Perioperative care in open aortic vascular surgery: A consensus statement by the Enhanced Recovery After Surgery (ERAS) Society and Society for Vascular Surgery

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ABSTRACT

The Society for Vascular Surgery and the Enhanced Recovery After Surgery Society formally collaborated and elected an international, multidisciplinary panel of experts to review the literature and provide evidence-based recommendations related to all the health care received in the perioperative period for patients undergoing open abdominal aortic operations (both transabdominal and retroperitoneal approaches, including supraceliac, suprarenal, and infrarenal clamp sites) for aortic aneurysm and aortoiliac occlusive disease. Structured around the Enhanced Recovery After Surgery core elements, 36 recommendations were made and organized into preadmission, preoperative, intraoperative, and postoperative recommendations. (J Vasc Surg 2022;75:1796-820.)

Keywords: Abdominal aortic aneurysm; Analgesia and anesthesia; Aortic occlusive disease; Evidence-based recommendations; Enhanced recovery after surgery; Guidelines; Perioperative care

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DISCLAIMER

The Society for Vascular Surgery (SVS) develops evidenced-based documents as a resource to assist members in the practice of vascular surgery. The recommendations contained herein are based on a recent review of published evidence and expert opinion. They reflect the available body of evidence, and their applicability reflects the limitations of those data and are subject to reassessment and revision as new knowledge emerges. Given these limitations, consensus documents do not represent a statement of the standard of care, nor do they substitute for clinician judgment or supplant patient preference or shared decision-making. The Society for Vascular Surgery recognizes that departure from these recommendations could be warranted when, in the reasonable judgment of the treating clinician, such a course of action is indicated by the clinical presentation of the patient, limitations of available resources, advances in knowledge or technology, or patient preference. The reader must rely solely on their own judgment to determine which practices and procedures, whether included in this document or not, are appropriate for them, their patient, their institution, or their practice.

Enhanced Recovery After Surgery (ERAS) pathways have been shown to be beneficial for many surgical specialties.[1] The concept of multidisciplinary care to control postoperative physiology and maintain homeostasis to attenuate stress and accelerate convalescence was first described in 1997.[2] Soon thereafter, the perioperative enhanced recovery after surgery study group was formed in Europe, and their first consensus statement for perioperative care to enhance recovery after colorectal surgery was published.[3] The group formed the ERAS Society in 2010. Its mission has since spread to six continents, and 19 surgical specialties have published formal ERAS Society guidelines or consensus statements (available at: www.erassociety.org). Although each specialty and geographic region might be unique, the common foundational theme across all ERAS guidelines and consensus statements is to create a culture in which all perioperative caregivers, including anesthesiologists, surgeons, nurses, and therapists work together within a clinical pathway to apply evidence-based practice in unison. In addition to these recommendations, auditing systems with data points corresponding to each ERAS element are supported by the ERAS Society, allowing those who choose to participate a method to monitor the fidelity of their enhanced recovery programs.

Compared with the general population, vascular surgery patients are more likely to present with specific perioperative challenges owing to age, frailty, and multiple comorbidities and the highly invasive operations that are sometimes required for limb or life preservation. This combination of factors results in complex management strategies, increased usage of health care resources, prolonged hospitalization stays, and increased rehabilitation needs. ERAS, with its aim of delivering high-quality perioperative care and accelerating recovery, appears well suited to address the needs of patients undergoing open aortic operations. The present

consensus statement focused on both transabdominal and retroperitoneal approaches (including supraceliac, suprarenal, and infrarenal clamp sites) for aortic aneurysm and aortoiliac occlusive disease operations.

METHODS

Formation of the guideline development group and selection of guideline topics. In collaboration, the SVS and the ERAS Society initiated the formation of the multidisciplinary, international guideline development group (GDG) comprising vascular surgeons, anesthesiologists, and advanced practice providers with expertise in ERAS and vascular pathophysiology. Guideline topic selection was performed according to the recommendations for the development of clinical guidelines within the ERAS Society framework.[4] The GDG was consulted for advice on the appropriate items to be included in the guideline, with the final decision made by the lead authors (K.L.M. and H.D.B.). The guideline items were allocated to the authors for literature summary and grading, depending on each individual's expertise. The final content was agreed on by all the authors.

Literature search strategy. A third-party team of investigators and a reference librarian specializing in literature reviews assisted the GDG in identifying and categorizing the existing effectiveness and comparative effectiveness literature on ERAS protocols relevant to vascular surgery. The librarian executed and documented the search in July 2019. The databases queried included PubMed, CINAHL, and ClinicalTrials.gov. Systematic reviews, randomized controlled trials (RCTs), and observational cohort studies reporting on adults (age ≥18 years) undergoing aortic surgery and reporting on any one or combinations of the ERAS guideline items were included. Many items had not been studied for open aortic surgery patients; thus, for elements that could be reasonably applied to all types of surgical patients, the reported data and ERAS guidelines from other surgical specialties were included. In some cases, the data from aortic and other patient populations were insufficient, or the existing data could not be reasonably extrapolated. Thus, no recommendations were made. The GDG members then searched reference lists and also repeated literature searches to include any new publications up to and including April 2021. The final included studies were carefully reviewed by the GDG, and any disagreements were resolved through group consensus via the Delphi method.

Quality assessment, data analyses and consensus generation. The GRADE (grading of recommendations, assessment, development, and evaluation) system was used to evaluate the quality of evidence and recommendations for each of the ERAS topics.[5,6] Recommendations were made according to whether the quality of evidence was high, moderate, low, or very low. Conclusions based on high-quality evidence are unlikely to change with further investigation. Those based on moderate-quality evidence are more likely to be affected by future research. Finally, those based on low-quality evidence are the least supported, might not include prospective study designs, and are the most likely change in the future if more rigorous research is performed. In the case of recommendations made solely from literature of nonaortic cohorts, the quality of evidence was downgraded. The strength of the recommendation was based on the balance between the desirable and undesirable effects of the recommendation. A strong recommendation for an ERAS item is possible even with a low quality of evidence, if the risk of harm is negligible.

RESULTS

The literature search yielded 3460 citations. Of these 3460 citations, 109 studies had addressed enhanced recovery interventions, as either individual core elements or combinations of elements, for vascular surgery patients. Another 18 studies had included mixed cohorts, including vascular surgery patients. In addition, 463 studies were identified that had not included vascular surgery patients but that might have been applicable to patients undergoing open aortic operations. A total of 590 of these abstracts were screened. After discussions and reviews, no disagreements were found between the authors in the assessment of the quality of evidence and grading of the included reports. Structured around the ERAS core elements, 36 recommendations were made and organized into preadmission, preoperative, intraoperative, and postoperative recommendations (Table; Fig).[7] For some of the ERAS elements, insufficient data were found to support a recommendation; however, summary statements based on expert opinion were provided.

PREADMISSION RECOMMENDATIONS

1. Patient information, education, and counseling

Preoperative education and counseling are essential to engage patients and caregivers in the perioperative process. A recent systematic review and meta-analysis showed that two thirds of studies (two RCTs and five observational studies) of different enhanced recovery programs for open aortic surgeries had used some form of patient education, although education had not been studied as a specific intervention.[8] A retrospective study showed effectiveness in enhanced recovery after open abdominal aortic aneurysm (AAA) repair through counseling before and during hospitalization regarding nutrition, early rehabilitation, and setting expectations and daily goals.[9] Preoperative education can be provided using various methods, such as illustrated booklets,[10] in addition to written informed consent, surgeon patient discussion,[11] and

multidisciplinary education with surgery and anesthesia services.[12] Counseling of patients and families regarding early mobilization[10,11] and discharge criteria[13] are essential to achieve length of stay (LOS) reductions. Studies, including an RCT, from other surgical specialties have shown that extended pre- and postoperative counseling, guidance by an ERAS nurse, and written information will lead to less pain, decreased nausea and vomiting, reduced hospital LOS, and increased enhanced recovery pathway adherence.[14-16]

Recommendation: Patients should receive dedicated verbal and written preoperative education and counseling.
Quality of evidence: C (low)
Strength of recommendation: Grade 1 (strong)

2. Preadmission screening, assessment, and optimization (a, anemia screening; b, nutritional deficiency; c, frailty; d, delirium risk; e, tobacco and alcohol overconsumption; f, medical risk)

Delivery of optimal care in aneurysm disease requires balancing the operative risk relative to the likelihood of survival in the perioperative period and beyond. A recent systematic review and meta-analysis of RCTs and observational studies found that only 3 of 12 studies of ERAS-like pathways in aortic surgery had had any medical screening and preoperative optimization documented.[8,9,11,17] Patients should undergo a thorough preoperative assessment and optimization across a breadth of risk factors for aortic surgery, as detailed in the next sections.

