Circulation

This 2026 guideline replaces the 2024 perioperat... ...mmittee evaluated the evidence published through March 2026 and d... remains valid and current. No new evidence was identified that chan... ...s. The recommendations, supportive text, figures, tables, and references are identical to those in the 2024 publication. Details of the process are described in the 2026 ACC/AHA Methodology and Policies Manual.

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CLINICAL PRACTICE GUIDELINES

2026 AHA/ACC/ACS/ASNC/HRS/SCA/SCCT/SCMR/SVM Guideline for Perioperative Cardiovascular Management for Noncardiac Surgery: A Report of the American College of Cardiology/American Heart Association Joint Committee on Clinical Practice Guidelines

Developed in Collaboration With and Endorsed by the American College of Surgeons, American Society of Nuclear Cardiology, Heart Rhythm Society, Society of Cardiovascular Anesthesiologists, Society of Cardiovascular Computed Tomography, Society for Cardiovascular Magnetic Resonance, and the Society for Vascular Medicine

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AIM: The "2026 AHA/ACC/ACS/ASNC/HRS/SCA/SCCT/SCMR/SVM Guideline for Perioperative Cardiovascular Management for Noncardiac Surgery" provides recommendations to guide clinicians in the perioperative cardiovascular evaluation and management of adult patients undergoing noncardiac surgery.

METHODS: A comprehensive literature search was conducted from August 2022 to March 2023 to identify clinical studies, reviews, and other evidence conducted on human subjects that were published in English from MEDLINE (through PubMed), EMBASE, the Cochrane Library, the Agency for Healthcare Research and Quality, and other selected databases relevant to this guideline.

*Writing committee members are required to recuse themselves from voting on sections to which their specific relationships with industry may apply; see Appendix 1 for detailed information. †Former ACC/AHA Joint Committee on Clinical Practice Guidelines member; current member during the writing effort. ‡ACC/AHA Joint Committee on Clinical Practice Guidelines. §AHA/ACC Joint Committee on Clinical Data Standards. ‖Society for Vascular Medicine representative. ¶Society of Cardiovascular Computed Tomography representative. #Society of Cardiovascular Anesthesiologists representative. **AHA/ACC Joint Committee on Performance Measures. ††Society for Cardiovascular Magnetic Resonance representative. ‡‡Heart Rhythm Society representative. §§American College of Surgeons representative. ‖‖American Society of Nuclear Cardiology representative.

Peer Review Committee Members and AHA/ACC Joint Committee on Clinical Practice Guidelines Members, see page e475.

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CLINICAL STATEMENTS AND GUIDELINES

STRUCTURE: Recommendations from the "2014 ACC/AHA Guideline on Perioperative Cardiovascular Evaluation and Management of Patients Undergoing Noncardiac Surgery" have been updated with new evidence consolidated to guide clinicians; clinicians should be advised this guideline supersedes the previously published 2014 guideline. In addition, evidence-based management strategies, including pharmacological therapies, perioperative monitoring, and devices, for cardiovascular disease and associated medical conditions, have been developed.

Key Words: AHA Scientific Statements ■ anesthetics ■ biomarkers ■ cardiac ■ preoperative evaluation ■ cardiovascular ■ diagnostic testing ■ cardiovascular diseases ■ cardiovascular risk score ■ heart failure ■ heart valve diseases ■ intraoperative period ■ major adverse cardiovascular events ■ myocardial protection ■ noncardiac surgery ■ perioperative management ■ postoperative complications ■ preoperative care ■ revascularization ■ risk assessment ■ treatment outcome

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TOP TAKE-HOME MESSAGES

1. A stepwise approach to perioperative cardiac assessment assists clinicians in determining when surgery should proceed or when a pause for further evaluation is warranted.
2. Cardiovascular screening and treatment of patients undergoing noncardiac surgery should adhere to the same indications as nonsurgical patients, carefully timed to avoid delays in surgery and chosen in ways to avoid overscreening and overtreatment.
3. Stress testing should be performed judiciously in patients undergoing noncardiac surgery, especially those at lower risk, and only in patients in whom testing would be appropriate independent of planned surgery.
4. Team-based care should be emphasized when managing patients with complex anatomy or unstable cardiovascular disease.
5. New therapies for management of diabetes, heart failure, and obesity have significant perioperative implications. Sodium-glucose cotransporter 2 inhibitors should be discontinued 3 to 4 days before surgery to minimize the risk of perioperative ketoacidosis associated with their use.
6. Myocardial injury after noncardiac surgery is a newly identified disease process that should not be ignored because it portends real consequences for affected patients.
7. Patients with newly diagnosed atrial fibrillation identified during or after noncardiac surgery have an increased risk of stroke. These patients should be followed closely after surgery to treat reversible causes of arrhythmia and to assess the need for rhythm control and long-term anticoagulation.
8. Perioperative bridging of oral anticoagulant therapy should be used selectively only in those patients at highest risk for thrombotic complications and is not recommended in the majority of cases.
9. In patients with unexplained hemodynamic instability and when clinical expertise is available, emergency focused cardiac ultrasound can be used for perioperative evaluation; however, focused cardiac ultrasound should not replace comprehensive transthoracic echocardiography.

PREAMBLE

Since 1980, the American College of Cardiology (ACC) and American Heart Association (AHA) have translated scientific evidence into clinical practice guidelines with recommendations to improve cardiovascular health. These guidelines, which are based on systematic methods to evaluate and classify evidence, provide a foundation for the delivery of quality cardiovascular care. The ACC and AHA sponsor the development and publication of clinical practice guidelines without commercial support, and members volunteer their time to the writing and review efforts. Guidelines are official policy of the ACC and AHA. For some guidelines, the ACC and AHA collaborate with other organizations.

Intended Use

Clinical practice guidelines provide recommendations applicable to patients with or at risk of developing cardiovascular disease (CVD). The focus is on medical practice in the United States, but these guidelines are relevant to

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patients throughout the world. Although guidelines may be used to inform regulatory or payer decisions, the intent is to improve quality of care and align with patients' interests. Guidelines are intended to define practices meeting the needs of patients in most, but not all, circumstances and should not replace clinical judgment.

Clinical Implementation

Management, in accordance with guideline recommendations, is effective only when followed by both practitioners and patients. Adherence to recommendations can be enhanced by shared decision-making between clinicians and patients, with patient engagement in selecting interventions based on individual values, preferences, and associated conditions and comorbidities.

Methodology and Modernization

The AHA/ACC Joint Committee on Clinical Practice Guidelines (Joint Committee) continuously reviews, updates, and modifies guideline methodology on the basis of published standards from organizations, including the National Academy of Medicine (formerly the Institute of Medicine),[1,2] and on the basis of internal reevaluation. Similarly, presentation and delivery of guidelines are reevaluated and modified in response to evolving technologies and other factors to optimally facilitate dissemination of information to health care professionals at the point of care.

