Surgical Technical Evidence Review for Acute Appendectomy Conducted for the Agency for Healthcare Research and Quality Safety Program for Improving Surgical Care and Recovery

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In 2017, the Safety Program for Improving Surgical Care and Recovery (ISCR Program) was created through collaboration with AHRQ (funder), American College of Surgeons, and Johns Hopkins Medicine Armstrong Institute for Patient Safety and Quality. The ISCR Program supports hospitals in implementing perioperative enhanced recovery pathways (ERPs) across multiple service lines, including colorectal, orthopaedic, gynecology, and emergency general surgery. The program goals are to meaningfully improve perioperative outcomes and patient experience and reduce healthcare resource use in US hospitals.

Enhanced recovery pathways are multidisciplinary protocols comprising patient engagement, optimal nutrition, multimodal analgesia, early mobility, and evidence-based practices to avoid preventable harms. Consistent implementation of ERPs has reduced surgical site infections (SSIs) and other healthcare-acquired infections, decreased length of stay (LOS), and reduced postoperative costs.[1-3] Among hospitals that have implemented ERPs, adherence can vary widely, and the effectiveness of ERPs is significantly associated with high and consistent compliance with pathway processes.[4] To achieve these goals, the ISCR Program seeks to improve a hospital's ability to consistently and sustainably implement each pathway process by assimilating best evidence for perioperative care for each procedure area and providing tools and support for implementation.

The evidence-based pathways form the backbone of this effort; however, there is little codified work in this area for emergency general surgery. Yet, many of the procedures are analogous to other surgery areas where ERPs have been tremendously helpful. Therefore, the objective of this review is to assimilate appropriate evidence to support pathway development for the surgical processes of acute appendectomy. A complementary review of the anesthesia processes was done in parallel and will be reported separately.

METHODS

The research protocol guiding this review has been published previously.[5] The components of this ERP were identified through an iterative process that involved review of ERPs in existence for other surgical disciplines, such as colorectal and orthopaedic, and elicited input from experts in enhanced recovery and emergency general surgery and, through iteration, identified individual processes for the appendectomy ISCR protocol (Table 1). Individual literature searches for each protocol component were performed in PubMed for English-language articles published before January 2018. Specific search terms were generated by a research librarian (QEW) and are provided in the eTable 1. Additional citations were identified through reference mining of included studies and by technical experts.

We classified appendicitis into uncomplicated (nonperforated) and complicated (perforated or gangrenous) because medical management varies by type. This was selected because that was the most common delineation that was noted in the articles. A more detailed grading scale put forward by the American Association for the Surgery of Trauma (AAST) is commonly used to classify individual cases to help with risk stratification (Table 2).[6] According to the AAST taxonomy, AAST grade I applies to our uncomplicated classification and AAST grades II to

CME questions for this article available at http://jacscme.facs.org

Disclosure Information: Authors have nothing to disclose. Timothy J Eberlein, Editor-in-Chief, has nothing to disclose.

Received August 31, 2018; Revised September 24, 2018; Accepted September 25, 2018.

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https://doi.org/10.1016/j.jamcollsurg.2018.09.024
ISSN 1072-7515/18

Abbreviations and Acronyms

AAST = American Association for the Surgery of Trauma
EAES = European Association for Endoscopic Surgery
ERP = enhanced recovery pathway
IPC = intermittent pneumatic compression
ISCR = Improving Surgical Care and Recovery
LOS = length of stay
MA = meta-analysis
NG = nasogastric
OR = odds ratio
RCT = randomized controlled trial
SIS = Surgical Infection Society
SR = systematic review
SSI = surgical site infection
VTE = venous thromboembolism
WSES = World Society of Emergency Surgery

V apply to our complicated classification. Some processes of care described here apply to both types, and others apply to only one. The search focused on adult patients undergoing appendectomy, but because there was a surfeit of studies involving children, this evidence was sometimes included.

We used the hierarchy of evidence and preferentially included systematic reviews (SR) with or without a meta-analysis (MA), randomized controlled trials (RCTs), observational design if the study was not covered in the SR/MA, and clinical guidelines from professional societies, where applicable. General exclusion criteria included editorials, case reports, and articles reporting interventions or outcomes that were not applicable to US hospitals. The results are presented in narrative format.

RESULTS

We identified 13 components for appendectomy for review (Table 3). The processes are organized by perioperative phase, and each process includes the rationale, evidence review, summary of guidelines (if available), and a summary of the evidence with our recommendation for or against inclusion in the ERP. Table 3 summarizes the evidence for each component, the strength and consistency of the evidence, and the level of guideline support. Table 4 summarizes the professional society guideline recommendations for each component and the corresponding strength of evidence.

Preoperative management: patient education and counseling

Rationale

Preoperative education and counseling can improve patient outcomes through improved informed consent, clarify postoperative expectations, and, in general, enhance the patient's experience with the healthcare system.

Evidence

We identified 7 articles, in which 2 observational studies implemented educational interventions, and both were done in the inpatient phase after diagnosis of acute appendicitis of any type. One study used a standardized portable computer presentation as an informed consent tool for parental education for children undergoing acute appendectomy.[7] The group educated using the computer tool had a higher grasp on the content ($p = 0.003$) compared with the normal informed consent group. The second study examined the effect of a written preoperative education tool on adults undergoing acute appendectomy.[8] Eight of 9 (89%) patients agreed or strongly agreed that the information was helpful.

Summary and recommendations

Although there is minimal objective information to conclude that patient education is associated with better postoperative outcomes, such education is patient-centered and likely improves knowledge retention with minimal patient risk. Patient educational resources are recommended for ERPs for appendectomy.

Preoperative antibiotics

Rationale

Timely prophylactic antibiotic administration can reduce infectious complications after appendectomy for all types of appendicitis.