2a. Anemia screening. Anemia is associated with poor outcomes after surgery.[18,19] Although a preoperative blood transfusion will corrects anemia rapidly and can be used for severely anemic patients and/or patients undergoing surgery with expected profound blood loss, caution should be used because transfusions have been associated with increased mortality and morbidity.[20,21] Medical management of preoperative anemia requires time and should be planned ≥3 to 4 weeks before elective surgery. However, aortic surgery-specific evidence has remained lacking. Extrapolated from other specialties, iron (oral and intravenous), folate, and vitamin B_{12} supplements might reduce the need for blood transfusions but did not affect the incidence of adverse events or mortality.[22-27] In colorectal ERAS pathways, iron supplementation has been recommended.[28] However, the balance of trial evidence in mixed surgical populations has not shown clinically significant reductions in the need for allogeneic blood transfusions for patients receiving preoperative iron therapy.[29,30] Caution is advised in translating certain anemia therapies to open aortic operations amid the presence of U.S. Food and Drug Administration limitations on the use of erythropoietin-stimulating agents for patients undergoing cardiac or vascular surgery and an adverse event profile that includes thrombotic events.[31]

Recommendation: The cause of preoperative anemia should be evaluated and treated.
Quality of evidence: D (very low)
Strength of recommendation: Grade 2 (weak)

2b. Nutritional deficiency. Preoperative nutritional deficiency can be established by screening and, as needed, assessed using a combination of clinical and biochemical parameters. Several assessment tools are available to assist in this regard, including Malnutrition Universal Screening Tool, Nutritional Risk Screening 2002, Mini Nutritional Assessment, Short Nutritional Assessment Questionnaire, Malnutrition Screening Tool, and Subjective Global Assessment.[32-34] In a single-site retrospective study of open AAA repairs, a moderate risk of malnutrition determined from Controlling Nutritional Status scores (derived from serum albumin, cholesterol levels, and lymphocyte counts in peripheral blood) was associated with mid-term mortality and life-threatening complications.[35]

If the screening results indicate risk, a nutritional assessment should be performed if expertise is available and appropriate nutritional care delivered.[36,37] Oral nutritional supplements, including those containing immunonutrients,[38-40] should almost always be preferred to enteral or parenteral nutrition regimens.[37] Regimens for correcting malnutrition via oral nutritional supplementation have shown the greatest effect if started ≥7 to 10 days preoperatively in nonvascular cohorts.[32,41-43]

Recommendation: Screening should be performed for malnutrition and nutritional deficiencies corrected, preferably with oral regimens.
Quality of evidence: B (moderate)
Strength of recommendation: Grade 1 (strong)

2c. Frailty. Frailty is a syndrome defined as increased vulnerability because of a physiologic decline in reserve and function and consists of physical, functional, social, nutritional, and cognitive domains. For aortic aneurysm patients, frailty has been associated with increased adverse outcomes at 30 days (ie, morbidity, mortality, failure to rescue) and an increased LOS.[44,45] Preoperative frailty is associated with increased discharge to non–home destination, a loss of independence after major vascular surgery, and decreased long-term survival.[46-48] Often used scales to measure frailty include the Clinical Frailty Scale, modified Frailty index, and the Risk Analysis Index. The use of standardized frailty assessments for aneurysm patients more than doubles the pool of the at-risk or frail patients identified for preoperative optimization.[49]

Table. Recommendations and GRADE (grading of recommendations, assessment, development, evaluation) for each Enhanced Recovery After Surgery (ERAS) element

ERAS element	Recommendation	GRADE	Evidence level
Preadmission			
1. Patient information, education, counseling	Patients should receive dedicated verbal and written preoperative education and counseling (grade 1C)	Strong	Low[a]
2a. Screening, assessment, and optimization: anemia screening	Evaluate the cause of and treat chronic preoperative anemia (grade 2D)	Weak	Very low[a]
2b. Screening, assessment, and optimization: nutritional deficiency	Screen for malnutrition and correct nutritional deficiency, preferably with oral regimens (grade 1B)	Strong	Moderate[a]
2c. Screening, assessment, and optimization: frailty	Frailty screening is recommended as a routine part of preoperative patient assessment (grade 1B)	Strong	Moderate
2d. Screening, assessment, and optimization: delirium risk	Screen for delirium risk and implement preoperative practices to minimize onset of delirium as a routine part of practice (grade 1C)	Strong	Low
2e. Screening, assessment, and optimization: tobacco and alcohol			
	i. Prescribe smoking cessation therapy and recommend a minimum of 4 weeks smoking cessation before surgery (grade 1A)	Strong	High[a]
	ii. Recommend alcohol cessation 4 weeks before surgery, particularly for patients who consume more than five alcohol equivalents or 15 alcohol units per day (grade 1C)	Strong	Low[a]
2f. Screening, assessment, and optimization: medical risk			
	i. Cardiac risk should be evaluated and optimized with antiplatelet therapy, statins, antihypertensive therapy, and diabetes control before elective surgery (grade 1A)	Strong	High
	ii. Risk of acute kidney injury should be evaluated and optimized before elective surgery (grade 1A)	Strong	High
3. Preoperative exercise therapy and prehabilitation	Recommend 6 weeks of supervised exercise therapy before elective surgery (grade 2C)	Weak	Low
4. Perioperative antiplatelet or anticoagulation plan			
	i. Continue aspirin throughout the perioperative period (grade 1A)	Strong	High
	ii. Stop secondary antiplatelet medications and anticoagulant agents before surgery, except for select patient populations (grade 1B)	Strong	Moderate
Preoperative			
5. Fasting	Avoid overnight fasting; encourage clear fluids for ≤2 hours and light foods for ≤6 hours before the induction of general anesthesia (grade 1A)	Strong	High[a]
6. Carbohydrate loading	Patients without diabetes should receive a preoperative carbohydrate drink (grade 2B)	Weak	Moderate[a]
7. Venous thromboembolism prophylaxis	Routinely use calf-length intermittent compression devices combined with either low-dose unfractionated heparin or low-molecular-weight heparin starting immediately before surgery and continuing at least throughout the hospitalization (grade 1B)	Strong	Moderate[a]
8. Preanesthetic sedative and analgesia medication			
	i. Do not routinely use sedatives to reduce anxiety preoperatively (grade 1C)	Strong	Low[a]

Table. Continued.

ERAS element	Recommendation	GRADE	Evidence level
	ii. Routinely use preoperative administration of acetaminophen, NSAIDs, and gabapentinoids as part of a multimodal opioid-sparing analgesia strategy (grade 1C)	Strong	Low[a]
9. Antimicrobial agents	Prophylactic intravenous antibiotic dosing should begin 30-60 minutes preoperatively, with redosing intraoperatively within two serum half-lives of the antimicrobial agent used or with substantive intraoperative blood loss, and extending no more than 24 hours postoperatively (grade 1A)	Strong	High
10. Prevention of nausea and vomiting	Perform a risk assessment for PONV, routinely use multimodal PONV prophylaxis based on the assessment findings, and use PONV rescue with a different class of antiemetic (grade 1A)	Strong	High[a]
Intraoperative			
11a. Anesthetic protocol: neuromuscular blocking agents and monitoring	Neuromuscular monitoring should be used to ensure adequate intraoperative muscle relaxation and full reversal of neuromuscular blockade before extubation (grade 1A)	Strong	High[a]
11b. Anesthetic protocol: cardiovascular monitoring	Invasive cardiovascular monitoring with an arterial catheter is essential; the MAP should be maintained to near baseline values and at or >65 mm Hg (grade 1B)	Strong	Moderate
11c. Anesthetic protocol: renal protection	Adjunctive renal protective medications and methods of ischemic preconditioning of any type can cause harm and should not be used for infrarenal repairs (grade 1B)	Strong	Moderate
11d. Anesthetic protocol: cell salvage	Use cell salvage (grade 1B)	Strong	Moderate
11e. Anesthetic protocol: lung-protective ventilation	Use lung protective strategies (grade 2C)	Weak	Low[a]
11f. Epidural analgesia	Mid-thoracic (T6-T9) epidural analgesia should be used intraoperatively and continued postoperatively as an infusion or patient-controlled analgesia using a combination of a local anesthetic and an opioid (grade 1B)	Strong	Moderate
12. Body temperature management	Use multiple strategies to maintain normothermia, including prewarming and active warming of patients intraoperatively (grade 1B)	Strong	Moderate[a]
13. Drainage of surgical site	Do not routinely use drains in the surgical wound (grade 2C)	Weak	Low
Postoperative			
14. Multimodal analgesia and opioid reduction strategies	Routinely use multimodal analgesic regimens to improve pain control and reduce opioid consumption (grade 1B)	Strong	Moderate[a]
15. Nasogastric drainage	Avoid the routine use of postoperative nasogastric tubes (grade 1A)	Strong	High[a]
16. Oral feeding	An early return to a normal diet and oral nutritional supplements should be promoted (grade 1B)	Strong	Moderate
17. Fluid therapy	If intravenous fluids are indicated, restrict postoperative fluid therapy to 1.5 L/d (grade 1B)	Strong	Moderate
18. Urinary drainage	Early removal of urinary drainage catheters is recommended (grade 1C)	Strong	Low[a]
19. Glycemic control	Maintain glycemic control, with attention to avoiding hypoglycemia (grade 1B)	Strong	Moderate

(Continued on next page)

Table. Continued.