Numerous modifications to the guidelines have been implemented to make them shorter and enhance "user friendliness." Guidelines are written and presented in a modular recommendation format in which each chunk includes a table of recommendations, a brief synopsis, recommendation-specific supportive text and, when appropriate, flow diagrams or additional tables. Hyperlinked references are provided for each modular knowledge chunk to facilitate quick access and review.

In recognition of the importance of cost–value considerations, in certain guidelines, when appropriate and feasible, an assessment of value for a drug, device, or intervention may be performed in accordance with the ACC/AHA methodology.[3]

To ensure that guideline recommendations remain current, new data will be reviewed on an ongoing basis by the writing committee and staff. When applicable, recommendations will be updated with new evidence, or new recommendations will be created when supported by published evidence-based data. Going forward, targeted sections/knowledge chunks will be revised dynamically after publication and timely peer review of potentially practice-changing science. The previous designations of "full revision" and "focused update" will be phased out. For additional information and policies on guideline development, readers may consult the ACC/AHA guideline methodology manual[4] and other methodology articles.[5–7]

Selection of Writing Committee Members

The Joint Committee strives to ensure that the guideline writing committee contains requisite content expertise and is representative of the broader cardiovascular community by selection of experts across a spectrum of backgrounds, representing different geographic regions, sexes, races, ethnicities, intellectual perspectives/biases, and clinical practice settings. Organizations and professional societies with related interests and expertise are invited to participate as collaborators.

Relationships With Industry and Other Entities

The ACC and AHA have rigorous policies and methods to ensure that documents are developed without bias or improper influence. The complete policy on relationships with industry and other entities (RWIs) can be found online. Appendix 1 of the guideline lists writing committee members' comprehensive and relevant RWIs.

Evidence Review and Evidence Review Committees

In developing recommendations, the writing committee uses evidence-based methodologies that are based on all available data.[4,5] Literature searches focus on randomized controlled trials (RCTs) but also include registries, nonrandomized comparative and descriptive studies, case series, cohort studies, systematic reviews, and expert opinion. Only key references are cited.

An independent evidence review committee is commissioned when there are ≥1 questions deemed of utmost clinical importance and merit formal systematic review to determine which patients are most likely to benefit from a drug, device, or treatment strategy, and to what degree. Criteria for commissioning an evidence review committee and formal systematic review include absence of a current authoritative systematic review, feasibility of defining the benefit and risk in a time frame consistent with the writing of a guideline, relevance to a substantial number of patients, and likelihood that the findings can be translated into actionable recommendations. Evidence review committee members may include methodologists, epidemiologists, clinicians, and biostatisticians. Recommendations developed by the writing committee on the basis of the systematic review are marked "SR."

Guideline-Directed Management and Therapy

The term guideline-directed management and therapy (GDMT) encompasses clinical evaluation, diagnostic testing, and both pharmacological and procedural treatments. For these and all recommended drug treatment regimens, the reader should confirm dosage with product insert material and evaluate for contraindications and interactions. Recommendations are limited to drugs,

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devices, and treatments approved for clinical use in the United States.

Joshua A. Beckman, MD, MS, FACC, FAHA
Chair, AHA/ACC Joint Committee on Clinical Practice Guidelines

1. INTRODUCTION

1.1. Methodology and Evidence Review

The recommendations listed in this guideline are, whenever possible, evidence based. An initial extensive evidence review—which included literature derived from research involving human subjects, published in English, and indexed in MEDLINE (through PubMed), EMBASE, the Cochrane Library, the Agency for Healthcare Research and Quality, and other selected databases relevant to this guideline—was conducted from August 2022 to March 2023. Key search words included but were not limited to the following: ACC/AHA clinical practice guideline; anesthesia, general; anesthetics; anesthetics, inhalation; anesthetics, intravenous; bariatric surgery; cardiac assessment; cardiac evaluation; cardiac preoperative evaluation; cardiac protection; cardiovascular risk prediction; cardiovascular risk score; death; death, sudden, cardiac; elective surgical procedures; evaluation; heart function tests; hospital mortality; intraoperative period; intraoperative complications; lifestyle; major adverse cardiovascular events; myocardial injury time factors; myocardial protection; noncardiac surgery; outcome assessment, health care; patient care team; perioperative; perioperative cardiovascular risk; periprocedural; perioperative assessment; perioperative management; perioperative medicine; perioperative nursing; perioperative period; postoperative complications; predictive value of tests; preoperative care; preoperative stress testing; quality of life; risk assessment; risk, cardiac; risk factors; surgical procedures, operative; treatment outcome.

Additional relevant studies, which were published through November 2023 during the guideline writing process, were also considered by the writing committee and added to the evidence tables when appropriate. The final evidence tables are included in the Online Data Supplement and summarize the evidence used by the writing committee to formulate recommendations. References selected and published in the present document are representative and not all-inclusive.

1.2. Organization of the Writing Committee

The writing committee consisted of anesthesiologists, general cardiologists, interventional cardiologists, electrophysiologists, heart failure cardiologists, cardiac imaging experts, critical care physicians, internists, internal medicine hospitalists, general surgeons, family practitioners, advance practice nurses, clinical pharmacists, health economists, and patient advocates. The writing committee included representatives from the AHA, ACC, American College of Surgeons, American Society of Nuclear Cardiology, Heart Rhythm Society, Society of Cardiovascular Anesthesiologists, Society of Cardiovascular Computed Tomography, Society for Cardiovascular Magnetic Resonance, and the Society for Vascular Medicine. Appendix 1 of the current document lists writing committee members' comprehensive and relevant RWIs.

1.3. Guideline Review and Approval

The Joint Committee appointed a peer review committee to review the document. The peer review committee comprised individuals nominated by the ACC, AHA, and the collaborating organizations. Reviewers' RWI information was distributed to the writing committee and is published in this document (Appendix 2). This document was approved for publication by the governing bodies of the ACC and the AHA and was endorsed by the American College of Surgeons, American Society of Nuclear Cardiology, Heart Rhythm Society, Society of Cardiovascular Anesthesiologists, Society of Cardiovascular Computed Tomography, Society for Cardiovascular Magnetic Resonance, and the Society for Vascular Medicine.

1.4. Scope of the Guideline

The focus of this clinical practice guideline is the perioperative cardiovascular evaluation and management of the adult patient (≥18 years of age) being considered for noncardiac surgery (NCS). This guideline addresses the time spanning from preoperative evaluation through postoperative care and emphasizes risk assessment, evaluation of functional status, appropriate use of cardiovascular testing and screening, and management of cardiovascular conditions and risks. Also addressed are evidence-based management strategies, including pharmacological therapies, perioperative monitoring, and devices, for CVD and associated medical conditions.