Table 1. Improving Surgical Care and Recovery: Appendectomy Protocol Components—Surgery

Preoperative management
Education and counseling
Preoperative antibiotics
Initial nonsurgical management for perforated appendicitis with abscess or phlegmon
Venous thromboembolism prophylaxis
Delay of operation for 12 to 24 h for uncomplicated appendicitis
Intraoperative management
Laparoscopic surgical technique
Peritoneal drain placement
Urinary catheter placement
Prophylactic nasogastric tube insertion
Postoperative management
Same-day surgery discharge for uncomplicated appendicitis
Antibiotics
Early oral alimentation
Early mobilization

Table 2. American Association for the Surgery of Trauma Grading Scale for the Severity of Appendicitis

AAST grade	Description	Clinical criteria	Imaging criteria (CT finding)	Operative criteria	Pathologic criteria
I	Acutely inflamed appendix, intact	Pain, leukocytosis, and RLQ tenderness	Inflammatory changes localized to appendix ± appendiceal dilation ± contrast nonfilling	Acutely inflamed appendix, intact	Presence of neutrophils at the base of crypts, submucosa ± in muscular wall
II	Gangrenous appendix, intact	Pain, leukocytosis, and RLQ tenderness	Appendiceal wall necrosis with contrast nonenhancement ± air in appendiceal wall	Gangrenous appendix, intact	Mucosa and muscular wall digestion; not identifiable on hematoxylin and eosin stain
III	Perforated appendix with local contamination	Pain, leukocytosis, and RLQ tenderness	Above with local periappendiceal fluid ± contrast extravasation	Above, with evidence of local contamination	Gross perforation or focal dissolution of muscular wall
IV	Perforated appendix with periappendiceal phlegmon or abscess	Pain, leukocytosis, and RLQ tenderness; can have palpable mass	Regional soft-tissue inflammatory changes, phlegmon, or abscess	Above, with abscess or phlegmon in region of appendix	Gross perforation
V	Perforated appendix with generalized peritonitis	Generalized peritonitis	Diffuse abdominal or pelvic inflammatory changes ± free intraperitoneal fluid or air	Above, with addition of generalized purulent contamination away from appendix	Gross perforation

AAST, American Association for the Surgery of Trauma; RLQ, right lower quadrant. From The American Association for the Surgery of Trauma, with permission.

Evidence

We identified 144 articles in which 1 Cochrane SR studied timely administration of perioperative antibiotics in adults and children undergoing appendectomy for all types of appendicitis.[9] They found that administration of single-agent, single-dose antibiotics was superior to placebo for preventing wound infection (odds ratio [OR] 0.34; 95% CI 0.25 to 0.45) and intra-abdominal abscess (OR 0.34; 95% CI 0.05 to 2.45); and multiple-agent, single-dose antibiotics were superior to placebo in reducing wound infection (OR 0.14; 95% CI 0.05 to 0.39). Although the type of antibiotics varied widely, most included a cephalosporin, metronidazole, or both. Preoperative timing of antibiotics was heterogeneous among the studies and defined by Cochrane reviewers as any time before the surgical incision.

The World Society of Emergency Surgery (WSES) guidelines recommend broad-spectrum antibiotics for all patients with acute appendicitis.[10] The Surgical Infection Prevention Guideline Writers Workgroup recommends antibiotic administration within 60 minutes of incision.[11] The Surgical Infection Society (SIS) guidelines present strong evidence for administration of cefoxitin, cefotetan, or cefazolin plus metronidazole before appendectomy.[12]

Summary and recommendations

All patients undergoing appendectomy for appendicitis should receive antibiotics before the operation. The selected antibiotics should be appropriate for the bacterial spectrum encountered in the condition. Guidelines for antibiotic selection have been published recently[13] and should be referenced along with local resistance patterns. Antibiotics should be administered as soon as possible after diagnosis. If the operation is delayed, patients might require re-dosing within 60 minutes before incision.

Initial nonoperative management of stable patients with contained perforation

Rationale

Initial nonoperative management (antibiotics with or without image-guided placement of a percutaneous drain) of perforated appendicitis with abscess or phlegmon can reduce complication rates, reoperation rates, and LOS. Unstable patients and patients with free abdominal perforation will require immediate operation.

Evidence

We identified 19 articles and 4 studies that met the inclusion criteria: 2 SR/MAs, 1 RCT, and 1 observational study. The 2010 SR/MA[14] compared conservative treatment with operation (laparoscopic and open) for complicated appendicitis, which included 17 studies (7 pediatric and 10 adult studies). Conservative management of complicated appendicitis was associated with a decrease in complications (OR 0.24; 95% CI 0.13 to 0.44; $p < 0.001$) and reoperations (OR 0.17; 95% CI 0.04 to 0.75; $p = 0.02$), but no difference was observed for LOS or duration of antibiotics. The 2007 SR/MA[15]

Table 3. Summary of Reviewed Appendectomy Protocol Components, Outcomes, and Guideline Support