ERAS element	Recommendation	GRADE	Evidence level
20. Early mobilization strategy	Use a formal plan for early mobilization, with early physical therapy involvement when needed (grade 1C)	Strong	Low[a]
21. Discharge education	Use both written and verbal discharge education and follow-up telephone calls within 24-48 hours of hospital discharge and arrange clinic follow-up visits with both the surgeon and the primary care physician at least once by 30 days postoperatively (grade 1C)	Strong	Low[a]
22. Audit of outcomes	Routine auditing of ERAS care processes and feedback to all staff involved are necessary (grade 1C)	Strong	Low[a]

MAP, Mean arterial pressure; *NSAIDs,* nonsteroidal anti-inflammatory drugs; *PONV,* postoperative nausea and vomiting.
[a]Some of the evidence used to make the recommendation was extrapolated from nonaortic patient cohorts.

Based on the consensus of best practices from the Society for Perioperative Assessment and Quality Improvement, a patient who has a positive frailty screening result should be followed up with a diagnostic assessment of frailty, and, when feasible, a comprehensive geriatric assessment with a tailored intervention (shared decision-making or prehabilitation) should be performed, ideally by a geriatric specialist.[50] Specifically, a small RCT testing an outpatient comprehensive geriatric assessment and optimization program for elderly patients scheduled for elective vascular surgery was associated with reduced complications, shorter LOSs, and a lower rate of patients discharged to a higher level of care dependency.[51]

Recommendation: Frailty screening is recommended as a routine part of preoperative patient assessments.
Quality of evidence: B (moderate)
Strength of recommendation: Grade 1 (strong)

2d. Delirium risk. Delirium can contribute to adverse events, prolonged hospital LOSs, non–home discharge destinations, and mortality following surgery.[52] Those with a medical history of delirium, advancing age by decade, and American Society of Anesthesiologists score of ≥3 were at the highest risk of delirium in a prospective cohort of patients undergoing surgery for AAAs and colorectal cancer.[52] A subsequent cohort study of the same patient population additionally showed renal impairment, cognitive impairment, active smoking, intensive care unit admission, and blood transfusion were associated with an increased risk of postoperative delirium, but prehabilitation program participation was protective.[53,54]

Preoperative identification of cognitive risk using standardized cognitive scales such as the mini-mental state examination can also allow engagement of patients and/or families to discuss the implications of proposed surgery (capacity to consent and risk of postoperative complications, including delirium) and the long-term effects of cognitive impairment.[51,55]

Recommendation: Patients should undergo screening for delirium risk and preoperative practices to minimize the onset of delirium should be implemented as a routine part of practice.
Quality of evidence: C (low)
Strength of recommendation: Grade 1 (strong)

2e. Tobacco and alcohol cessation. The SVS practice guidelines for AAAs recommend smoking cessation for ≥2 weeks before aneurysm repair,[56] although the supporting literature is limited. In a systematic review and meta-analysis of 25 studies (2 RCTs, 7 prospective cohort studies, and 16 retrospective studies), including >20,000 cardiac and noncardiac surgical patients, a 23% and 47% reduction was found in the incidence of respiratory complications for patients who had stopped smoking for 4 and 8 weeks before surgery, respectively.[57] Another meta-analysis of four RCTs demonstrated that smoking cessation interventions reduced surgical site infections (SSIs), and pooled data from 140 cohort studies supported the finding that 1 month of smoking cessation was associated with improved postoperative outcomes.[57-59] In the perioperative period, nicotine replacement therapy and smoking cessation medications have proved efficacious for smoking cessation.[60]

Recommendation: Smoking cessation therapy should be prescribed and a minimum of 4 weeks smoking cessation before surgery recommended.
Quality of evidence: A (high)
Strength of recommendation: Grade 1 (strong)

In a Cochrane review of two RCTs comprising 69 surgical patients, overall postoperative morbidity was increased by two- to threefold for patients who had abused alcohol. One month of preoperative abstinence significantly improved the outcomes for a group who

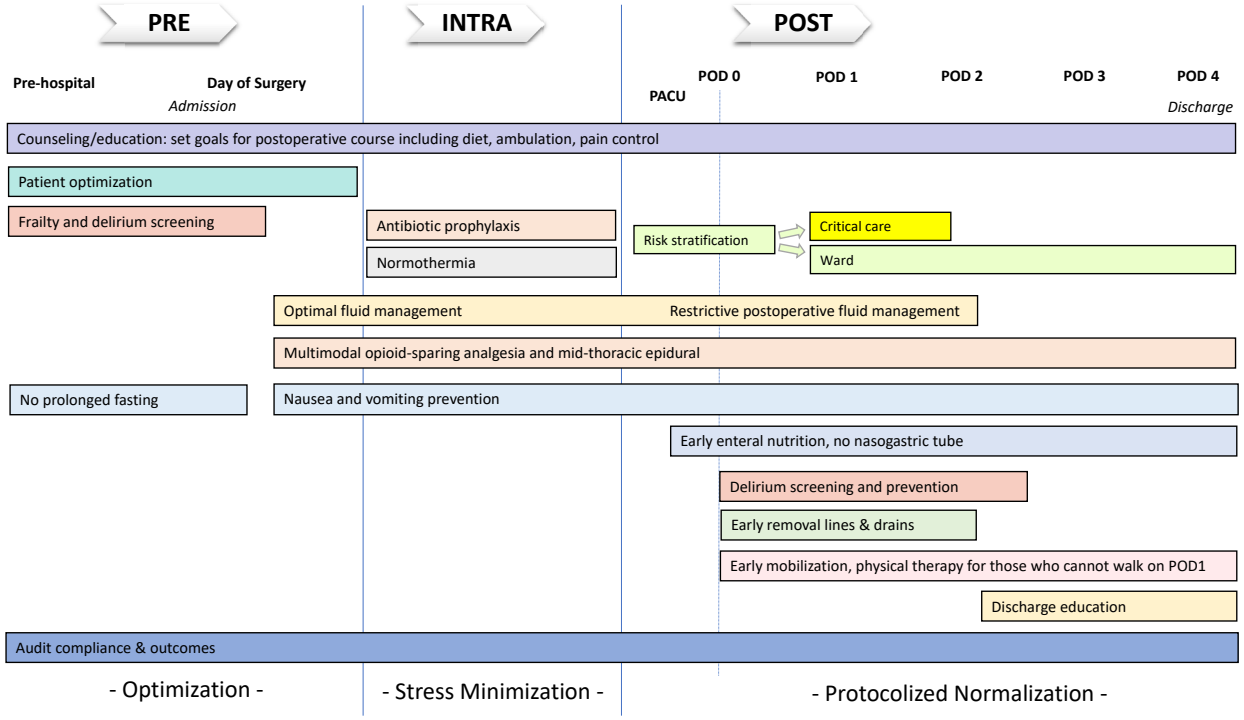

Fig. Enhanced Recovery After Surgery (ERAS) diagram graphically showing the timeline for each of the ERAS elements to be performed during the perioperative period. *Intra,* Intraoperative; *PACU,* postanesthesia care unit; *POD,* postoperative day; *Post,* postoperative; *Pre,* preoperative.

had imbibed at least five alcohol equivalents (or 15 units) per day.[61] Another meta-analysis of multiple RCTs in mixed surgical cohorts showed that drinking more than one alcohol equivalent (or two units) per day increased the risk of non-SSI but did not increase postoperative mortality.[62]

Recommendation: Alcohol cessation should be recommended for 4 weeks before surgery, especially for patients who consume more than five alcohol equivalents or 15 alcohol units per day.
Quality of evidence: C (low)
Strength of recommendation: Grade 1 (strong)

2f. Medical risk. Delivering optimal care in aortic disease requires balancing the operative risk relative to the likelihood of survival in the perioperative period and beyond. Patients with AAA are known to experience higher rates of heart attack, stroke, major amputation, and 5-year mortality compared with age-matched controls.[63] Patients should undergo a thorough preoperative assessment and optimization across a breadth of risk factors for aortic surgery as detailed in the guidelines for perioperative cardiovascular evaluation and management of patients undergoing noncardiac surgery.[64]

Risk scores can be used to quantify the overall risk of open aortic surgery and/or specific risk to a single physiologic system; multiple validated risk calculators are available.[65-67] The SVS Clinical Practice Guidelines for AAA suggest "informing patients contemplating open repair or endovascular AAA repair of the VQI [Vascular Quality Initiative] perioperative mortality risk score."[56] The Vascular Quality Initiative mortality risk model predicts for mortality well (C = 0.802).[68] However, the model discrimination for predicting for postoperative myocardial infarction after open aortic surgery was only 0.68.[67] Predicting the risk to a single organ system is less accurate with the available tools, which are not universally recommended.[69]