This guideline is intended to inform all clinicians involved in the care of patients being considered for NCS. Preoperative evaluation encompasses the assessment of perioperative risk and determination of the need for additional cardiovascular testing through exercise, imaging, or biomarker assessment. Although the primary goal of the evaluation should be evaluation and reduction of a patient's immediate surgical risk, follow-up is warranted throughout and beyond the surgical period, when modifiable cardiovascular risk is identified. The preoperative cardiovascular evaluation begins with a focused history and physical examination and a careful review of a patient's medical history. This assessment informs perioperative care and can be used to implement changes in management and therapy. Through a patient-centered,

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team-based approach, management changes could be made to medical therapy, lifestyle modifications, interventional treatment, and perioperative monitoring. Additional management strategies may include modifications of the surgical technique or procedure, identification of the appropriate surgery location (ambulatory surgery center, outpatient surgery, or inpatient surgery), and optimal disposition and monitoring of the patient after surgery and upon discharge from the hospital. At times, the best decision from a team-based, patient-centered approach might be to pursue noninvasive or palliative strategies.

The guideline is developed to assist clinicians in applying an evidence-based, expert-informed approach to the perioperative cardiovascular management of patients being considered for NCS. This optimally occurs when there is communication between all relevant parties: surgeon, anesthesiologist, intensivist, primary clinician, and consultants, and especially the patient. The overarching goal of perioperative evaluation and management is to encourage patient engagement and facilitate shared decision-making through clear and understandable communication of information regarding perioperative cardiovascular risk and recommendations for risk mitigation and management. This guideline is primarily, but not exclusively, focused on the perioperative management of patients referred for elevated-risk NCS. Little evidence exists to support extensive preoperative testing in patients planned for low-risk surgeries, and care is rarely improved by additional cardiovascular testing. This is particularly true for very low-risk

Table 1. Associated Guidelines and Statements

Title	Organization	Publication Year (Reference)
Guidelines		
Focused update on DAPT with coronary artery disease	ACC/AHA	2016[1]
Management of blood cholesterol	AHA/ACC/AACVPR/AAPA/ABC/ACPM/ADA/AGS/APhA/ASPC/NLA/PCNA	2018[2]
Prevention, detection, evaluation, and management of high blood pressure in adults	ACC/AHA/AAPA/ABC/ACPM/AGS/APhA/ASH/ASPC/NMA/PCNA	2018[3]
Management of adults with congenital heart disease	AHA/ACC	2018[4]
Diagnosis and treatment of patients with hypertrophic cardiomyopathy	AHA/ACC	2020[5]
Management of patients with valvular heart disease	ACC/AHA	2021[6]
Coronary artery revascularization	ACC/AHA/SCAI	2021[7]
Evaluation and diagnosis of chest pain	AHA/ACC/ASE/CHEST/SAEM/SCCT/SCMR	2021[8]
Prevention of stroke in patients with stroke and transient ischemic attack	AHA/ASA	2021[9]
Management of heart failure	AHA/ACC/HFSA	2022[10]
Management of patients with chronic coronary disease	AHA/ACC/ACCP/ASPC/NLA/PCNA	2023[11]
Management of atrial fibrillation	ACC/AHA/ACCP/HRS	2023[12]
Scientific Statements		
Evaluation and management of right-sided heart failure	AHA	2018[13]
Cardiovascular considerations in caring for pregnant patients	AHA	2020[14]
Emerging evidence on coronary heart disease screening in kidney and liver transplantation candidates	AHA	2022[15]
Diagnosis and management of patients with myocardial injury after noncardiac surgery	AHA	2021[16]
Evaluation and management of pulmonary hypertension in noncardiac surgery	AHA	2023[17]
Consensus Document/Reports		
Prevention of premature discontinuation of DAPT in patients with coronary artery stents	AHA/ACC/SCAI/ACS/ADA/ACP	2007[18]
Expert consensus statement on perioperative management of patients with implantable defibrillators, pacemakers and arrythmia monitors	AHA/ASA/HRS/STS	2011[19]
Expert consensus decision pathway for periprocedural management of anticoagulation in patients with nonvalvular atrial fibrillation	ACC	2017[20]

AACVPR indicates American Association of Cardiovascular and Pulmonary Rehabilitation; AAPA, American Academy of Physician Associates; ABC, Association of Black Cardiologists, ACC, American College of Cardiology; ACCP, American College of Clinical Pharmacy; ACP, American College of Chest Physicians; ACPM, American College of Preventive Medicine; ADA, American Diabetes Association; AGS, American Geriatrics Society; AHA, American Heart Association; APhA, American Pharmacists Association; ASA, American Society of Anesthesiologists; ASE, American Society of Echocardiography; ASH, American Society of Hematology; ASPC, American Society for Preventive Cardiology; CHEST, American College of Chest Physicians; DAPT, dual antiplatelet therapy; HFSA, Heart Failure Society of America; HRS, Heart Rhythm Society; NLA, National Lipid Association; NMA, National Medical Association; PCNA, Preventive Cardiovascular Nurses Association; SAEM, Society for Academic Emergency Medicine; SCAI, Society for Coronary Angiography and Interventions; SCCT, Society of Cardiovascular Computed Tomography; SCMR, Society for Cardiovascular Magnetic Resonance; and STS, Society of Thoracic Surgery.

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procedures, including cataract and other ophthalmology surgeries, dental procedures, endoscopic procedures, and skin biopsies. Surgical procedures that are low risk but require general anesthesia may require additional preoperative consideration given the hemodynamic effects of anesthesia.

In developing this guideline, the writing committee reviewed previously published guidelines and related scientific statements. Table 1 contains a list of publications deemed pertinent to this writing effort and is intended for use as a resource, obviating the need to repeat existing guideline recommendations, some of which have been carried forward from previously published guidelines. If unchanged, those recommendations remain current. Any changes to the formatting or content of these recommendations are defined as:

- Modified: formatting changes (eg, minor modifications such as PICO[TS] [patient population, intervention, comparator, outcome, time, setting] structure)
- Adapted: substantive changes (eg, major adaptations, such as a change in Class of Recommendation [COR], Level of Evidence [LOE], drug or device classification).

Changes are depicted in a footnote below the recommendation tables. Clinicians should be advised that this guideline supersedes the previously published "2014 ACC/AHA Guideline on Perioperative Cardiovascular Evaluation and Management of Patients Undergoing Noncardiac Surgery."[21]

1.5. Definitions of Surgical Timing and Risk

In describing the temporal necessity of operations within this guideline, we have developed the definitions in Table 2 by writing committee consensus. Elevated risk encompasses intermediate or high surgical risk and is generally defined as a ≥1% risk of a major adverse cardiovascular event (MACE); however, due to varying populations, risk criteria, and endpoints, there is significant variability in the reporting of predicted risk of cardiovascular complications among the available risk-prediction tools (Section 3.1, "Cardiovascular Risk Indices").[1,2] Although many risk scores exist, data are lacking to support the use of one risk index over another.