Component	Outcomes	Study	Population studied	Evidence*	Guideline support†
Preoperative management					
Education and counseling	No measurable effect	2 Obs	All types	+	NA
Preoperative antibiotics	↓ infectious complication	1 SR	All types	++	√√
Initial nonsurgical management‡	↓ postoperative morbidity	2 SRs, 1 RCT, 1 Obs	Complicated appendicitis	+	√√
VTE prophylaxis	Can reduce VTE in moderate- to high-risk patients only	1 Obs	All types	+	√√
Delay of operation 12 to 24 h for uncomplicated appendicitis	No difference in postoperative outcomes with delay	1 SR/MA, 1 Obs	Uncomplicated appendicitis	+	√
Intraoperative management					
Laparoscopic surgical technique	↓ LOS, ↓ SSI, ↓ postoperative pain, no difference in intra-abdominal abscess	1 SR of 9 SR/MAs	Uncomplicated appendicitis	++	√√√
	↓ LOS, ↓ SSI, ↓ postoperative pain, no difference in intra-abdominal abscess	1 SR/MA	Complicated appendicitis	++	√
Peritoneal drain placement	No benefit, can ↑ LOS	1 SR, 1 Obs	All types	+	√√
Urinary catheter insertion	Evidence is unclear	1 case study	NA	NA	NA
Nasogastric tube insertion	No improvement in outcomes, can ↑ pulmonary complications	1 Obs, 1 SR	All types	+	√√
Postoperative management					
Same-day surgery protocols (fast-track)	No difference in postoperative outcomes with same-day discharge	1 SR, 1 Obs	Uncomplicated appendicitis	++	NA
Postoperative antibiotics	No difference in postoperative outcomes	1 RCT, 2 Obs	Uncomplicated appendicitis	++	√√
	↓ Infectious complications		Complicated appendicitis	++	√√
Early oral alimentation	No evidence of complications with early feeding	1 RCT, 2 SRs	Patients of all ages with any type of appendicitis	+	√
Early mobilization	Can reduce LOS and improve gastrointestinal function	1 SR	Patients of all ages with any type of appendicitis	+	NA

*Evidence grading: ++, consistent evidence across studies showed benefit (interventions) or impact (risk assessment); +, evidence was either mixed with the majority favoring benefit/impact or little evidence existed in only one direction; +/-, evidence either did not exist or existed in both directions without one direction being favored; -, evidence showed no effect of a given practice or the intervention's harms outweighed its benefits.

†Consistency with clinical guidelines: √√, all guidelines supported a given practice or the guidelines cited strong evidence of support; √ guidelines cited weak evidence or expert opinion.

‡Initial laparoscopic operation is acceptable if the center is well-equipped and surgeons are well-trained in advanced laparoscopic skills.

LOS, length of stay; MA, meta-analysis; NA, not applicable; Obs, observation; RCT, randomized controlled trial; SR, systematic review; SSI, surgical site infection; VTE, venous thromboembolism.

Table 4. Summary of Expert Society Guidelines Supporting the Reviewed Components

Component	Patient population	Society	Year	Recommendation/statement
Preoperative management				
Education and counseling	Not available	—	—	—
Preoperative antibiotics	Complicated and uncomplicated appendicitis	SIPGWW	2004	Infusion of preoperative antibiotics should begin within 60 min before surgical incision (level of evidence not stated)
	Complicated and uncomplicated appendicitis	WSES	2016	In patients with acute appendicitis, preoperative broad-spectrum antibiotics are always recommended (strong evidence)
	Uncomplicated appendicitis	SIS	2010	Acute appendicitis without evidence of perforation, abscess, or local peritonitis requires only prophylactic administration of narrow-spectrum regimens active against aerobic and facultative and obligate anaerobes; treatment should be discontinued within 24 h
Initial nonsurgical management	Perforated appendicitis with phlegmon or abscess	WSES	2016	Nonoperative management is a reasonable first-line treatment for appendicitis with phlegmon or abscess (strong evidence). Operative management of acute appendicitis with phlegmon or abscess is a safe alternative to nonoperative management in experienced hands (moderate evidence)
	Perforated appendicitis with phlegmon or abscess	EAES	2016	Nonoperative treatment is suggested as the procedure of choice (moderate evidence).
	Perforated appendicitis with phlegmon or abscess	SIS	2010	Patients with a well-circumscribed periappendiceal abscess can be treated with percutaneous drainage initially (strong evidence)
Venous thromboembolism prophylaxis	All ages, all types	CHEST	2012	Mechanical prophylaxis with IPC for low-risk patients, IPC plus low-molecular-weight heparin or unfractionated heparin for moderate- or high-risk patients
Delay of operation for 12 to 24 h for uncomplicated appendicitis	Uncomplicated appendicitis	WSES	2016	Short, in-hospital surgical delay up to 12 to 24 h is safe in uncomplicated acute appendicitis and does not increase complications and/or perforation rate (moderate evidence)
Intraoperative management				
Laparoscopic surgical technique	Complicated and uncomplicated appendicitis	WSES	2016	Laparoscopic appendectomy should represent the first choice where laparoscopic equipment and skills are available, because it offers clear advantages in terms of less pain, lower incidence of SSI, decreased LOS, earlier return to work, and overall costs (strong evidence)
	Uncomplicated appendicitis	EAES	2016	Laparoscopic appendectomy recommended as the procedure of choice (strong evidence)
	Complicated appendicitis	EAES	2016	Laparoscopic appendectomy is suggested as the procedure of choice (weak evidence)
	Complicated appendicitis	SAGES	2010	Laparoscopic appendectomy can be performed safely in patients with perforated appendicitis (moderate evidence) and is possibly the preferred approach (weak evidence)

(Continued)

Table 4. Continued

Component	Patient population	Society	Year	Recommendation/statement
Peritoneal drain placement	All types	WSES	2016	In adult patients, drain after appendectomy for perforated appendicitis and abscess/peritonitis should be used with judicious caution, given the absence of good evidence from the literature. Drains did not prove any efficacy in preventing intraabdominal abscess and seem to be associated with delayed hospital discharge (strong evidence)
	All types	EAES	2016	Routine use of drains does not reduce the incidence of abscesses. Necessity of a drain for special indications is left to the discretion of the surgeon (evidence level not stated)
Urinary catheter placement	Not available	—	—	—
Prophylactic nasogastric tube placement	All types	EAES	2016	There is no indication for routine postoperative nasogastric tube placement in children or adults (weak evidence)
Postoperative management				
Same-day surgery discharge for uncomplicated appendicitis	Not available			
Antibiotics	Uncomplicated appendicitis	WSES, CDC, SIS, EAES	2016	Postoperative antibiotics are not recommended (strong evidence)
	Complicated appendicitis	WSES, CDC, SIS, EAES	2016	Postoperative, broad-spectrum antibiotics are always recommended (moderate evidence)
Early oral alimentation	Uncomplicated appendicitis	EAES	2016	There is no reason to restrict the postoperative diet after uncomplicated appendectomy (weak evidence)
Early mobilization	Not available	—	—	—