2f-i. Cardiovascular risk. Based on multiple high-quality RCTs of cardiovascular disease prevention, it is recommended that all patients with aneurysmal disease and aortoiliac occlusive disease should be offered antiplatelet therapy, statins (even if the low-density lipoprotein cholesterol level is <100 mg/dL), and antihypertensive agents to maintain the systolic blood pressure at <140 mm Hg.[64,70-72] However, we caution against starting a beta-blocker for blood pressure control immediately before surgery because its use appears to increase the 30-day mortality for noncardiac surgical populations.[73] Diabetes control with oral agents and/or insulin is also recommended because diabetes mellitus is a risk factor for cardiovascular disease, in general, and postoperative major adverse cardiac events, specifically. However, specific hemoglobin A1c targets and associated risks have not been specified in the setting of aortic surgery.[64,74,75]

Recommendation: Patients' cardiac risk should be evaluated and optimized with antiplatelet therapy, statins, antihypertensive therapy, and diabetes control before elective surgery.
Level of evidence: A (high)
Strength of recommendation: Grade 1 (strong)

2f-ii. Renal risk. Even in patients with normal baseline renal function, transient postoperative renal impairment has been associated with increased morbidity and the need for critical care support.[76] Furthermore, patients with existing chronic kidney disease face a well-established risk of poor outcomes after open aortic operations.[77] In accordance with the Kidney Disease: Improving Global Outcomes recommendations determined from systematic reviews of RCTs, angiotensin-converting enzyme inhibitors and angiotensin receptor antagonists should be withheld on the morning of surgery and only restarted once euvolemia has been achieved postoperatively.[78] Patients with severe renal insufficiency (ie, chronic kidney disease stage 4 or 5; estimated glomerular filtration rate <30 mL/min/1.73 m^2) should be evaluated by a specialist to optimize renal function before elective aortic repair.[79]

Recommendation: The patient's risk of acute kidney injury should be evaluated and optimized before elective surgery.
Level of evidence: A (high)
Strength of recommendation: Grade 1 (strong)

3. Preoperative exercise therapy and prehabilitation

Although frailty screening can be used in the preoperative discussion about proceeding with surgery, the nascent work in prehabilitation regimens has aimed to reduce the limitations in functional capacity among frail patients to better allow them to withstand the stress of surgery.[80,81] Prehabilitation engages the patient in a combination of exercise training, nutrition therapy, and mental preparation for surgery.[82] Based on several studies within cardiac[83-85] and abdominal surgery,[86-88] 3 to 4 weeks of prehabilitation is considered feasible and has been recommended in other specialties' ERAS guidelines.[89,90]

Studies of the exercise component of prehabilitation have been shown to be beneficial in the recovery after open aortic surgery; however, none of the vascular studies of ERAS-like programs in aortic surgery had had a complete prehabilitation program available.[8] A systematic review of the effects of exercise alone for AAA patients awaiting surgery found only four studies, all of which favored exercise training.[91] One RCT of 124 patients undergoing open or endovascular AAA repair examined the standard treatment vs 6 weeks of preoperative supervised exercise, comprising aerobic, stretching, and resistance training for 1 hour, three times per week.[92] Overall, a significant decrease was found in postoperative complications and shorter LOSs; however, the study was not powered to analyze open aortic surgery alone. Inspiratory muscle training for 6 d/wk for 2 weeks in 15-minute sessions showed a trend toward a decreased occurrence and duration of atelectasis in the intervention vs control group in another small RCT.[93] A cohort study demonstrated the feasibility of a high intensity interval training regimen for 12 weeks with three session per week.[94] Another cohort study found that AAA patients who had exercised early in preparation for surgery compared with later in recovery from surgery had had a significantly shorter LOS and time to attaining independence in sitting, standing, and walking.[95] Although the studies had included a diversity of training programs and had reported mixed results, they favored the use of the exercise component of prehabilitation and showed the safety of exercise for AAA patients with no adverse events related to the aneurysm.

Recommendation: Six weeks of supervised exercise therapy before elective surgery should be recommended.
Level of evidence: C (low)
Strength of recommendation: Grade 2 (weak)

4. Perioperative anticoagulation strategy or plan

Based on a RCT and a prospective cohort study of >1600 patients undergoing vascular surgery, aspirin reduces the incidence of adverse cardiovascular events and mortality among patients with coronary artery disease and should be continued during the perioperative period.[96-98] Often, patients with coexistent coronary and aortic disease will be receiving dual antiplatelet therapy, and the 2016 American College of Cardiology/American Heart Association guidelines recommend avoiding discontinuation of the second agent within 1 month after bare metal stent placement and 6 months after drug-eluting coronary stent placement, although the risk of stent thrombosis must be weighed against the risk of delaying aortic surgery on a case-specific basis.[98] These guidelines were determined by from multiple large observational studies of mixed surgical populations evaluating the timeframe for an increased risk of coronary stent thrombosis.[99-102] Practical recommendations for standardizing the perioperative management of antiplatelet and anticoagulation therapy for patients with coronary stents who require vascular surgery have been developed.[103]

When feasible, any antiplatelet medication, other than aspirin, should be stopped 7 days before surgery to reduce the risk of regional anesthesia techniques, including epidural placement, and can be resumed 6 hours after block performance or epidural catheter removal.[104,105] Both warfarin and non–vitamin K

antagonist oral anticoagulants should be discontinued ≥5 days and 2 days in advance of surgery, respectively, to allow for regional anesthetic techniques and to reduce the risk of intraoperative bleeding.[106] The need for low-molecular-weight heparin as a bridge should be determined by the indication for anticoagulation.[106]

Recommendation: Aspirin should be continued throughout the perioperative period.
Level of evidence: A (high)
Strength of recommendation: Grade 1 (strong)
Recommendation: Secondary antiplatelet medications and anticoagulant agents should be stopped before surgery, except for select patient populations.
Level of evidence: B (moderate)
Strength of recommendation: Grade 1 (strong)

PREOPERATIVE RECOMMENDATIONS

5. Fasting. Modern preoperative fasting guidelines have been a part of many enhanced recovery bundles studied in open aortic surgery, and limited fasting is feasible.[8] Based on a meta-analysis of multiple RCTs that included a range of surgical patients and according to both the American Society of Anesthesiologists' and European Society of Anesthesiology's preoperative fasting guidelines, which give strong recommendations based on high-quality evidence, patients should be allowed to drink clear fluids for ≤2 hours before elective surgery but should not eat any solid food for ≥6 hours for "light meals" or 8 hours for fatty foods and meat.[107,108] However, it is important to note that these recommendations only apply to patients who will undergo elective procedures, and a longer fasting period might be necessary for patients with delayed gastric emptying.

Recommendation: Patients should avoid overnight fasting and should be encouraged to drink clear fluids for ≤2 hours and light foods ≤6 hours before the induction of general anesthesia.
Level of evidence: A (high)
Recommendation: Grade 1 (strong)

6. Carbohydrate loading. No RCTs have specifically examined the role of oral carbohydrate loading for patients undergoing open aortic surgery; however, this practice was included as a part of a bundle of care in two "fast-track" aortic surgery publications.[8,9,11] Extrapolated from other specialties, the most commonly studied regimen has been 800 mL of a clear 12.5% carbohydrate drink the evening before surgery and 400 mL ≤2 hours before surgery.[109,110] Several RCTs of preoperative oral carbohydrate drinks reported that their use can reduce postoperative insulin resistance and result in less perioperative hyperglycemia compared with either placebo or fasting after midnight.[111-113] Other RCTs of variable size and quality have demonstrated that carbohydrate administration can modulate postoperative metabolic and inflammatory responses, decrease protein breakdown, and better preserve patients' lean body mass and muscle strength compared with preoperative fasting.[114] Several medium-size RCTs of coronary artery bypass surgery have demonstrated that the consumption of preoperative carbohydrates can reduce the incidence of myocardial injury, the intensive care unit LOS, and the need for vasoactive drug administration.[115-117] A systematic review of 22 RCTs found that oral carbohydrate loading is safe for ≤2 hours before surgery and can improve postoperative discomfort.[118] A Cochrane review of 27 RCTs of variable quality in mixed surgical populations concluded that preoperative carbohydrate loading reduces the hospital LOS, especially after major operations.[119]

Because many patients undergoing vascular surgery will have diabetes, the question of effectiveness and safety has been raised. Despite the low-quality evidence, it appears that oral carbohydrates are safe and effective in patients with diabetes.[120,121] However, no recommendations can be made for patients with diabetes.