NCS can be classified by the risk of major adverse cardiac and cerebral event (MACCE) associated with each surgery. Risk calculator criteria (Section 3.1, "Cardiovascular Risk Indices") frequently include the type and location of surgery. Suprainguinal vascular, thoracic, transplant, and neurosurgery operations are associated with the highest risk of MACCE. General, otolaryngology, genitourinary, and orthopedic surgery are considered intermediate risk, and endocrine, breast, gynecology, and obstetrics are considered to have the lowest risk of MACCE. This list does not include the breadth of surgical procedures or account for changes in surgical approach and should therefore only be used as a guide.[3] Additionally, patient comorbidities may also affect the risk of MACCE, and the risk associated with anesthesia in patients with comorbid disease may not be completely captured when solely considering surgery type. Changes in surgical approach can reduce the risk of MACE in some surgeries. For instance, an aortic aneurysm repair has a lower risk of MACE when performed using endovascular techniques rather than an open repair.[4] The timing of surgery also affects risks, with emergency surgeries generally associated with a higher risk of MACCE than elective surgeries.

1.6. Class of Recommendations and Level of Evidence

The COR indicates the strength of recommendation and encompasses the estimated magnitude and certainty of benefit in proportion to risk. The LOE is a measure

Table 2. Definitions of Surgical Timing and Surgical Risk

Timing	Definition
Emergency	Immediate threat to life or limb without surgical intervention, where there is very limited or no time for preoperative clinical evaluation, typically <2 h.
Urgent	Threat to life or limb without surgical intervention, where there may be time for preoperative clinical evaluation to allow interventions that could reduce risk of MACE or other postoperative complications, typically ≥2 to <24 h.
Time-sensitive	Surgery may be delayed up to 3 mo to allow for preoperative evaluation and management without negatively impacting outcomes.
Elective	The surgical procedure can be delayed to permit a complete preoperative evaluation and appropriate management.
Risk Category*	**Definition**
Low risk	Combined surgical and patient characteristics predict a low risk of MACE of <1%.*
Elevated risk†	Combined surgical and patient characteristics predict an elevated risk of MACE of ≥1%.*

*Determining elevated calculated risk depends on the calculator used. Traditionally a RCRI >1 or a calculated risk of MACE with any perioperative risk calculator >1% is used as a threshold to identify patients at elevated risk.

†Encompasses patients at intermediate or high surgical risk.

MACE indicates major adverse cardiovascular event; and RCRI, Revised Cardiac Risk Index.

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of the quality of scientific evidence supporting the intervention on the basis of the type, quantity, and consistency of data from clinical trials and other sources (Table 3).[1]

1.7. Abbreviations

Abbreviations	Meaning/Phrase
ACEi	angiotensin-converting enzyme inhibitors
ACHD	adult congenital heart disease
ACS	acute coronary syndrome
AF	atrial fibrillation
AR	aortic regurgitation
ARB	angiotensin receptor blocker
AS	aortic stenosis
ASCVD	atherosclerotic cardiovascular disease
AVR	aortic valve replacement
BMS	bare-metal stent
BNP	B-type natriuretic peptide
BP	blood pressure
CAD	coronary artery disease
CCB	calcium channel blocker
CCD	chronic coronary disease
CCTA	coronary computed tomography angiography
CHD	congenital heart disease
CIED	cardiovascular implantable electronic device
CKD	chronic kidney disease
CPET	cardiopulmonary exercise testing
CT	computed tomography
cTn	cardiac troponin
CVD	cardiovascular disease
DAPT	dual antiplatelet therapy
DASI	Duke Activity Status Index
DBP	diastolic blood pressure
DES	drug-eluting stent
DOAC	direct oral anticoagulants
ECG	electrocardiogram
EF	ejection fraction
EMI	electromagnetic interference
ESU	electrosurgery unit
FDA	US Food and Drug Administration
FoCUS	focused cardiac ultrasound
GDMT	guideline-directed management and therapy
GLP-1	glucagon-like polypeptide-1
HCM	hypertrophic cardiomyopathy
HF	heart failure
HFrEF	heart failure with reduced ejection fraction
HR	hazard ratio
ICA	invasive coronary angiography
ICD	implantable cardioverter-defibrillator
LV	left ventricular
LVAD	left ventricular assist device
LVEF	left ventricular ejection fraction
LVOT	left ventricular outflow tract
MACCE	major adverse cardiac and cerebral event
MACE	major adverse cardiovascular event
MAP	mean arterial pressure
MCS	mechanical circulatory support
METs	metabolic equivalents
MI	myocardial infarction
MICA	myocardial infarction and cardiac arrest
MINS	myocardial injury after noncardiac surgery
MR	mitral regurgitation
MS	mitral stenosis
MV	mitral valve
NCS	noncardiac surgery
NSQIP	National Surgical Quality Improvement Program
NSTEMI	non–ST segment elevation myocardial infarction
NT-proBNP	N-terminal pro-B-type natriuretic peptide
NYHA	New York Heart Association
OAC	oral anticoagulant/anticoagulation
OR	odds ratio
OSA	obstructive sleep apnea
P2Y12	platelet adenosine diphosphate receptor
PA	pulmonary artery
PAH	pulmonary arterial hypertension
PCI	percutaneous coronary intervention
PH	pulmonary hypertension
POAF	perioperative/postoperative atrial fibrillation
QOL	quality of life
RAASi	renin-angiotensin-aldosterone system inhibitors
RCT	randomized controlled trial
RCRI	Revised Cardiac Risk Index
RV	right ventricular
SBP	systolic blood pressure
SGLT2i	sodium-glucose cotransporter-2 inhibitors
STEMI	ST-segment elevation myocardial infarction
TAVI	transcatheter aortic valve implantation
TEA	thoracic epidural analgesia
TEE	transesophageal echocardiography
TEER	transcatheter edge-to-edge repair
TTE	transthoracic echocardiogram
VHD	valvular heart disease
VKA	vitamin K antagonist

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Table 3. Applying the American College of Cardiology/American Heart Association Class of Recommendation and Level of Evidence to Clinical Strategies, Interventions, Treatments, or Diagnostic Testing in Patient Care (Updated May 2019)