CHEST, American College of Chest Physicians; EAES, European Association for Endoscopic Surgery; IPC, intermittent pneumatic compression; SAGES, Society of American Gastrointestinal and Endoscopic Surgeons; SIPGWW, Surgical Infection Prevention Guideline Writers Workgroup; SIS, Surgical Infection Society; WSES, World Society of Emergency Surgery.

investigated the failure of initial nonsurgical treatment in patients with appendicitis with abscess or phlegmon and the risk of long-term recurrence. Failure of nonsurgical treatment was defined as requiring an appendectomy during the same hospital stay after an initial period of conservative treatment. Twenty studies were included in this SR/MA (10 pediatric only, 7 all ages, and 3 adults only). Failure rate of initial conservative treatment was low at 7.2% (95% CI 4.0% to 10.5%). Risk of long-term recurrence, which was surveilled for a range of 0.5 to 22 years, was low at 7.4% (95% CI 3.7% to 11.1%). Four studies from this SR/MA overlapped with the 2010 SR/MA. The RCT and observational study, published after the SR/MAs, challenged the practice of initial conservative management of complicated appendicitis in adults. The 2015 RCT[16] investigated the safety of immediate laparoscopic appendectomy for appendicitis with abscess vs nonsurgical treatment in a small sample of 60 adult patients. No difference was found in LOS between the 2 groups (4 days for laparoscopic vs 5 days for conservative management; $p = 0.105$), but the rate of uneventful recovery was lower in the laparoscopy group (90% vs 50%; $p = 0.002$). The 2017 observational study[17] examined the failure rate of conservative treatment vs acute appendectomy and elective interval appendectomy in 95 adult patients with complicated appendicitis. Of the 35 patients who underwent conservative management, 9 (25.7%) failed nonoperative management. More patients in the conservative management group required an open operation (n = 9 [100%]) and a bowel resection (n = 5 [55.6%]) compared with immediate appendectomy (n = 23 [38.3%] vs n = 2 [3.3%], respectively; $p = 0.048$). This study was limited by its retrospective design, small sample size, and single institution.

The WSES and European Association for Endoscopic Surgery (EAES) guidelines[10,18] found strong evidence demonstrating fewer postoperative complications when appendicitis with contained abscess or phlegmon is initially managed nonoperatively. The WSES guideline recommends laparoscopic management (by experienced surgeons only) as an appropriate alternative to nonoperative management (moderate evidence).[10]

Summary and recommendations

Complicated appendicitis can be managed conservatively initially in patients without systemic signs of sepsis or diffuse peritonitis. This treatment is associated with lower complication and reoperation rates and an acceptably low long-term recurrence rate. A cohort of adult patients with complicated appendicitis can benefit from immediate laparoscopic operation, if advanced expertise is present; additional research is needed to define this population.

Venous thromboembolism prophylaxis

Rationale

The provision of chemical and/or mechanical venous thromboembolism (VTE) thromboprophylaxis can prevent postoperative thromboembolic complications. Questions remain about the therapeutic need before and after appendectomy.

Evidence

Our literature search and reference mining identified 9 articles, and only 1 observational study included appendectomy (laparoscopic and open) as a procedure. This study[19] investigated the incidence of symptomatic VTE after elective or urgent surgical procedures among adults. Of 81,932 patients undergoing appendectomy, only 136 (0.2%) experienced symptomatic VTE within 91 days of operation.

One SR/MA[20] did investigate the effectiveness of combined intermittent pneumatic compression (IPC) and anticoagulation in the prevention of postoperative deep venous thrombosis in adult patients undergoing any surgical procedure requiring general anesthesia. They found that combined IPC and anticoagulation is more effective in preventing postoperative deep venous thrombosis than either modality alone. The CHEST (American College of Chest Physicians) guidelines[21] recommend the following for patients requiring an inpatient stay: low-risk patients (baseline risk of VTE approximately 1.5%), only mechanical prophylaxis with IPC postoperatively; moderate risk (VTE approximately 3%), mechanical prophylaxis with IPC and/or chemoprophylaxis with low-molecular-weight heparin or low-dose unfractionated heparin postoperatively, when safe from bleeding; and high risk (VTE approximately 6%), both IPC and pharmacologic prophylaxis with low-molecular-weight heparin or low-dose unfractionated heparin postoperatively, when safe from bleeding. Individual patient risk should be calculated using an assessment tool validated in the surgical population. The Caprini score[22] is a validated VTE risk assessment tool for abdominal surgery and is calculated based on patient and procedure-specific factors. Patients undergoing acute appendectomy can fall into any of the 3 risk strata, depending on their specific risk factors.

Summary and recommendations

Mechanical prophylaxis through IPC for VTE should be provided for low-risk patients undergoing appendectomy until discharge, or until the patient becomes ambulatory. Evidence supports preoperative VTE chemoprophylaxis for patients with a more than moderate risk for VTE. Individualized risk should be calculated based on patient-specific characteristics using a validated instrument.

Delay of operation of 12 to 24 hours for uncomplicated appendicitis

Rationale

System and personnel constraints can delay operative treatment until the following morning. Delay of operation for 12 to 24 hours for uncomplicated appendicitis likely results in noninferior patient outcomes.

