence
Preoperative		
Preadmission counseling and education	Included	Fortier, Klingman, Jaaniste, Kain[15,16,18,21]
Fluid and carbohydrate loading; no prolonged fasting	Gatorade®/Pedialyte® 2 hr before surgery	Gawecka[71]
Standardized bowel prep, if needed	Antibiotic + mechanical prep	Kiran[33]
Reduction of surgical site infection risk	Antibiotic prophylaxis	Sandora, Slusher[72,73]
Anxiolytic premedication	Often given rather than avoided	Lambert[43]
	Midazolam	
	Clonidine	
Nonopioid pain adjuncts	Gabapentin (PSF)	Rusy[41,42]
	Acetaminophen	Romej
Intraoperative		
Nonopioid pain adjuncts	Low-dose ketamine	Shay[54-56]
	Diazepam	Gornitzsky
	Butorphanol	Arora
Neuraxial or peripheral nerve block	Included, assuming no contraindication	Goeller[74]
Thromboembolism prophylaxis	Age and surgery dependent	National Guideline (BESt) summary[57]
Avoidance of salt and water overload	IVF selection on case-by-case basis	Schroeder[75,76]
	Fluid balance evidence for cardiac surgery	Hassinger
Maintenance of normothermia	Included	Kurz[38,77]
		Arndt
Blood transfusion minimization	Tranexamic acid infusion (PSF)	Sui[78]
BIS monitoring	Excluded-controversial	Ganesh, Denman[79,80]
Postoperative		
Pain control from regional technique	Epidural or peripheral nerve catheter infusion	Goeller[74]
Nasogastric tube avoidance	Included	Lacking evidence
Prevention of nausea and vomiting	Included	Smith's Textbook of Pediatric Anesthesia[81]
Early removal of urinary catheter	Included, except if epidural catheter infusion is used	Xu, Thomas[59,60]
Early oral nutrition	Included	Adibe[58]
Nonopioid analgesia	Diazepam	Shay
	Butorphanol	Gornitzky
	IV acetaminophen	Ziolkowski[54,55,82]
Early mobilization	Included	West[83]

BIS = bispectral index; IV = intravenous; IVF = intravenous fluid; PSF = posterior spinal fusion

preloading allows children to enter the operating room in a euvolemic state avoiding excess salt and water administration.[25] In adults, the goal is to maintain a "zero balance" in low-risk patients undergoing low-risk procedures, which reduces the time to oral intake, the time to first bowel motion, postoperative nausea and vomiting, overall rate of complications, and hospital LOS.[26-28] Randomized controlled trials have failed to show the efficacy of goal-directed fluid therapy within the setting of adult enhanced recovery protocols; therefore, current perioperative fluid management in children is provider and institution dependent.

Bowel preparation

Another difference between pediatric and adult patients is in the preoperative bowel preparation, for which little consensus exists among pediatric providers.[29] In adults, foregoing mechanical preoperative bowel preparation alone does not increase the risk of wound infection.[30-32]

Investigators in the field of adult colorectal surgery have shown that preoperative mechanical bowel preparation combined with oral antibiotics does reduce complications.[33] Although this finding has yet to be replicated in the pediatric literature, there is no obvious reason it should not be applicable.

Surgical site infection

Surgical site infection is one of the highest reported morbidities in pediatric surgical patients,[34] especially in those undergoing colorectal procedures[35] and spinal fusions.[36,37] Care pathways based on evidence synthesis have been proposed to improve outcomes through standardization of care and reduction of system- and provider-level variability. Pathways may incorporate maintenance of normothermia[38]; chlorhexidine baths the night before surgery; preoperative oral antibiotics; a methodical, timed, pre-surgery skin preparation in the operating room with chlorhexidine; and changing surgical gloves after completing portions of the procedure that could cause contamination (e.g., after bowel anastomoses). Although such pathways can improve outcomes, they have not been widely adopted.[11,39,40]

Analgesia

The goal of using multimodal opioid-sparing analgesia to minimize perioperative opioid requirements applies to both pediatric and adult patients. Pediatric patients are commonly premedicated with acetaminophen,[41] midazolam, gabapentin,[42] or clonidine[43] for postoperative pain reduction, which reduces overall opioid administration, and anxiolysis.