CLASS (STRENGTH) OF RECOMMENDATION	LEVEL (QUALITY) OF EVIDENCE‡
CLASS 1 (STRONG) — **Benefit >>> Risk** **Suggested phrases for writing recommendations:** • Is recommended • Is indicated/useful/effective/beneficial • Should be performed/administered/other • Comparative-Effectiveness Phrases†: – Treatment/strategy A is recommended/indicated in preference to treatment B – Treatment A should be chosen over treatment B	**LEVEL A** • High-quality evidence‡ from more than 1 RCT • Meta-analyses of high-quality RCTs • One or more RCTs corroborated by high-quality registry studies
CLASS 2a (MODERATE) — **Benefit >> Risk** **Suggested phrases for writing recommendations:** • Is reasonable • Can be useful/effective/beneficial • Comparative-Effectiveness Phrases†: – Treatment/strategy A is probably recommended/indicated in preference to treatment B – It is reasonable to choose treatment A over treatment B	**LEVEL B-R (Randomized)** • Moderate-quality evidence‡ from 1 or more RCTs • Meta-analyses of moderate-quality RCTs
CLASS 2b (WEAK) — **Benefit ≥ Risk** **Suggested phrases for writing recommendations:** • May/might be reasonable • May/might be considered • Usefulness/effectiveness is unknown/unclear/uncertain or not well-established	**LEVEL B-NR (Nonrandomized)** • Moderate-quality evidence‡ from 1 or more well-designed, well-executed nonrandomized studies, observational studies, or registry studies • Meta-analyses of such studies
CLASS 3: No Benefit (MODERATE) (Generally, LOE A or B use only) — **Benefit = Risk** **Suggested phrases for writing recommendations:** • Is not recommended • Is not indicated/useful/effective/beneficial • Should not be performed/administered/other	**LEVEL C-LD (Limited Data)** • Randomized or nonrandomized observational or registry studies with limitations of design or execution • Meta-analyses of such studies • Physiological or mechanistic studies in human subjects
Class 3: Harm (STRONG) — **Risk > Benefit** **Suggested phrases for writing recommendations:** • Potentially harmful • Causes harm • Associated with excess morbidity/mortality • Should not be performed/administered/other	**LEVEL C-EO (Expert Opinion)** • Consensus of expert opinion based on clinical experience

COR and LOE are determined independently (any COR may be paired with any LOE).

A recommendation with LOE C does not imply that the recommendation is weak. Many important clinical questions addressed in guidelines do not lend themselves to clinical trials. Although RCTs are unavailable, there may be a very clear clinical consensus that a particular test or therapy is useful or effective.

* The outcome or result of the intervention should be specified (an improved clinical outcome or increased diagnostic accuracy or incremental prognostic information).

† For comparative-effectiveness recommendations (COR 1 and 2a; LOE A and B only), studies that support the use of comparator verbs should involve direct comparisons of the treatments or strategies being evaluated.

‡ The method of assessing quality is evolving, including the application of standardized, widely-used, and preferably validated evidence grading tools; and for systematic reviews, the incorporation of an Evidence Review Committee.

COR indicates Class of Recommendation; EO, expert opinion; LD, limited data; LOE, Level of Evidence; NR, nonrandomized; R, randomized; and RCT, randomized controlled trial.

2. EPIDEMIOLOGY OF CARDIOVASCULAR DISEASE AND COMPLICATIONS IN PATIENTS UNDERGOING NONCARDIAC SURGERY

Each year, approximately 14.4 million inpatient and 19.2 million ambulatory surgeries are performed in the United States, with an estimated 313 million surgeries performed worldwide.[1–3] Cardiovascular risk factors and disease are prevalent among adults undergoing NCS, and perioperative cardiovascular complications are an important cause of morbidity and mortality. Multiple cardiovascular risk factors are reported in 45% of surgical inpatients age ≥45 years, with an increasing prevalence reported over time.[4] Atherosclerotic cardiovascular disease (ASCVD) is diagnosed in nearly 25% of surgical inpatients.[4] Between 2008 and 2013, the proportion of surgical inpatients with elevated cardiovascular risk, defined by a Revised Cardiac Risk Index (RCRI) ≥3, increased from 6.6% to 7.7%.[4]

In a large retrospective analysis of adults ≥45 years undergoing in-hospital surgery, perioperative death, myocardial infarction (MI), or ischemic stroke occurred in 1 of every 33 surgical admissions, corresponding to >150 000 annual perioperative events in the United States.[5]

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Although orthopedic (40.0%), general (21.4%), and vascular (10.7%) surgeries were the most commonly performed, patients undergoing vascular, thoracic, and solid organ transplantation surgeries had the highest incidence of cardiovascular events.[5] Irrespective of the surgical subtype, perioperative cardiovascular complications are associated with prolonged inpatient hospitalizations, significantly higher medical costs, and increased mortality.[6–9]

2.1. Team-Based Care

Synopsis

Multidisciplinary care models are increasingly used to manage complex conditions and care pathways in perioperative medicine. Team-based care models in the perioperative setting span the pre-, intra-, and posthospital phases of care and are important parts of the care delivery system, providing efficiency of care, ability to improve broad clinical outcomes, and alignment with patient-centered care goals, such as recovery at home. Few data exist demonstrating that interdisciplinary models improve perioperative cardiac care quality or outcomes, but they provide the framework that is critical to meaningful quality and outcome improvements. These models are often described as "pathways" that standardize perioperative cardiac care practices and accelerate the coordination of recovery activities (eg, early mobilization and feeding, use of opioid-sparing pain regimens, deep venous thrombosis prophylaxis). Although there are concerns about patients leaving the hospital after a shorter inpatient stay, these concerns have largely been offset by focusing on improved pain control and earlier rehabilitation and recovery.[1–9] Few data from these meta-analyses support whether standardized protocols or enhanced recovery pathways specifically reduce the risk for cardiovascular complications of surgery, GDMT, or use of preoperative cardiac testing.[1–10] In the contemporary era, screening and preoperative planning is often conducted by phone or video visits, with trends accelerated during the coronavirus disease-2019 pandemic.[10–13] Similar to the results for enhanced recovery pathways, substantial evidence supports the use of remote visits/televisits to lower rates of case cancellation and improve patient satisfaction, although the impact of remote visits on cardiovascular outcomes, guideline-concordant preoperative testing practices, or how remote preoperative consultations might be used to coordinate specialty care for higher risk patients has not been reported.[2–4,6–9,14–20] The role of telemedicine, remote monitoring (gathering patient weights, oxygen saturation, or physical activity data remotely), and mobile ("m-health") interventions in managing chronic illnesses such as heart failure (HF) is increasingly described.[21] The evidence base for similar models for the postoperative care of patients undergoing NCS is still early in its development.[22–30] Available evidence supports the benefit to readmission and patient satisfaction with use of these approaches.[4,28,31–36]

2.2. Quality of Life

Synopsis

The World Health Organization defines quality of life (QOL) as "an individual's perception of their position in life in the context of the culture and value systems in which they live and about their goals, expectations, standards and concerns."[1] Assessment of QOL may improve patient experiences and outcomes of health care procedures and treatments. Patient-reported outcome measures can be used to survey patients' health-related QOL. Instruments specific to the therapeutic area may be more sensitive than those that are generic.[2,3] Although questionnaires are commonly employed, listening to patients and inquiring about their priorities is extremely important to tailor care to their unique needs. Because surgery confers risks of complications, especially for high-risk patients with existing CVD, discussing patients' goals and priorities with respect to QOL may guide perioperative planning.[4] In the last decades, a few groups have assessed interventions that might impact perioperative QOL.[5,6] Unfortunately, solid evidence is still lacking to formulate actionable recommendations aimed at improving QOL in patients undergoing NCS. Although long-term benefits on QOL from an NCS may outweigh short-term cardiac risks for some patients, this ratio is unevenly balanced in the literature. Greater patient satisfaction has been associated with perioperative assessment that involves shared decision-making.[7]

3. RISK CALCULATORS

3.1. Cardiovascular Risk Indices

Recommendation for Cardiovascular Risk Indices
Referenced studies that support the recommendations are summarized in the Online Data Supplement.