Evidence

We identified 550 articles and 2 met the inclusion criteria. One study (SR/MA)[23] reported on 14 RCTs that examined outcomes from delay of operation for complicated appendicitis (perforation or gangrenous) in a mixed population of children and adults. A 12- to 24-hour delay after admission did not increase the risk of complex appendicitis (OR 0.97; $p = 0.750$). There was no difference in the rate of wound infection or intra-abdominal abscess between operation delay (12 to 24 hours) and within 6 hours (OR 1.03; $p = 0.870$). The second and recently published observational study[24] confirmed the SR/MA results, the odds of complications were the same for adults who waited 6 to 24 hours for appendectomy compared with fewer than 6 hours. Complications were higher in patients who waited more than 24 hours for operation compared with fewer than 6 hours (OR 1.27; 95% CI 1.14 to 1.43).

The WSES guidelines found moderate evidence for the safety of in-hospital surgical delays of up to 12 to 24 hours for uncomplicated acute appendicitis.[10]

Summary and recommendations

It is safe to delay acute appendectomy for 12 to 24 hours in patients with nonperforated appendicitis. However, where resources allow, immediate appendectomy leads to faster patient symptom resolution.

Intraoperative management: laparoscopic surgical technique

Rationale

Laparoscopic appendectomy is believed to decrease surgical morbidity and postoperative pain, and to shorten LOS compared with open appendectomy.

Evidence

We identified 111 articles and 2 SRs that met the inclusion criteria. A 2010 Cochrane review[25] had 56 of 67 RCTs that compared laparoscopic and open appendectomy in adults. Wound infections were less common after laparoscopic appendectomy compared with open (OR 0.43; 95% CI 0.34 to 0.54), pain measurements on postoperative day 1 decreased by 8 mm on the visual analog scale (95% CI 5 to 11 mm), and LOS was reduced (1.1 days; 95% CI 0.7 to 1.5 days). Intra-abdominal abscesses, however, were increased with laparoscopic compared with open technique (OR 1.77; 95% CI 1.14 to 2.76). Notably, there was moderate heterogeneity detected among the studies that examined intra-abdominal abscesses. Overall in-hospital costs were higher for laparoscopic compared with open appendectomy, but outside-hospital costs were lower in laparoscopic approach.

Historically, some question whether laparoscopic is superior to open technique for perforated appendicitis (eg severe inflammation and poorly defined anatomy). A 2017 SR/MA[26] of 2 RCTs and 14 observational studies found that laparoscopic operation (compared with open) for perforated appendicitis in patients of all ages was associated with a lower risk of SSI (OR 0.28; 95% CI 0.25 to 0.31; $p < 0.00001$), shorter LOS (weighted mean difference $= -2.47$, 95% CI -3.75 to -1.19; $p < 0.0002$), and shorter time to oral intake (weighted mean difference $= -0.88$, 95% CI -1.20 to -0.55; $p < 0.00001$), without increasing the likelihood of intra-abdominal abscess (OR 0.79; 95% CI 0.45 to 1.34; $p = 0.40$). There was no crossover in reported studies between the 2 SRs.

The EAES, WSES, and Society of American Gastrointestinal and Endoscopic Surgeons guidelines strongly favor the laparoscopic approach for uncomplicated appendicitis due to lower rates of SSI, improved pain outcomes, and reduced LOS.[10,18,27] All 3 guidelines recommend the laparoscopic approach for complicated appendicitis, but their recommendations are supported by weak evidence. Of note, all 3 guidelines were published before the 2017 SR/MA.

Summary and recommendations

Although both operative techniques are safe and effective for treating appendicitis, the laparoscopic technique achieves superior patient outcomes (less pain and lower SSI rates) and conserves hospital resources (reduces LOS and overall costs) for all types of appendicitis, if an experienced surgeon is available. It is also acceptable to initially manage complicated appendicitis nonsurgically with broad-spectrum antibiotics and percutaneous drain placement, if necessary. An ongoing clinical trial will help answer what the benefits and risks are to nonsurgical vs surgical management of complicated appendicitis.[28]

Peritoneal drain placement

Rationale

Prophylactic drain placement is likely unnecessary after appendectomy and should be reserved for unique clinical situations (ie immunocompromised patient, unclear source control) at the surgeons' discretion.

Evidence

We identified 20 studies in which 1 SR included patients undergoing open appendectomy and 1 observational study investigated laparoscopic appendectomy.

The SR[29] included 6 RCTs that examined the efficacy of abdominal drainage to prevent intra-peritoneal abscess after open appendectomy for complicated appendicitis (majority were perforated appendicitis with local or general peritonitis) in patients of all ages. All patients received postoperative antibiotics. They found an increased risk of 30-day morbidity (risk ratio 6.67; 95% CI 2.13 to 20.87) and LOS (+2.17 days; 95% CI 1.76 to 2.58 days) in the drainage group compared with the no-drainage group. The observational study[30] presents additional evidence against this practice in adults (aged older than 16 years) undergoing laparoscopic appendectomy for complicated appendicitis. Length of stay was prolonged in patients with drains compared with no drains (7.3 vs 4.2 days; $p < 0.0001$) and complications were more common (18.5% vs 7.7%; $p = 0.01$).

The EAES and WSES guidelines recommend against the routine use of drains after acute appendectomy for complicated or uncomplicated appendicitis.[10,18]

Summary and recommendations

There is no evidence to support the routine use of abdominal drainage in patients undergoing appendectomy for complicated or uncomplicated appendicitis, and the practice can prolong LOS and increase complications.

Urinary catheter insertion

Rationale

Bladder catheterization before laparoscopic appendectomy decompresses the urinary bladder and can reduce the incidence of iatrogenic bladder perforation, particularly those resulting from suprapubic trocar insertion.