Intraoperatively, a rectus sheath and/or transabdominal plane blocks are performed for laparoscopic or minimally invasive procedures. In infants and young children undergoing open abdominal procedures, caudal catheters are commonly used. After the age of six years, the position of the sacrum changes in relation to the lumbosacral spine; therefore, an epidural catheter is placed. Local anesthetics are often combined with adjuvants such as dexamethasone, opioids, or clonidine to prolong postoperative analgesia. The addition of dexamethasone, whose use has not been well researched in the pediatric population, reduces pain severity and analgesic consumption for up to 48 hr postoperatively.[44] Opioids, such as fentanyl, enhance existing dermatomal spread and are particularly useful in patients with unilateral blocks,[45] but opioids, which are classically minimized in ERAS pathways, are not initially ordered in the epidural infusion. In the past, ketamine was used as an epidural adjunct; however, current pediatric evidence suggests that ketamine may be neurotoxic and promote premature apoptosis.[45]

Enteral opioid-sparing analgesics include alpha agonists and acetaminophen. The most commonly used alpha agonist is clonidine. A 1-3 $\mu g \cdot kg^{-1}$ dose three to four times daily can decrease postoperative analgesic requirements.[46] Rectal administration of acetaminophen is often discouraged because of its unreliable absorption and the excessively high doses (35-45 $mg \cdot kg^{-1}$) needed to achieve a sustained therapeutic plasma concentration.[47-49] Rectal administration is also ill advised for children who have undergone rectal surgery. On the other hand, intravenous administration of acetaminophen has a well-established role and has been shown to decrease postanesthesia care unit LOS, over-sedation, and total opioid consumption.[50-52] Access to the intravenous formulation of acetaminophen may be challenging based on the provider's geographic location, institutional pharmacy, or expense limitations. Depending on the surgical procedure and postoperative bleeding risk, intravenous ketorolac may be considered. Its analgesic efficacy is similar to that of morphine, and it can help reduce the incidence of opioid-associated postoperative nausea and vomiting.[53] Other options for intravenous non-opiate analgesia include low-dose ketamine infusions, intermittent diazepam,[54,55] and butorphanol[56] injections.

Thromboembolic prophylaxis

In general, there is varying consensus regarding thomboembolism prophylaxis in younger children. The National Guideline Clearinghouse summary recommends that for children ages ten to 17 yr undergoing a procedure that will last more than 60 min, a sequential compression device should be placed and started at the time of anesthesia induction for thromboembolism prophylaxis.[57] Nevertheless, these guidelines are based in part on the adult literature and are not routinely implemented into daily practice in the United States, Canada, or the United Kingdom. Preoperatively, children should be evaluated for venous thromboembolism risk factors, stratified into the appropriate risk category, and assessed to determine whether other interventions, such as perioperative administration of anticoagulants (e.g., heparin), are warranted.[57] Currently, thromboembolic prophylaxis for pediatric enhanced recovery patients is being discussed, but not routinely included in implemented protocols.

Omission of nasogastric feeding tubes, catheters, and drains

Early postoperative oral intake is important for both pediatric and adult patients. In pediatric patients, early

enteral nutrition and mobilization have been correlated with quicker resumption of full feeding and have not been shown to affect readmission rates.[12,58] Unlike findings in the adult surgical literature, several studies in pediatric patients have shown that the omission of catheters, drains, and tubes in selected procedures is appropriate. For instance, children who underwent hypospadias repair without an indwelling urethral catheter exhibited no increase in risk of postoperative meatal stenosis, urethral stricture, or fistula formation.[59] Additionally, children without indwelling urethral catheters reported less pain secondary to bladder spasms and/or urinary tract infection postoperatively.[59,60]

Outcomes assessments

Though standardization of processes is important, ultimately the goal of enhanced recovery protocols is to improve patient outcomes and experience. Therefore, as part of protocol implementation, it is important to select metrics that are likely to be affected (either positively or negatively) by the pathway and ensure that they can be measured. Surgical performance measurement is complex, and national debate continues regarding how it can be achieved. To date, outcome data considered to be the most reliable are from clinical registries. In pediatric surgery, the most robust registry is the American College of Surgeons Pediatric National Surgical Quality Improvement Program (Peds ACS NSQIP), which measures risk-adjusted 30-day outcomes after surgery in a sample of patients. A dedicated nurse who reviews the inpatient and outpatient surgical record abstracts the data and, when needed, contacts patients and their family members directly. All data points have detailed definitions, and data collection subsequently undergoes an inter-rater reliability audit to ensure accuracy.

Outcomes measured by Peds ACS NSQIP that may be impacted by enhanced recovery protocols include unplanned re-intubations (especially in the neonatal age group), the setting and severity of event occurrences (for instance, was the event linked to cardiac arrest), blood transfusion frequency, surgical site infection/wound dehiscence, 30-day readmission rate after hospital discharge, and LOS. Peds ACS NSQIP requires a significant institutional commitment (program subscription and nurse for data abstraction), which, in many cases, may be cost prohibitive; therefore, if ACS NSQIP is not available at an institution, LOS and readmission data can be obtained from administrative data sources and hospital administrators.[61] Because pediatric ERAS protocols are in their infancy, it is important to monitor outcomes and make further adjustments to the pathways accordingly.