COR	LOE	Recommendation
2a	B-NR	1. In patients with known CVD being considered for NCS, a validated risk-prediction tool can be useful to estimate the risk of perioperative MACE.[1–4]

Synopsis

Preoperative cardiovascular risk assessment can help estimate the likelihood of perioperative adverse outcomes. Several risk indices have been developed based on multivariable analyses of large observational data and have been validated in large datasets (Table 4). Commonly used cardiovascular risk scores include the RCRI,[2] the American College of Surgeons National Surgical Quality Improvement Program (NSQIP) perioperative MI and cardiac arrest (MICA) risk calculator,[5] and the universal American College of Surgeons NSQIP surgical risk calculator.[3] Risk calculators can be used in addition or as an alternative to the assessment of separately discussed

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Table 4. Risk Scores and Calculators

	Goldman Index of Cardiac Risk[16] (1977)	RCRI[2] (1999)	Gupta NSQIP Risk Calculator for Perioperative MICA[5] (2011)	American College of Surgeons NSQIP Surgical Risk Calculator[3,13] (2023)	Surgical Outcome Risk Tool[12] (2014)	NSQIP Geriatric-Sensitive Perioperative Cardiac Risk Index[17] (2017)	AUB-HAS2 Cardiovascular Risk Index[14] (2019)
Criteria	Age >70 y (5 points) Recent MI within 6 mo (10 points) Jugular venous distention or a third heart sound on auscultation (11 points) ≥5 PVCs per minute (7 points) Nonsinus rhythm or PACs on preoperative ECG (7 points) Aortic stenosis (3 points) Intraperitoneal, intrathoracic, or aortic surgery (3 points) Any emergency surgery (4 points)	Ischemic heart disease Cerebrovascular disease History of HF Insulin therapy for diabetes Serum creatinine ≥2.0 mg/dL Planned high-risk procedure (intraperitoneal, intrathoracic, or vascular surgery) (1 point for each criterion)	Age ASA class Preoperative function Creatinine Procedure type (anorectal surgery, aortic, bariatric, brain, breast, cardiac, ENT, foregut/hepato-pancreatobiliary, gallbladder/appendix/adrenal/spleen, intestinal, neck, obstetric/gynecologic, orthopedic, other abdomen, peripheral vascular, skin, spine, thoracic, urology, vein)	Age group Sex ASA class Functional status Emergency case Steroid use for chronic condition Ascites within 30 d preoperatively System sepsis within 48 h preoperatively Ventilator dependent Disseminated cancer Diabetes Hypertension requiring medication Previous cardiac event HF in 30 d preoperatively Dyspnea Current smoker within 1 y History of COPD Dialysis Acute renal failure BMI class CPT-specific linear risk	Age group ASA class Urgency of surgery Specialty Severity of surgery Cancer	ASA class History of HF History of stroke Diabetes Functional status (partially versus totally dependent) Creatinine >1.5 mg/dL Surgical category	Age ≥75 y History of heart disease Symptoms of angina/dyspnea Hemoglobin <12 mg/dL Vascular surgery Emergency surgery
Score Range	Class I: 0-5 points (lowest risk) Class II: 6-12 points Class III: 13-25 points Class IV: ≥26 points (highest risk)	Class I: RCRI 0 (lowest risk) Class II: RCRI 1 Class III: RCRI 2 Class IV: RCRI 3+ (highest risk)	0%-100% (0% lowest risk, 100% highest risk)	0%-100% (0% lowest risk, 100% highest risk)	0%-100% (0% lowest risk, 100% highest risk)	0%-100% (0% lowest risk, 100% highest risk)	CVRI Score 0 (lowest risk) CVRI Score 1 CVRI Score 2 CVRI Score 3 CVRI Score >3 (highest risk)
Threshold Denoting Elevated Risk	Class II or higher (≥6 points)	RCRI >1	>1%	>1%		>1%	CVRI Score ≥2
Outcome	Intraoperative/postoperative MI, pulmonary edema, VT, cardiac death	MI, pulmonary edema, ventricular fibrillation, complete heart block, cardiac death	Intraoperative/postoperative MI or cardiac arrest within 30 d	Cardiac arrest, MI, all-cause mortality within 30 d	30-d mortality	Cardiac arrest, MI, all-cause mortality within 30 d	Death, MI, or stroke at 30 d
Derivation (n)	1001	1422	211 410	1 414 006	19 097	584 931	3284
Derivation Set ROC	0.61	0.76	0.88	0.90 (cardiac arrest or MI) 0.94 (mortality)		N/A	0.90
Validation Set ROC	0.70	0.81 0.75†	0.87*	0.88 (cardiac arrest or MI)* 0.94 (mortality)*	0.91‡	0.83* (0.76 in adults age ≥65 y)	0.82*

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*Validated using the NSQIP database.

†Pooled validation studies assessing the performance of the RCRI in mixed noncardiac surgery.

‡Derived and validated using the NCEPOD Knowing the Risk study.

ASA indicates American Society of Anesthesiologists; AUB, American University of Beirut; BMI, body mass index; COPD, chronic obstructive pulmonary disease; CPT, current procedural terminology; CVRI, Coronary Vascular Resistance Index; ECG, electrocardiogram; ENT, ear, nose, and throat; HF, heart failure; MI, myocardial infarction; MICA, MI and cardiac arrest; NCEPOD, National Confidential Enquiry into Patient Outcome and Death; NSQIP, National Surgical Quality Improvement Program; PAC, premature atrial contraction; PVC, premature ventricular complex; RCRI, Revised Cardiac Risk Index; ROC, receiver operating characteristic; and VT, ventricular tachycardia.