Evidence

We identified 28 articles, none of which met the inclusion criteria. Urinary catheter insertion for laparoscopic appendectomy is not mentioned in any of the professional society guidelines. Society of American Gastrointestinal and Endoscopic Surgeons guidelines for laparoscopic ventral hernia repair[28] recommend placement of a urinary bladder catheter for lengthy operations and for when the hernia is located near the pubic symphysis. Laparoscopic appendectomy does not require dissection near the bladder, but in complicated cases, procedure duration can be lengthy and patients can be seriously ill, which might warrant catheter placement for urinary drainage or close monitoring of urinary output.

Summary and recommendations

The intraoperative insertion of a urinary catheter is common practice, but we found no evidence to justify this practice. Additional research is needed to determine whether urinary catheter insertion during laparoscopic appendectomy reduces iatrogenic bladder injury or increases the risk of urinary tract infections. If a catheter is inserted intraoperatively, it is judicious to remove it before leaving the operating room.

Prophylactic nasogastric tube placement

Rationale

Prophylactic nasogastric (NG) decompression is likely unnecessary after appendectomy and should be inserted only as needed based on postoperative symptoms indicative of severe ileus.

Evidence

We identified 14 articles in which 1 SR investigated the prophylactic use of NG tubes in adults undergoing abdominal operations of all types (found through reference mining). No efficacy studies of NG tube placement were found for adults undergoing appendectomy.

An observational study[31] from 2007 investigated NG tube placement vs no placement in pediatric patients undergoing laparoscopic appendectomy for perforated appendicitis. Patients with NG tubes left in place had longer time to oral intake (3.8 vs 2.2 days; $p < 0.001$) and prolonged LOS (6.0 vs 5.6 days; $p = 0.002$), but no difference in postoperative complications. The SR[32] of prophylactic NG tube placement in adult patients undergoing any type of abdominal operation examined efficacy and found higher rates of pulmonary complications with placement (OR 1.45; 95% CI 1.10 to 1.92) and no benefit in terms of wound infection, LOS, or gastric upset.

The EAES guidelines[18] found weak evidence to support their recommendation against placing routine postoperative NG tubes in children or adults undergoing appendectomy of all types.

Summary and recommendations

Prophylactic NG tube insertion is ineffective and results in prolonged return of bowel function and LOS. Nasogastric tubes should be inserted only as needed for severe gastric symptoms.

Postoperative management: same-day surgery protocols (fast-track)

Rationale

Hospital discharge the same day of appendectomy for uncomplicated appendicitis has the potential to reduce hospital resource-use and improve patient experience. There is concern that the practice might increase the rate of hospital readmissions.

Evidence

We identified 44 articles in which 1 SR and 1 observational study examined the safety of same-day discharge after acute appendectomy for uncomplicated appendicitis. The SR, published in 2014,[33] investigated outcomes after same-day discharge among adults; 77% of the 13 relevant studies involved laparoscopic appendectomy. Mean hospital readmission rate was 2.01% (range 0% to 5.1%) and mean morbidity rate was 4.2% (range 0% to 13%). Readmission and morbidity were low after same-day operation. Since then, a single-site, retrospective review[34] investigated the success of same-day discharge and found that of 563 adult patients admitted for acute uncomplicated appendicitis, 484 (86%) were successfully managed as outpatients, 7 (1.2%) required readmission, and 38 (6.7%) experienced postoperative morbidity. Patients were eligible for discharge if they met the following criteria: ability to tolerate liquid intake, ability to ambulate, pain controlled with oral analgesics, hemodynamic stability, adequate respiratory effort, no alteration in mental status from baseline, ability to urinate, nausea and vomiting controlled, physician approval, and appropriate supervision and assistance at home.

Summary and recommendations

Evidence supports the safety of same-day discharge in patients undergoing laparoscopic appendectomy for uncomplicated appendicitis that meet acceptable baseline criteria for hospital discharge (ability to tolerate liquid intake, ability to ambulate, pain controlled with oral analgesics, hemodynamic stability, adequate respiratory effort, no alteration in mental status from baseline, ability to urinate, nausea and vomiting controlled, physician approval, and appropriate supervision and assistance at home).

Postoperative antibiotics

Rationale

Postoperative antibiotics can reduce infectious complications after appendectomy for complicated appendicitis (ie perforated appendicitis, abscess, phlegmon). Patients with uncomplicated and gangrenous appendicitis likely do not benefit from postoperative antibiotics.

Evidence

We identified 156 articles, of which 1 RCT and 2 observational studies met the inclusion criteria. The RCT from 2005[35] included patients aged 15 to 70 years with uncomplicated appendicitis who underwent open appendectomy and found no reduction in infectious complications with postoperative antibiotic administration. The preoperative antibiotics-only group had a 6.5% infectious complication rate compared with the 3-dose (2 doses given postoperatively) group (6.4% rate; $p = 0.97$), and the 5-day antibiotic group (3.6% rate; $p = 0.5$). The 5-day antibiotic group had a higher rate of complications related to antibiotic treatment than the single-dose preoperative group (4.8% vs 1.1%; $p < 0.048$). A retrospective analysis of adult patients with gangrenous appendicitis found no difference in intra-abdominal abscess at 1 month with postoperative antibiotics (1.9%) and without postoperative antibiotics (1.1%).[36]

The optimal duration of antibiotic treatment after perforated appendicitis is not well studied, and the standard practice ranges from 3 to 5 days.[37] A prospective observational study assessed postoperative antibiotic duration on infectious complications after laparoscopic appendectomy in pediatric and adult patients for perforated appendicitis. No differences were found in infectious complications between patients receiving 3 vs 5 days of antibiotics (OR 0.93; 95% CI 0.38 to 2.32).[38]

The WSES, EAES, SIS, and CDC guidelines all found strong evidence to support postoperative antibiotics strictly for complicated appendicitis.[10,13,18,39] The WSES guidelines[10] found moderate evidence supporting the recommendation that 3 to 5 days of antibiotics is generally sufficient for complicated appendicitis, but treatment should be based on clinical and laboratory criteria. The SIS guidelines[40] state that antimicrobial therapy for abdominal infections should be limited to 7 days or fewer, unless adequate source control was not achieved. Antimicrobial course can be completed with oral antibiotics in patients tolerating an oral diet.