Recommendation: Patients without diabetes should receive a preoperative carbohydrate drink.
Level of evidence: B (moderate)
Strength of recommendation: Grade 2 (weak)

7. Venous thromboembolism prophylaxis. Based on two RCTs, multiple prospective cohort studies of >1500 patients combined, and a retrospective analysis of registry data, the incidence of deep vein thrombosis (DVT) after open aortic surgery has been high, even among patients receiving perioperative chemoprophylaxis.[122-128] Within the initial hospitalization, the rate of DVT diagnosed with screening venous duplex ultrasound has ranged from 7.5% to 18% and might be as great as 37% within the 30-day postoperative period.[123] Specific to open aortic surgery, one RCT of 100 patients compared unfractionated heparin of 5000 U twice daily and calf-length intermittent mechanical compression to no DVT prophylaxis.[128] They found no differences in the rate of DVT or pulmonary embolism and reported no bleeding events.[128] Another RCT of 224 patients compared the effectiveness of unfractionated heparin to low-molecular-weight heparin and found a high rate of DVT (7.5% within 10 days) but no differences in effectiveness between the treatment groups.[122] Three patients (1%) had developed a wound hematoma requiring exploration; however, no major bleeding events were reported.[122]

Although aortic surgery is considered high risk for the development of venous thromboembolism (VTE),[129,130] most of the literature supporting specific pharmacomechanical thromboprophylaxis regimens have been from mixed surgical populations.[123,129] Compiling data from >100 RCTs of mixed abdominal surgery populations

comparing low-dose unfractionated heparin, low-molecular-weight heparin, and no chemoprophylaxis, the American College of Chest Physicians guidelines on the prevention of VTE in nonorthopedic surgical patients noted a significant reduction in VTE when prophylactic doses of either of these anticoagulant agents are used and that bleeding complications are rare.[129] On a case by case basis, if the consequences of bleeding are thought to be particularly severe, mechanical prophylaxis should be used until the risk abates and chemoprophylaxis can be initiated postoperatively.

If epidural or other neuraxial anesthesia is planned, it should be placed before the administration of the preoperative dose of venous thromboembolism chemoprophylaxis.[104,105] Chemoprophylaxis is safe throughout the hospitalization when the epidural is in place but must be held before epidural removal.

Recommendation: Calf-length intermittent compression devices combined with either low-dose unfractionated heparin or low-molecular-weight heparin starting immediately before surgery should be used routinely and continued at least throughout the hospitalization.
Level of evidence: B (moderate)
Strength of recommendation: Grade 1 (strong)

8. Preanesthetic sedative and analgesia medication. Preoperative anxiety is frequent and can lead to increased perioperative analgesic requirements. Multiple prospective and retrospective cohort studies have demonstrated benzodiazepines can cause neurocognitive impairment and have unwanted sedative effects.[131-134] Therefore, sedative or anxiolytic drugs should be avoided. This is especially important for patients aged >65 years because the American Geriatric Society has made a strong recommendation, with moderate evidence, against the use of benzodiazepines for older adults.[132]

Preanesthetic analgesia administered orally on the day of surgery has generally been accepted as a part of a multimodal opioid-sparing perioperative analgesia strategy. The most frequently used drugs include acetaminophen, nonsteroidal anti-inflammatory drugs (NSAIDs), and gabapentinoids, all of which have been shown to decrease postoperative pain scores, facilitate opioid-sparing pain management, and can be administered cost-effectively.[134,135] However, although rare, the use of gabapentinoids was associated with serious respiratory depression, which was amplified when used in combination with opioid or other sedative drugs.[136,137] Caution should be taken in the dosing of NSAIDs and gabapentinoids in the vascular population, with adjustments determined by patient age and renal function. Consideration of NSAID-related bleeding risk is also important. However, no studies have been performed of aortic surgery to classify the risk for bleeding in the setting of low-dose NSAIDS used for a short duration in the perioperative period.[138] Two of the reported enhanced recovery programs for aortic surgery included routine administration of NSAIDs but did not report adverse events.[9,11] Acknowledging the potential complications that can result from poor pain control or the overuse of opioids, it seems imprudent to exclude NSAIDs from perioperative use for all patients undergoing aortic surgery. No RCTs could be found in the literature of preanesthetic analgesia in open aortic surgery; however, many other surgical specialties have made strong recommendations, with low to moderate evidence, for the use of multimodal, opioid-sparing analgesia.

Recommendation: Sedatives should not be routinely used to reduce patient anxiety preoperatively.
Quality of evidence: C (low)
Strength of recommendation: Grade 1 (strong)
Recommendation: Preoperative administration of acetaminophen, NSAIDs, and gabapentinoids should be routinely used a as part of a multimodal opioid-sparing analgesia strategy.
Quality of evidence: C (low)
Strength of recommendation: Grade 1 (strong)

9. Antimicrobial prophylaxis and skin preparation. Preoperative intravenous prophylactic antibiotics should be administered immediately before (within 30-60 minutes before) open aortic aneurysm repair, with prophylactic antibiotics continued for not >24 hours postoperatively based on a meta-analysis of RCTs.[56,139,140] A meta-analysis of RCTs of antibiotic regimens and dosing did not demonstrate a significantly greater reduction in wound infection among comparable regimens of first- or second-generation cephalosporins, penicillin/β-lactamase inhibitors, aminoglycosides, or the glycopeptide agents vancomycin or teicoplanin.[139] Extrapolated from cardiac and spine surgery, the intraoperative antibiotic should be redosed within two serum half-lives of the agent[141-143] and can be additionally recommended for substantive procedural blood loss.[144]

Recommendation: Prophylactic intravenous antibiotic dosing should begin 30 to 60 minutes preoperatively, with redosing intraoperatively within two serum half-lives of the antimicrobial agent used or with substantive intraoperative blood loss and extending no more than 24 hours postoperatively.
Quality of evidence: A (high)
Strength of recommendation: Grade 1 (strong)

10. Prevention of nausea and vomiting. The prevention and treatment of postoperative nausea and vomiting (PONV) is an important component of perioperative care and one of the most common adverse events. The incidence of nausea and vomiting has been estimated to be 50% and 30% in the general surgical population, respectively, and might approach 80% for patients with

a high risk of PONV.[145] The risk factors for PONV include female sex, younger age, a history of PONV or motion sickness, nonsmoking, general (volatile) anesthesia, the use of postoperative opioids, and the duration of anesthesia.[146] The most commonly used PONV risk scoring systems are the scores by Apfel et al[147] and Koivuranta et al.[148] It is important to use PONV mitigation strategies such as minimizing the use of nitrous oxide and volatile anesthetics,[149] using regional anesthesia such as peripheral nerve blocks and neuraxial anesthesia,[150] and including opioid-sparing, multimodal analgesia techniques.[151,152]

Significant high-quality evidence is available from multiple RCTs supporting the use of multimodal prophylaxis and treatment of PONV that can be generalized to major vascular surgery.[153] Pharmacologic agent classes and other interventions available at present include 5-HT3 receptor antagonists, corticosteroids, antihistamines, dopamine antagonists, propofol anesthesia, natural killer-1 receptor antagonists, anticholinergics, and acupuncture.[154] For rescue treatment, one should use an antiemetic from a different class than had been used for prophylaxis.

Recommendation: A risk assessment for PONV should be performed, multimodal PONV prophylaxis according to the findings from the assessment should be routinely used, and a PONV rescue should use a different class of antiemetic.
Quality of evidence: A (high)
Strength of recommendation: Grade 1 (strong)

INTRAOPERATIVE RECOMMENDATIONS

11. Standard anesthetic protocol

Patients undergoing open aortic repair will have a high prevalence of comorbidities that predispose them to higher rates of postoperative complications and delayed recovery from surgery. The key components and aims of a standard anesthetic protocol are to use short-acting anesthetic agents and lung-protective ventilation and to achieve complete reversal of neuromuscular blockade as defined by appropriate monitoring. This allows for reversal for the patient with minimal side effects and facilitates early mobilization and feeding. A standardized multimodal anesthetic protocol should be considered in the aim to minimize the effects of anesthesia and surgery in open aortic repair and enhance recovery.