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surgery-related (eg, anesthesia type, surgery type) and patient-related (eg, physical activity, physical examination) risk factors. Combined, there is significant variability in the predicted risk of cardiovascular complications using different risk-prediction tools.[1,6] Evaluated endpoints were not consistent in all risk scores (Table 4). Although many risk scores exist, data are lacking to support the use of one risk index over another, and research is underway to further refine perioperative risk. For example, a recently published study has shown that perioperative risk stratification may be enhanced by combining traditional risk indices with estimates of coronary calcium burden from existing, nongated chest computed tomography (CT) imaging in the year before NCS.[4] Differences in surgical populations may also affect risk prediction. Risk scores have poorer discrimination in patients undergoing vascular surgery, likely due to the underestimation of the risk of MI.[7–9] Despite their reasonable ability to predict perioperative risk of MACE, there have been few studies in which perioperative treatment strategies were modified based on preoperative risk prediction tools; future studies are needed to inform this practice.

Recommendation-Specific Supportive Text

1. There are several indices available for perioperative cardiovascular risk prediction. The American Society of Anesthesiologists (ASA) Physical Status Classification System classifies patients into categories according to their overall health status.[10] With 6 predictors of risk (1 point assigned for each criterion), the RCRI is a simple, validated, and commonly used tool to assess perioperative risk of major cardiac complications.[3] In a pooled analysis of 24 validation studies, the RCRI had modest risk discrimination for cardiac events in patients undergoing NCS, although there is discordance among the various risk-prediction tools in identifying low-risk patients, defined as having an estimated risk of MACE of <1%.[7,11] The Surgical Outcome Risk Tool estimates 30-day mortality after NCS based on the ASA Physical Status grade, urgency of surgery, surgical specialty and severity, cancer, and age ≥65 years.[12] The 21-component universal NSQIP surgical risk calculator may provide superior predictive discrimination.[13] The AUB (American University of Beirut)-HAS2 cardiovascular risk index is easily calculated and used to assess 30-day event risk, stratifying patients undergoing NCS into low (score 0-1), intermediate (score 2-3), and high risk (score >3) based on 6 data elements.[14] A simplified method using 3 traditional risk factors for hypertension, diabetes, and current smoking identified a low incidence of MI (0.10%) among patients without risk factors who underwent NCS.[15]

3.2. Functional Capacity Assessment

Recommendation for Functional Capacity Assessment Referenced studies that support the recommendations are summarized in the Online Data Supplement.		
COR	**LOE**	**Recommendation**
2a	**B-NR**	1. In patients undergoing elevated-risk NCS, a structured assessment of functional capacity (such as the Duke Activity Status Index [DASI]) is reasonable to stratify the risk of perioperative adverse cardiovascular events.[1–8]

Synopsis

Functional capacity is an important predictor of risk of adverse cardiovascular events after NCS.[1–9] It is usually measured in metabolic equivalents (METs) of task, with 4 METs considered the threshold for poor functional capacity. Functional capacity is commonly assessed by asking patients if they can climb 2 flights of stairs (an activity associated with >4 METs) or by using a patient-reported instrument such as the DASI (Table 5), a semiquantitative tool to assess functional capacity based on patients' reported ability to perform a set of 12 daily activities.[6] In selected cases, exercise stress testing (Section 4.3, "Stress Testing") can provide an objective assessment of functional capacity. Patients with poor functional capacity are at increased risk of cardiac events post surgery. Assessments of functional capacity can be used to identify patients who may warrant additional preoperative cardiovascular risk stratification before surgery. In most cases, functional, asymptomatic

Table 5. Duke Activity Status Index (DASI)

Activity: Can you…	Weight
take care of yourself (eg, eating, dressing, bathing, or using the toilet)?	2.75
walk indoors, such as around your house?	1.75
walk a block or 2 on level ground?	2.75
climb a flight of stairs or walk a hill?	5.5
run a short distance?	8
do light work around the house (eg, dusting, washing dishes)?	2.7
do moderate work around the house (eg, vacuuming, sweeping floors, carrying in groceries)?	3.5
do heavy work around the house (eg, scrubbing floors, lifting or moving heavy furniture)?	8
do yardwork (eg, raking leaves, weeding, pushing a power mower)?	4.5
have sexual relations?	5.25
participate in moderate recreational activities (eg, golf, bowling, dancing, doubles tennis, throwing a baseball or football)?	6
participate in strenuous sports (eg, swimming, singles tennis, basketball, skiing)?	7.5

The DASI score is calculated by adding the points of all performed activities together. The higher the score (range, 0-58.2), the higher the functional status. Reprinted from Hlatky et al.[6] Copyright 1989 Elsevier, with permission from Elsevier.

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patients may proceed with planned NCS without further cardiovascular testing.

Recommendation-Specific Supportive Text

1. In a study of 600 patients undergoing NCS, self-reported poor functional capacity, defined as the inability to walk 4 blocks or climb 2 flights of stairs, was associated with an almost 2-fold greater risk of in-hospital cardiovascular events (9.6% versus 5.2%; *P*=0.04).[1] The BASEL-PMI (Incidence and Outcome of Perioperative Myocardial Injury After Noncardiac Surgery) study (n=4560) included patients at elevated cardiovascular risk (ASA class ≥3) and showed that functional capacity <2 flights of stairs was associated with a 1.63 higher rate of death, MI, acute HF, or life-threatening arrythmias at 30 days.[2] Furthermore, the addition of the functional capacity data to the RCRI significantly increased its predictive power. In a large analysis from NSQIP (n=211 410), functional capacity comprised 1 of 5 elements in a multivariate model predicting MI/MICA at 30 days after surgery.[4] Functional capacity was classified into 3 categories: independent, partially dependent, and totally dependent. Using the same classification, a retrospective observational cohort study (n=12 324) from the US Department of Veterans Affairs Surgical Quality Improvement Project demonstrated that functional capacity was independently associated with mortality and added discriminatory power to traditional ASA classification.[5] The METs study compared the power of the DASI score for predicting death or MI at 30 days after major NCS with cardiopulmonary exercise testing (CPET) and a subjective assessment of functional capacity by the anesthesiologist, classified as good (>10), moderate (4-10), or poor (<4).[7] Subjective assessment of functional capacity by the clinician was not associated with outcomes, whereas the DASI score was associated with death or MI at 30 days after surgery (N=1401, mean age 65 years).[7] DASI scores ≤34 were associated with increased odds of 30-day death or MI.[8]

3.3. Frailty

Recommendation for Frailty Referenced studies that support the recommendations are summarized in the Online Data Supplement.		
COR	**LOE**	**Recommendation**
2a	**B-NR**	1. In all patients ≥65 years of age and in those <64 years with perceived frailty who are undergoing elevated-risk NCS, preoperative frailty assessment using a validated tool can be useful for evaluating perioperative risk and guiding management.[1–5]