Summary and recommendations

Patients with acute or gangrenous nonperforated appendicitis should only receive antibiotics prophylactically. Patients with perforated appendicitis should receive postoperative antibiotics to prevent SSI. The route of administration, type, and duration recommended will depend on clinical and patient factors and be left to the discretion of the treating clinician. The treatment decision should be deliberate and consider the risks and benefits of extended antibiotic therapy.

Early oral alimentation

Rationale

Early oral feeding after appendectomy for uncomplicated appendicitis is considered standard of care. Questions remain about the most efficacious refeeding regimen in patients with complicated appendicitis.

Evidence

We identified 46 articles, 1 RCT in the literature search and 2 SRs through reference mining. The RCT[41] investigated oral feeding within 24 hours vs traditional postoperative care (initiating diet with passage of flatus or stool) in adults undergoing emergency abdominal operation. Almost half of the patients underwent emergency appendectomy, and half of these were for perforated appendicitis. There were no differences in postoperative complications between the early feeding group and traditional care (45.3% vs 37.4%; $p = 0.1$), but a higher rate of postoperative emesis was observed (13.5% vs 6.1%, respectively; $p = 0.03$). No differences were observed in NG tube insertion, postoperative ileus, or LOS. The traditional care group did report a higher rate of postoperative hunger ($p < 0.01$).

Although early refeeding is not well studied in appendectomy specifically, it has been demonstrated to be safe in patients undergoing more invasive procedures. One SR/MA[42] of RCTs ($n = 587$) found that patients undergoing resectional gastrointestinal operations who receive early postoperative nutrition (feeding within 24 hours) experience less postoperative complications (OR 0.55; 95% CI 0.35 to 0.87; $p = 0.01$) and have no significant differences in anastomotic dehiscence rate (OR 0.75; 95% CI 0.39 to 1.4; $p = 0.39$). Another SR/MA[43] of RCTs

containing 631 women undergoing abdominal gynecologic operations revealed that feeding within 24 hours of operation had similar rates of abdominal distention and postoperative NG tube placement, and maintain a faster onset of flatus, shorter hospital stay, and fewer infectious complications.

The EAES guidelines[18] report weak evidence to support their recommendation to allow early refeeding after uncomplicated appendectomy, but do not provide recommendations about diet after complicated appendectomy.

Summary/recommendations

Because the safety of oral feeding has been well-demonstrated in more invasive operations, it is likely beneficial for laparoscopic appendectomy. Patients who undergo uncomplicated appendectomy should have their diet restarted as soon as anesthesia-related nausea resolves (usually approximately 6 hours). Patients who undergo complicated appendicitis should have their diet restarted within 24 hours after operation. Systematic reduction of opioid-based analgesia and enhancement of multimodal analgesia will likely make this approach even more successful.

Early mobilization

Rationale

Early mobilization after operation has been proposed to improve postoperative outcomes and reduce LOS.

Evidence

We identified 37 articles, of which none studied appendectomy. One SR in adult patients who underwent abdominal operations of all types is summarized here.

The SR[44] included 3 RCTs and 1 observational study of patients undergoing laparoscopic and open abdominal operations, ranging from colon resection for cancer, hysterectomy for benign and malignant disease, and various other gastrointestinal procedures. The early mobilization protocols were a heterogeneous range of exercises performed on postoperative day 1 compared with movement at the patient's discretion. There were no differences in postoperative complications between early-mobility groups and controls. One study did find LOS to be shorter in the mobilization group (7.82 vs 9.86 days; $p = 0.005$), and one study showed improved gastrointestinal function in the mobilization group.

Summary and recommendations

Early mobilization is an important component of an enhanced recovery protocol for patients after appendectomy. There is evidence that mobilizing patients early reduces LOS and can marginally improve other secondary outcomes. We recommend mobilizing patients within 24 hours of operation as long as no contraindication exists.

DISCUSSION

This evidence review covers 13 surgical interventions potentially relevant to developing an ERP for patients undergoing appendectomy for both uncomplicated and complicated appendicitis. Although ERPs are widely available for all types of elective procedures, there are few established protocols within the realm of emergency general surgery. However, evidence does show that patients undergoing emergency general surgery procedures benefit from ERPs.[45] Although the evidence supporting each component described here varies in strength, the overall findings support implementation of ERP in appendectomy.

The preoperative intervention with the highest strength of evidence was the timely administration of preoperative antibiotics. Given the strength of evidence supporting timely preoperative administration of antibiotics in appendicitis, the SIS Expert Panel recommends the following performance measures for hospital quality improvement: time from appendicitis diagnosis to antibiotic administration, duration of antibiotic administration after nonperforated appendectomy, and duration of antibiotic administration and SSI after perforated appendectomy.

To our knowledge, this is the first literature review to cover a wide breath of ERP components for appendectomy in complicated and uncomplicated appendicitis. The strength of this review is that it included interventions backed by strong evidence, as well as interventions that should be abandoned because of little or no evidence basis. Implementation and consistent compliance with the ERP outlined here, combined with the anesthesia components (reported separately), will allow patients to recover optimally from appendectomy.