11a. Neuromuscular blocking agents and monitoring. Based on analyses of registries and other retrospective studies that have demonstrated similar results over the decades, the use of neuromuscular blocking agents should be monitored with quantitative methods (eg, acceleromyography) to ensure adequate intraoperative muscle relaxation and to prevent the delayed return of full neuromuscular function at the end of surgery. Approximately 5% of patients will experience a major pulmonary complication after noncardiac surgery, and inadequate reversal of neuromuscular blockade increases the risk of postoperative pulmonary complications.[155-158] A matched cohort analysis found that selective relaxant binding agents provide a rapid and complete reversal of common steroidal neuromuscular blocking agents without adverse effects found with other drugs.[158] The benefits of these new agents of neuromuscular blockade reversal include fewer pulmonary complications, reduced LOS, and reduction in 30-day unplanned readmission after major abdominal surgery.[159,160]

Recommendation: Neuromuscular monitoring should be used to ensure adequate intraoperative muscle relaxation and full reversal of neuromuscular blockade before extubation.
Quality of evidence: A (high)
Strength of recommendation: Grade 1 (strong)

11b. Cardiovascular monitoring. Open aortic surgery has been associated with swings in hemodynamics owing to the potential for blood loss and cross-clamping and unclamping the aorta in a surgical cohort, also known to have a high prevalence of occult cardiovascular disease. Many of the changes in blood pressure and cardiovascular tone occurring during aortic surgery are well described and should be anticipated. Invasive arterial and central venous monitoring, coupled with noninvasive cardiac output monitoring, are useful in mitigating labile hemodynamics.[161,162] The use of transesophageal echocardiography has been well described in noncardiac surgery, in particular, its utility in the assessment of intraoperative volume status, ventricular function, and regional wall motion abnormalities.[163,164] These capabilities are likely to provide useful clinical information when considering the most appropriate intraoperative hemodynamic intervention at any given time; however, the specific use of transesophageal echocardiography in open aortic operations has not been studied in depth nor has any clinical outcome benefit ever been described. No evidence has shown that pulmonary artery catheters are of benefit in aortic surgery.[161,162,165]

Changes in mean arterial pressure, cardiac output, and heart rate associated with clamping and unclamping of the aorta make maintaining hemodynamics and intraoperative fluid therapy much more challenging in aortic cases compared with other major abdominal operations. The judicious use of vasodilators could be necessary in those with cross-clamping above the renal arteries; however, increasing the depth of anesthesia for a period after clamping will often be all that is necessary for uncomplicated cases. It is ideal to maintain the baseline blood pressure during cross-clamping to maximize collateral flow to the distal tissues. The strategies to be considered before the release of the cross-clamp include, but are not limited to, increasing the minute ventilation, reducing

the depth of anesthesia, titrating up the doses of the vasopressor or inotrope, volume loading, and sequential release of the iliac clamps.

An association exists between myocardial injury during noncardiac surgery and the intraoperative mean arterial pressure (MAP). Even relatively short periods of a low MAP have been associated with a significantly increased risk of myocardial injury.[166] In a prospective cohort study of vascular surgery, a 40% MAP reduction from baseline for ≤30 minutes was shown to be a significant risk.[167] A large retrospective cohort study (n = 57,315) reported that although relative reductions in blood pressure were a useful measure, any decrease in MAP <65 mm Hg should be avoided, because this cutoff was strongly associated with an increased rate of myocardial injury.[168] Maintaining MAP target levels has great importance in this patient population given the effect of aortic cross-clamping and unclamping on distal tissue and end-organ perfusion and the associated deleterious effects of ischemia–reperfusion injury during open aortic operations.

Recommendation: Invasive cardiovascular monitoring with an arterial line is essential. Also, the MAP should be maintained to near baseline values and at or >65 mm Hg.
Level of evidence: B (moderate)
Strength of recommendation: Grade 1 (strong)

11c. Renal protection.

11c-i. Ischemic preconditioning. Much interest has ensued in the use of specific techniques to reduce organ failure or impairment after aortic surgery. One such example is ischemic preconditioning; however, this might actually cause harm.[169] A meta-analysis of nine trials of aortic surgery with 599 patients, of whom 336 had undergone open repair, concluded again that no benefit of renal ischemic preconditioning has been reported regarding mortality, kidney injury requiring renal support, and myocardial infarction.[170]

11c-ii. Renal protective medications. Two small RCTs of AAA patients and a meta-analysis of five small RCTs of other major cardiac and abdominal surgery have been conducted to evaluate the use of low-dose dopamine and fenoldopam on renal function in different clinical contexts. However, it appears that neither offers an advantage to euvolemic patients after elective abdominal aortic surgery.[171-173] The Kidney Disease: Improving Global Outcomes committee advised against the use of fenoldopam in 2012.[174] Similarly, RCTs have not demonstrated any clinical reductions in the incidence of renal failure with the use of mannitol.[175] A retrospective analysis of a single-center cohort of 169 patients who had undergone suprarenal clamping during AAA repair noted a renal protective effect for 0.5 g/kg mannitol given before clamping.[176] However, a small retrospective series from the Vascular Quality Initiative registry did not note any differences in renal outcomes when stratified by mannitol administration.[177]

Recommendation: Adjunctive renal protective medications and the methods of ischemic preconditioning of any type can cause harm and should not be used for infrarenal repairs.
Level of evidence: B (moderate)
Strength of recommendation: Grade 1 (strong)

11d. Cell salvage. The use of blood conservation strategies and, in particular, cell salvage is an established part of clinical practice and was reported in a meta-analysis of four RCTs with 292 patients to be associated with a reduced LOS in critical care, overall hospital LOS, and the use of allogeneic red blood cell transfusion, specifically for patients undergoing open AAA repair.[178,179] Citing these same studies, the Association of Anesthetists 2018 guidelines supported the routine use of red blood cell salvage during open AAA surgery and any surgery in adults if the blood loss could be expected to exceed 500 mL.[180]

Recommendation: Red blood cell salvage should be used.
Level of evidence: B (moderate)
Strength of recommendation: Grade 1 (strong)

11e. Lung protective ventilation. A number of intraoperative techniques (low tidal volumes [typically 6-8 mL/kg]), the use of positive end-expiratory pressure [typically 5-7 cm H_2O], and regular intraoperative recruitment maneuvers) can reduce the incidence of postoperative pulmonary complications. However, data are lacking for open aortic surgery. A recent systematic review and meta-analysis of 95 RCTs enrolling 18,062 patients reported that in enhanced recovery programs, lung-protective ventilation, goal-directed fluid therapy, and thoracic epidural analgesia are each independently associated with the reduced rates of pulmonary complications after major abdominal surgery.[181] Moderate quality evidence within this meta-analysis reported significant reductions in postoperative pulmonary complications for patients who had received intraoperative lung protective ventilation strategies. Owing to the high statistical heterogeneity, it is not possible to draw firm conclusions. No studies have reported evidence of harm using this strategy, and, as such, it is reasonable to adopt lung-protective ventilation strategies during open AAA surgery until further studies are undertaken and reported.[182,183]

Recommendation: Lung protective strategies should be used.
Level of evidence: C (low)
Strength of recommendation: Grade 2 (weak)

11f. Epidural analgesia. RCTs have compared general anesthesia with intraoperative epidural anesthesia to general anesthesia with systemic opioids with respect to reported pain, major complications, and death after open AAA surgery.[184-190] These studies were included in a Cochrane review in 2016, which reported no differences in 30-day mortality after open AAA surgery. However, they found low to moderate quality evidence of a reduced rate of myocardial infarction, time to extubation, LOS in critical care, and postoperative respiratory failure, favoring epidural analgesia.[191] The recently published National Institute for Health and Care Excellence clinical guidance on AAA management used stricter inclusion criteria and included fewer trials than those in the Cochrane group but also recommended that anesthesiologists consider using epidural analgesia in this high-risk patient group.[169]

One small RCT compared thoracic epidural infusion and continuous local wound infiltration in a "fast-track" abdominal aortic surgery cohort and found that the local analgesia group had required more oral and intravenous analgesics but had had a similarly short time to ambulation, regular diet, and hospital discharge.[189] No other data were available to make a recommendation regarding the use of transversus abdominis plane blocks or other locoregional anesthesia techniques (eg, rectus sheath and wound catheters) in open aortic surgery, although this is an area of rapidly advancing scientific study and recommendations could be possible in the future.

Recommendation: Mid-thoracic (T6-T9) epidural analgesia is recommended intraoperatively and should be continued postoperatively as an infusion or patient-controlled analgesia using a combination of local anesthetic and an opioid.
Level of evidence: B (moderate)
Strength of recommendation: Grade 1 (strong)

12. Body temperature management

Perioperative hypothermia (core body temperature <36°C) results from cold operating room temperatures, patient exposure, and anesthesia-related impairment of central thermoregulatory control. Hypothermia leads to cardiac arrhythmia, coagulopathy, altered levels of consciousness, decreased drug metabolism, impaired renal function, a leftward shift in the hemoglobin oxygen saturation curve, resulting in reduced oxygen delivery, prolonged wound healing, and an increased incidence of SSI. From a combination of RCTs and prospective and retrospective cohorts across many surgical specialties, evidence has shown that maintaining normothermia reduces these undesired outcomes.[192] Strategies to maintain normothermia include preoperative warming (10-30 minutes before the induction of anesthesia), intraoperative warming with a forced air heating blanket, and the use of fluid warmers and prewarmed irrigation.[192]

Recommendations: Multiple strategies should be used to maintain normothermia, including prewarming and active warming of patients intraoperatively.
Quality of evidence: B (moderate)
Strength of recommendation: Grade 1 (strong)

13. Drainage of surgical site strategy

Drains are not routinely used during elective transabdominal aortic surgery because these are sterile cases that do not involve the intestinal or genitourinary systems. Postoperative fluid collections will most be often hematomas, which will be ineffectively drained by small percutaneous drains. Retroperitoneal aortic surgery can result in a higher rate of lymphatic disruption. Drains have, anecdotally, been used in this approach; however, no published data were found on the benefit or harm of this practice.