Length of stay is a key metric affected by the implementation of an ERAS pathway. In colorectal surgery, opioid-sparing analgesia protocols and goal-directed intraoperative fluid management strategies are both associated with a reduction in postoperative ileus,[62,63] the most common reason for prolonged hospitalization after gastrointestinal surgery.[64] With any program that aims to reduce LOS, it is also important to monitor the hospital readmission rate because premature discharge may result in re-hospitalization. Assessments have shown that adult ERAS programs are, in fact, associated with a reduction in hospital readmissions. This reduction is likely related to improved patient engagement and a decrease in complications such as surgical site infections.[65] The mechanism(s) for reduction in surgical site infection remain unclear in the adult literature. It may involve enhanced fidelity to evidence-based surgical site infection prevention bundles such as a chlorhexidine bath the night before surgery, standardized preoperative oral antibiotics, and surgical field preparation[66] or avoidance of drugs that suppress immune function (e.g., opioids, ketamine, inhaled anesthetics).[67-69]

As a part of enhanced recovery protocols, increasing focus is being placed on the patient experience and patient and family engagement. Both adult and pediatric patients may be surveyed about their hospital experience with the Hospital Consumer Assessment of Healthcare Providers and Systems (HCAHPS, a registered trademark of the Agency for Healthcare Research and Quality, a United States Government Agency), and the hospital's performance can be shared publically on the Hospital Compare website. In the United States, many hospitals also have a portion of their reimbursements tied to performance on this survey.[70] Implementation of patient and family education programs as part of ERAS pathways has had a positive impact on HCAHPS performance for adult patients.[65] Currently, the only validated hospital satisfaction survey for children under age 17 is the CAHPS Child Hospital survey. It was developed at the Boston Children's Hospital, but is not in widespread use. It is anticipated that the CAHPS Child Hospital Survey will make the collection and interpretation of pediatric ERAS pathway data more feasible.

The variability in outcomes (LOS, readmission, and surgical site infection rates) among pediatric patients undergoing colorectal surgery is less than that for adults. When initiating a pediatric colorectal ERAS pathway, it is important to consider that improvement may be harder to detect because the baseline for adverse events in children is already lower than it is in adults, although LOS for pediatric patients undergoing colorectal surgery is often higher. Regardless of the type of pathway, it is important to consider new potential areas of improvement and how they

can be measured in children. Over time, new enhanced recovery outcome measures for children may evolve.

Future directions and research

The dearth of published research regarding the success of pediatric ERAS initiatives is noteworthy. The literature clearly illustrates the success of adult ERAS pathways, but the translation, creation, and utility of instituting pediatric ERAS pathways have yet to be determined. Because of the wide developmental range of pediatric patients, the associated pediatric ERAS pathways may require stratification by age group and surgical indication. Once a pathway is instituted, effectiveness must be evaluated to optimize patient outcomes.

Conflicts of interest None declared.

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Author contributions *Jessica A. George* was involved in the overall manuscript writing including the sections on pediatric evidence, pediatric enhanced recovery after surgery (ERAS) pathway components, and future directions. *Rahul Koka* was involved in the perioperative pediatric ERAS components. *Tong J. Gan* was involved in the adult ERAS literature comparison and guidance on pediatric *vs* adult ERAS components. *Eric Jelin* was involved in the surgical components of pediatric enhanced recovery pathways. *Emily F. Boss* was involved in the pediatric portion of introduction and outcomes measures. *Val Strockbine* was involved in the pediatric literature review. *Deborah Hobson* was involved in outcomes assessment. *Elizabeth C. Wick* was involved in outcomes assessment and current adult tools. *Christopher L. Wu* was involved in the background/introduction, and adult ERAS literature review.

Appendix

A PubMed search was performed using the following search strategy

("enhanced recovery" OR ("fast track" AND ("post operative" OR postoperative OR surgery OR surgical))) AND ("Child"[mh] OR "Infant"[mh] OR "Infant, Newborn"[mh] OR "Adolescent"[mh] OR "Child, Preschool"[mh] OR "child"[tiab] OR "infant"[all] OR "adolescent"[all] OR "children"[all] OR "infants"[all] OR "adolescents"[all] OR "pediatric patient"[all] OR "pediatric patients"[all] OR "adolescence"[all] OR "youth"[all] OR "youths"[all] OR "juvenile"[all] OR "childhood"[all] OR "teenager"[all] OR "teenagers"[all] OR "teen"[all] OR "teens"[all] OR "preschool child"[all] OR "neonate"[all] OR "newborn"[all] OR "baby"[all] OR "babies"[all] OR "pediatric"[tiab] OR "pediatrics"[tiab] OR "paediatric"[tiab] OR "paediatrics"[tiab] OR "toddler"[all] OR "toddlers"[all]) NOT ("animals"[mesh] NOT ("animals"[mesh] AND "humans"[mesh]))

Literature results from PubMed specifically included articles from MEDLINE, PubMed Central, and the NCBI Bookshelf. The search time interval was 1940 to present, and articles were restricted to the English language.

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