We identified 13 overall components for the surgical portion of the ISCR appendectomy protocol. The evidence base and guideline support for each component are described in detail in this review. These components, combined with the anesthesia components, should be delivered consistently for optimal care delivery for the patient undergoing appendectomy. The ISCR appendectomy pathway components span the preoperative, intraoperative, and postoperative phases of care and will require transdisciplinary collaboration among surgeons, nursing staff, anesthesia providers, hospital leadership,

and patients. Hospitals participating in the AHRQ Patient Safety in ISCR Program will be supported in carrying out this protocol and gathering data to support continuous quality improvement around the ERP. Our ultimate goal is to raise the bar for surgical care nationally.

Author Contributions

Study conception and design: Hornor, Liu, Hu, Ko, Wick, Maggard-Gibbons

Acquisition of data: Hornor, Liu, Hu

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Drafting of manuscript: Hornor, Wick, Maggard-Gibbons

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Acknowledgment: Q Eileen Wafford, MSt, MLIS, research librarian at Northwestern University Feinberg School of Medicine, aided with the identification of search terms. Christine G Holzmueller, senior technical writer at the Armstrong Institute for Patient Safety and Quality, copyedited the manuscript.

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APPENDIX

eTable 1. Inclusion Criteria for Improving Surgical Care and Recovery Protocol Components for Appendectomy

Component	Operation	Component	Qualifier
Preoperative management			
Education and counseling	("appendectomy" [MeSH] OR "appendicitis"[MeSH] OR "appendicectomy"[tiab] OR "appendectomy"[tiab] OR "appendicitis"[tiab])	("patient education as topic" [MeSH Major Topic] OR "pre-operative education" [tiab] OR "preoperative education"[tiab])	NA
Preoperative antibiotics	("appendectomy" [MeSH] OR "appendicitis"[MeSH] OR "appendicectomy"[tiab] OR "appendectomy"[tiab] OR "appendicitis"[tiab])	"antibiotics"[tw]	("prophylaxis"[tw] OR "preoperative"[tw])
Initial nonsurgical management for perforated appendicitis with abscess or phlegmon	("complicated appendicitis"[tiab] OR "appendiceal abscess"[tiab])	("non-surgical"[tiab] OR "conservative" [tiab])	NA
Preoperative venous thromboembolism prophylaxis	("appendectomy" [MeSH] OR "appendicitis"[MeSH] OR "appendicectomy"[tiab] OR "appendectomy"[tiab] OR "appendicitis"[tiab])	("thromboembolism" [MeSH] OR "thromboembolism" [tw] OR "thromboprophylaxis" [tw])	(Preop*[tw] OR preoperative [tw] OR intraoperative [tw])
Delay of operation 12 to 24 h for uncomplicated appendicitis	("appendectomy" [MeSH] OR "appendicitis"[MeSH] OR "appendicectomy"[tiab] OR "appendectomy"[tiab] OR "appendicitis"[tiab])	("delay"[tiab] OR "timing"[tiab])	NA
Intraoperative management			
Laparoscopic operation	("appendectomy" [MeSH] OR "appendicitis"[MeSH] OR "appendicectomy"[tiab] OR "appendectomy"[tiab] OR "appendicitis"[tiab])	"surgical technique" [tw]	NA
Peritoneal drain placement	("complicated appendicitis"[tiab] OR "appendiceal abscess"[tiab])	"drain" [tiab]	NA
Urinary catheter placement	("appendectomy" [MeSH] OR "appendicitis"[MeSH] OR "appendicectomy"[tiab] OR "appendectomy"[tiab] OR "appendicitis"[tiab])	("urinary catheter"[tw] OR "foley"[tw] OR "urinary catheterization"[tw] OR "bladder decompression"[tw])	NA
Prophylactic nasogastric tube placement	("appendectomy" [MeSH] OR "appendicitis"[MeSH] OR "appendicectomy"[tiab] OR "appendectomy"[tiab] OR "appendicitis"[tiab])	"nasogastric tube" [tw]	NA
Postoperative management			
Same-day surgery discharge for uncomplicated appendicitis	("appendectomy" [MeSH] OR "appendicitis"[MeSH] OR "appendicectomy"[tiab] OR "appendectomy"[tiab] OR "appendicitis"[tiab])	("clinical pathway" [tiab] OR "fast track"[tiab] OR "fast-track"[tiab] "same day discharge"[tiab] OR "early discharge"[tiab] OR "day surgery"[tiab] OR "day case surgery"[tiab] OR "ambulatory surgical procedures"[tiab])	NA

(Continued)

eTable 1. Continued

Component	Operation	Component	Qualifier
Antibiotics	(“appendectomy” [MeSH] OR “appendicitis”[MeSH] OR “appendicectomy”[tiab] OR “appendectomy”[tiab] OR “appendicitis”[tiab])	"antibiotics"[tw]	(“postoperative period”[MeSH] OR “postoperative”[tiab] OR “postop”[tiab] OR “post-operative”[tiab])
Early oral alimentation	(“appendectomy” [MeSH] OR “appendicitis”[MeSH] OR “appendicectomy”[tiab] OR “appendectomy”[tiab] OR “appendicitis”[tiab])	(“nutrition”[tiab] OR “feeding”[tiab] OR “alimentation”[tiab] OR “enteral”[tiab])	(“postoperative period”[MeSH] OR “postoperative”[tiab] OR “postop”[tiab] OR “post-operative”[tiab] OR “post-op”[tiab])
Early mobilization	(“appendectomy” [MeSH] OR “appendicitis”[MeSH] OR “appendicectomy”[tiab] OR “appendectomy”[tiab] OR “appendicitis”[tiab])	("ambulation"[tw] OR "mobilization"[tw])	NA

MeSH, medical subject heading; NA, not applicable.