In the management of groin incisions, a Cochrane review of three RCTs found no evidence demonstrating that the usage of drains will decrease groin incision complications.[193] The use of specific closure techniques and dressings has some increasing evidence. A single-center RCT and one cohort study of 115 patients undergoing vascular operations with a groin incision demonstrated lower rates of SSI in high-risk, but not average-risk, patients when negative pressure wound therapy was used.[194,195] However, a different single-center RCT of high-risk patients with groin incisions did not find a difference in SSIs when stratified by the use of negative pressure wound therapy, although the study was underpowered owing to a lower than expected rate of SSIs.[196]

Recommendation: Drains should not be routinely used in the surgical wound.
Level of evidence: C (low)
Strength of recommendation: Grade 2 (weak)

POSTOPERATIVE RECOMMENDATIONS

14. Multimodal analgesia and opioid reduction. A standardized, perioperative multimodal antinociceptive protocol in enhanced recovery pathways results in adequate postoperative pain relief and improved outcomes.[197-199] However, the results from well-designed studies of open aortic surgery have been inconclusive or are lacking.

Acetaminophen and NSAIDS, including selective COX-2 (cyclooxygenase-2) inhibitors, are a basic part of postoperative multimodal pain management and are used widely, either orally or intravenously.[198,200,201] Acetaminophen is an antipyretic, and its analgesic activity is additive to NSAIDs and opioids. NSAIDs should be part of a

multimodal strategy after open aortic surgery unless the patient has specific contraindications for its use. Several RCTs of other surgical specialties have also investigated other nonopioid postoperative analgesia, including gabapentin, α_2-agonists, S-ketamine, magnesium sulfate, β-blockade, and high dose steroids, which all resulted in a reduction in pain.[202-208]

Opioids have remained the most frequently prescribed class of drugs globally.[198] However, it has also been recognized that patients are at a high risk of opioid misuse and addiction in the long term.[209,210] In the short term, opioids have also been related to many undesirable side effects that slow recovery, specifically including delirium, which is of particular relevance to the aortic surgery population.[211,212] Oral or intravenous opioids might be less effective in treating acute postoperative pain following open aortic surgery compared with epidural analgesia.[213] However, in a single-center RCT of 168 patients undergoing open aortic surgery, patients with patient-controlled epidural analgesia had had similar outcomes and time to recovery compared with the patients with patient-controlled intravenous narcotic analgesia.[190]

Recommendation: Multimodal analgesic regimens should be routinely used to improve pain control and minimize opioid consumption.
Quality of evidence: B (moderate)
Strength of recommendation: Grade 1 (strong)

15. Nasogastric drainage. Meta-analyses of nonrandomized studies of patients undergoing gastrectomy or other abdominal surgery have demonstrated that the routine use of nasogastric tubes is associated with delayed oral intake and return of bowel function.[214-216] For operations that also involve foregut mobilization, the 2019 ERAS guidelines for pancreatoduodenectomy recommend against the routine use of nasogastric tubes and advocate removing them before the end of the anesthesia.[90] It is reasonable to generalize this practice of removing the nasogastric tube at the time of extubation to aortic patients who undergo duodenal mobilization, but not resection. The routine use of nasogastric tubes has been shown in large Cochrane analysis of RCTs to cause pneumonia.[217]

Recommendation: The routine use of postoperative nasogastric tubes should be avoided.
Level of evidence: A (high)
Strength of recommendation: Grade 1 (strong)

16. Oral feeding. Traditional signs of bowel function such as the presence of bowel sounds and passage of flatus are unreliable indicators of a return of gastric and intestinal function. In a cohort study of patients undergoing elective, open AAA repair, the median time to normal gastric emptying was 18 ± 7 hours, indicating that little reason exists to withhold solid food from patients after 24 hours.[218] Early enteral nutrition has been shown to reduce infectious complications and to be protective against the development of intestinal ischemia and stress ulcers in a prospective cohort study of AAA patients in critical care units.[219] Postoperatively, patients should be encouraged to reestablish oral nutrition as early as possible, allowing patients to eat what they are comfortable with and consume oral nutritional supplements daily. Oral intake of solid foods has been shown to be possible within 24 hours in multiple "fast-track" observational studies of patients recovering from open aortic surgery in Europe.[8,11,12,220,221]

Recommendation: An early return to a normal diet and oral nutritional supplements should be promoted.
Level of evidence: B (moderate)
Strength of recommendation: Grade 1 (strong)

17. Fluid therapy. Fluid management has been a central tool of postoperative therapy in aortic surgery, and appropriate fluid replacement is needed to maintain a euvolemic state and avoid postoperative complications, including acute kidney injury,[222,223] or the sequelae of fluid overload, including heart failure, decreased oxygenation, and prolonged ileus.[224-226] Ideally, patients will leave the operating room in a euvolemic state, rendering fluid boluses, on the one hand, or diuretics, on the other hand, unnecessary. One's best clinical judgement must be used to correct the fluid balance in patients who leave the operating room under- or over-resuscitated. However, one must remember that significant variability exists in the subjective fluid balance assessment between providers and within the same provider, which is strong predictor of fluid overload.[227,228]

If euvolemic patients are able to drink fluids, the use of intravenous fluids might not be needed to maintain euvolemia.[8] However, if needed, restrictive fluid therapy has been more beneficial than liberal fluid replacement. Three RCTs with a total of 125 aortic surgery patients without existing severe congestive heart failure or chronic kidney disease demonstrated that the group given ≤1.5 L/d had significantly fewer complications, a lower risk of cardiopulmonary complications, and shorter ICU and total hospital LOSs than the liberal fluid therapy group.[229-231] A Cochrane review reported no evidence for the use of a specific fluid or evidence to support colloids vs crystalloids for patients undergoing abdominal aortic surgery.[232]

Recommendation: If intravenous fluids are indicated, postoperative fluid therapy should be restricted to 1.5 L/d.
Level of evidence: B (moderate)
Strength of recommendation: Grade 1 (strong)

18. Urinary drainage. Accurate measurement of urine output is necessary in the immediate postoperative

period, because acute kidney injury has been estimated to develop in ≤15% of patients after infrarenal clamping and 21% of patients after suprarenal or supraceliac clamping.[177,233-235] Because of concerns of catheter-associated urinary tract infection and guidance from the U.S. Centers for Disease Control and Prevention, the use of prolonged urinary catheters has decreased.[236] As such, urinary catheters placed for surgical and postoperative monitoring should be removed as soon as possible, preferably within 24 hours.[236] The presence of a thoracic epidural should not preclude removal of urinary drainage catheters. However, ~10% of patients overall and 25% of patients with benign prostatic hyperplasia will require catheter replacement because of urinary retention.[237,238]

Recommendation: The early removal of urinary drainage catheters is recommended.
Level of evidence: C (low)
Strength of recommendation: Grade 1 (strong)

19. Glycemic control. Poor glycemic control is an independent risk factor for adverse events in vascular patients with or without a diagnosis of diabetes.[239,240] In a cohort study of >1000 patients undergoing vascular surgery, postoperative hyperglycemia was strongly associated with 11 different negative outcomes, including 30-day mortality, myocardial infarction, acute renal failure, stroke, wound complications, and a return to the operating room.[240] Nondiabetic patients with hyperglycemia demonstrated an even stronger association with these negative surgical outcomes.[240]

In a multicenter RCT of 880 nondiabetic patients undergoing major abdominal surgery, preoperative carbohydrate loading prevented postoperative hyperglycemia and significantly reduced the number of patients requiring insulin to maintain a glucose level <180 mg/dL.[110] A single-center RCT of 236 vascular patients undergoing open AAA repair, lower extremity bypass surgery, or limb amputation compared continuous insulin infusion to maintain glucose levels at 100 to 150 mg/dL to intermittent insulin boluses to maintain glucose levels >150 mg/dL during the first 48 hours after surgery. Insulin infusion was protective against a composite end point of all-cause death, myocardial infarction, and congestive heart failure, and those patients did not experience a statistically significant different rate of hypoglycemia.[239] Careful postoperative glycemic control with an emphasis on limiting extreme variability in glucose levels decreased the incidence of adverse cardiac events.[239] However, caution is advised because overly aggressive glucose control causing hypoglycemia can increase mortality.[241,242] No RCT data for a serum glucose threshold for initiating intraoperative insulin treatment, and no perioperative glucose targets have been agreed on for patients undergoing aortic operations.[243]

Recommendation: Glycemic control should be maintained, with intention of avoiding hypoglycemia.
Level of evidence: B (moderate)
Strength of recommendation: Grade 1 (strong)

20. Early mobilization. No high-quality studies regarding early mobility and open aortic surgery; however, many studies of ERAS-like pathways for open aortic surgery effectively used early mobility as a part of their care bundles.[8] Extrapolating from other specialties, early mobility after aortic surgery likely decreases complications and improves patient outcomes.[244,245] Successful mobilization strategies require a multidisciplinary approach, objective evaluation of patient safety and an ability for early ambulation, and tracking progress with a formal mobility scale.[246] An early mobility protocol with at least twice-daily assessments increases mobility and decreases delirium and LOS.[246] Those who are more physically fit preoperatively will be able to achieve postoperative mobility goals more quickly[95]; however, all patients should have a tailored, safe plan for ambulation.[246] If patients are not progressing, the causes of failure should be analyzed by the multidisciplinary team, including physical therapists, and corrective measures should be instituted quickly.

Recommendation: The use of a formal plan for early mobilization should be instituted, with early physical therapy involvement, when needed.
Level of evidence: C (low)
Strength of recommendation: Grade 1 (strong)

21. Discharge education. It is reasonable to believe that the standard discharge criteria for many general surgery operations are applicable to aortic surgery patients, including tolerance of oral intake, recovery of lower gastrointestinal function, adequate pain control, ability to mobilize and perform self-care, and no evidence of complications or untreated medical problems.[247] Up to 30% of aortic patients might have delirium or transient advanced mental impairment that complicates or delays discharge readiness.[248]

Patients undergoing vascular surgery have had 30-day readmission rates as high as 20% and up to one half of readmissions will be deemed avoidable.[249-251] In line with fundamental ERAS philosophy, a published conceptual model of preventing readmissions in vascular surgery that includes patient education and timely communication from the preoperative phase to the postoperative phase of care.[252] A Cochrane review of two RCTs concluded that written and verbal information on specific care instructions, medication lists, and when to seek medical attention at discharge significantly increased patient knowledge and satisfaction.[253,254] The data on follow-up postoperative telephone calls has

been mixed. A Cochrane review of 33 studies of mixed methods from different specialties was inconclusive; however, no adverse effects of the invention were reported.[255] In-person visits might be more beneficial. Among patients experiencing a complication after open thoracic aneurysm repair, having a visit with a primary care physician within 30 days of the operation reduced the readmission rates from 35% to 20%.[256]

Recommendation: Both written and verbal discharge education should be used, with follow-up telephone calls within 24 to 48 hours after hospital discharge, and clinic follow-up visits should be scheduled with both the surgeon and the primary care physician at least once by 30 days postoperatively.
Level of evidence: C (low)
Strength of recommendation: grade 1 (strong)

22. Audit of outcomes. Previous implementation of ERAS protocols in other surgical disciplines has led to a reduction in complications, shorter LOSs, and improved cost-savings. The analysis of the literature on ERAS audits has been based almost exclusively on systematic reviews, and prospective studies on this topic have yet to be developed. However, one prospective analysis comparing self-declared ERAS with non-ERAS hospitals demonstrated that having an ERAS protocol in place is not enough to improve patient outcomes.[257] Other surgical specialties have demonstrated an association between increasing ERAS compliance and decreased surgical complications and LOS.[258,259]

Interactive auditing and reporting will identify areas of noncompliance, improve tracking of outcomes, and facilitate continuous quality improvement related to specific patient populations, care settings, and/or logistical issues.[258] An observational study of >500 gynecologic patients found that using a compliance audit tool increased compliance from 56% to 77% and was associated with significant reductions in LOS.[260] Another single-center pre—post study of gynecologic patients demonstrated that structured ERAS implementation, including interactive auditing, resulted in better ERAS compliance and a shorter time to functional recovery and hospital discharge.[261] Similar results were found at 13 centers that had participated in an international ERAS database for colorectal surgery; however, interestingly, 2 years after initiating the ERAS programs, auditing reveled that implementation compliance had decreased, which correlated with an increase in the LOS and complication rates.[262] To improve the quality of ERAS auditing and reporting, the ERAS USA and ERAS Society have published the Reporting on ERAS Compliance, Outcomes, and Elements Research Checklist.[7] This tool delineates the best practices for reporting clinical pathways and describing compliance. Clinicians are encouraged to use auditing tools; examples include the ERAS Interactive Audit System (available at: http://erassociety.org/interactive-audit/) and the Agency for Healthcare Research and Quality safety program for improving surgical care and recovery (available at: https://www.ahrq.gov/hai/tools/enhanced-recovery/index.html).

Recommendation: The use of routine auditing of ERAS care processes and feedback to all staff involved is necessary.
Level of evidence: C (low)
Strength of recommendation: Grade 1 (strong)

CARE ELEMENTS WITH CONFLICTING OR INSUFFICIENT DATA FOR A RECOMMENDATION

Some traditional clinical practices are in use for which the literature does not allow firm recommendations; therefore, they were not included in our consensus statement. Nevertheless, because of their common use in many institutions, the writing group has summarized the current state of knowledge.

Preoperative medical risk assessment. A number of commonly used practices are of limited or no benefit in routine medical risk assessment. Preoperative routine chest radiography cannot be recommended because it has no supporting scientific evidence. It can be selectively used for patients with new or unstable cardiopulmonary signs or symptoms and for patients at increased risk of postoperative pulmonary complications if the results will alter management (ie, postpone surgery).[263-265] In a large, prospective cohort study, the results from preoperative pulmonary function studies did not correlate with the postoperative outcomes and cannot be recommended as a routine part of a preoperative workup.[266]

Sources of infection, apart from skin and the operative environment, should be considered, such as elimination of potential septic dental sources ≥2 weeks before implantation of an aortic prosthesis.[56] The predictive value of routine urinalysis in asymptomatic patients is poor[267,268] but must be weighed against the potential infectious risk to prosthetic material.[56] Although these measures make sense, no solid scientific background is available for a firm and specific recommendation.

Hematologic disorders, specifically thrombocytopenia, should be evaluated preoperatively, preferably by a hematologist, because of the associated bleeding and mortality risk.[269,270]

Skin preparation. Based on meta-analysis of a small number of RCTs with heterogeneous surgical procedures and quasi-experimental cohort studies of vascular operations, hair clipping should be performed immediately preoperatively.[271-273] Preoperative skin preparation should be standardized, with the operative area being scrubbed the day before and immediately before surgery with a chlorhexidine solution. This was based on RCTs of heterogeneous clean-contaminated surgeries, which indicated a benefit. However, conflicting evidence was

found in smaller RCTs and prospective observational studies of vascular reconstructions that did not demonstrate benefit.[274-276]

Intraoperative fluid therapy. No reliable data are available to guide fluid management during open aortic surgery, and the need for research is obvious. The use of goal-directed fluid therapy has been recommended for many other major abdominal surgeries. However, fluid management during open aortic surgery is particularly complicated because of cardiac disease and cross-clamping, which causes extreme disruptions in cardiac stress and fluid distribution in the body.

SUMMARY AND CONCLUSIONS

This consensus statement represents the most recent evidenced-based recommendations from the ERAS Society guideline group and the SVS for the perioperative management of patients undergoing open aortic vascular surgery.

These first ERAS recommendations for elective open aortic surgery are important in summarizing the large volume of heterogeneous studies across all ERAS elements for operations performed for either aortic aneurysm disease or aortoiliac occlusive disease. The authors' recommendations provided in this intersocietal consensus statement are in accordance with the methods set out by the ERAS Society and SVS and are based on the synthesis of an objective assessment of the best available evidence in open aortic surgery, other surgical disciplines, and consensus of the guideline development group. The available evidence was graded and potential harm from the use of the care element was also considered in the recommendations; therefore, strong recommendations could have been reached from low-quality or conflicting data and vice versa. Likewise, this method clearly accounts for, and indicates where recommendations have been made, based on data extrapolated from other surgical specialties.

The present consensus statement highlights the numerous research gaps that exist. Although the results from the few clinical studies available of cohorts of patients with aortic disease are promising, studies of high methodologic quality are needed. The lines of research to be developed could include any of the ERAS elements or combined elements but are likely to be particularly needed for preadmission optimization, prehabilitation, preoperative carbohydrate loading for those with diabetes, preanesthetic sedatives and analgesia, conditions for postoperative urinary catheter removal, early mobility protocols, postdischarge education, and auditing practices.

Our main purpose was to define the current standards based on the available literature and to enable multidisciplinary teams to implement these procedures in their practice to investigate to what extent they can improve outcomes.[1,277] As demonstrated in other specialties, using similar evidence-based guidelines and consensus statements to form care teams to enhance patient optimization and shared decision-making, focus on physiologic stress minimization, and reduce variations in postoperative convalescence promises to improve the safety and outcomes for patients undergoing open aortic operations.

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