Synopsis

Older patients undergoing NCS are at increased risk for numerous cardiac and noncardiac complications, including myocardial injury and infarction, atrial fibrillation (AF), acute kidney injury, and delirium. Frailty is a syndrome characterized by physiological declines across multiple organ systems that result in increased vulnerability to stressors. It is an independent risk factor for adverse outcomes after NCS across the age spectrum, including cardiac complications, infections, bleeding, falls, functional decline, increased length of stay, and mortality.[1,3,4] In a systematic review of 21 studies, the weighted prevalence of frailty was 10.7% among community-dwelling individuals ≥65 years of age.[6] That rate exceeds 25% among community-dwelling adults ≥85 years of age. Women have an almost 2-fold higher prevalence of frailty than men,[6] and the rates are markedly higher among older patients with HF (>40%).[7,8] A formal diagnosis of frailty using a validated screen instrument (Table 6) may impact perioperative management and inform benefit-risk discussions with patients and their families.[2,9] Emerging evidence suggests that prehabilitation (ie, physical conditioning, nutritional support, or both) before NCS may be associated with improved outcomes in selected patients with frailty.[10,11]

Recommendation-Specific Supportive Text

1. Frailty is a risk marker for adverse outcomes after NCS and for reduced benefit after cardiac procedures.[1,3,4] In a meta-analysis of 56 studies involving 1.1 million older adults undergoing NCS, frailty was associated with an increased risk of 30-day mortality (relative risk, 3.71 [95% CI, 2.89-4.77]) and 30-day complications (relative risk, 2.39 [95% CI, 2.02-2.83]).[4] Several validated tools are available to assess for frailty (Table 6).[12] Although most comparative studies have been neutral, 1 prospective evaluation found that the Clinical Frailty Scale outperformed the Fried phenotype and the Frailty Index for predicting death, disability, prolonged length of stay, or nonhome discharge after NCS in older adults.[5] In a single-center observational study involving 9153 patients undergoing major NCS, incorporation of routine frailty screening into the preoperative assessment was associated with a significant reduction in 30-day mortality.[2] In some cases, older patients with advanced frailty, poor functional status, and reduced life expectancy may derive limited benefit from surgery; in these patients, goals of care and shared decision-making should be integrated into preoperative planning.[13] In selected patients, prehabilitation before NCS may be associated with improved outcomes.[9–11,14]

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Table 6. Frailty Assessment Tools

Name	Items	Scoring
Physical Frailty Phenotype (Fried phenotype)[15]	Slowness, low activity, weight loss, exhaustion, weakness (1 point each)	0=Nonfrail 1-2=Prefrail 3-5=Frail
Deficit Accumulation Index[16]	Variable; typically 30-70 items from multiple domains	Number of deficits/number of items scored; higher scores indicate greater frailty
Edmonton Frail Scale[17]	10 items across multiple domains	Sum of scores/17; higher scores indicate greater frailty
FRAIL Scale[18]	Fatigue, stair climb, ambulation, illnesses >5, weight loss ≥5% (1 point each)	0=Nonfrail 1-2=Intermediate 3-5=Frail
Clinical Frailty Scale[19]	9 categories ranging from very fit to terminally ill as assessed by clinicians	Categories 5-8 indicate mild, moderate, severe, and very severe frailty
SPPB[20]	Gait speed, chair stands, balance tests	Maximum 4 points per item, range, 0-12 points; ≥10=Nonfrail, 3-9=Frail, ≤2=Disabled

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SPPB indicates Short Physical Performance Battery.

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3.4. Preoperative Biomarkers for Risk Stratification

Recommendations for Preoperative Biomarkers for Risk Stratification
Referenced studies that support the recommendations are summarized in the Online Data Supplement.

COR	LOE	Recommendations
2a	B-NR	1. In patients with known CVD, or age ≥65 years, or age ≥45 years with symptoms suggestive of CVD undergoing elevated-risk NCS, it is reasonable to measure B-type natriuretic peptide (BNP) or N-terminal pro–B-type natriuretic peptide (NT-proBNP) before surgery to supplement evaluation of perioperative risk.[1–3]
2b	B-NR	2. In patients with known CVD, or age ≥65 years, or age ≥45 years with symptoms suggestive of CVD undergoing elevated-risk NCS, it may be reasonable to measure cardiac troponin (cTn) before surgery to supplement evaluation of perioperative risk.[4–6]

Synopsis

cTn and BNP are inexpensive and widely available biomarkers that can detect and quantify myocardial injury and cardiac wall stress, respectively. Several large prospective studies have demonstrated that both biomarkers have high prognostic value and excellent negative predictive value for perioperative cardiac complications. To date, there have been no studies in patients with elevated preoperative biomarkers to recommend management that improves perioperative cardiovascular outcomes. The utility of preoperative biomarkers in low-risk patients has not been evaluated. Biomarker measurement poses the potential for increased risk via downstream tests predicated on the resulting value. For cost–value consideration, please refer to Section 11.1.1 ("Cost–Value Considerations for Biomarkers").

Recommendation-Specific Supportive Text

1. Several prospective observational studies and meta-analyses have documented the use of preoperative BNP and NT-proBNP concentrations to predict postoperative complications in selected patients undergoing NCS. Both preoperative and postoperative natriuretic peptide levels were independent predictors of the composite outcome of death or nonfatal MI at 30 days and at 180 days of follow-up.[3] In a nested substudy of VISION (Vascular Events in Noncardiac Surgery Patients Cohort Evaluation), preoperative NT-proBNP concentrations >100 pg/mL were independently associated with all-cause mortality.[1] Optimal threshold values of BNP or NT-proBNP for perioperative risk prediction are not clearly established. However, in a recent cohort study evaluating 3597 patients undergoing NCS, the addition of NT-proBNP to traditional risk scores did not significantly improve risk prediction beyond that of risk scores combined with self-reported measures of functional status.[7]
2. Preoperative high-sensitivity cTn concentrations in patients without symptoms or signs of ischemia can identify patients with chronic myocardial injury as well as those at increased risk during and after the procedure.[4,8] There is no action predicated on this knowledge alone, although preoperative baseline troponin concentrations also inform the interpretation of postoperative troponin measurements and can help confirm a diagnosis of acute myocardial injury in the postoperative setting. There is limited evidence from heterogenous populations that preoperative cTn can predict short- or long-term adverse outcomes.[4] The predictive performance of the RCRI to identify patients who develop perioperative MACE is improved with the addition of preoperative cTn concentrations.[5]

4. PREOPERATIVE CARDIOVASCULAR DIAGNOSTIC TESTING

4.1. 12-Lead Electrocardiogram

Recommendations for 12-Lead Electrocardiogram
Referenced studies that support the recommendations are summarized in the Online Data Supplement.

COR	LOE	Recommendations
2a	B-NR	1. For patients with known coronary heart disease, significant arrhythmia, peripheral arterial disease, cerebrovascular disease, other significant structural heart disease, or symptoms* of CVD undergoing elevated-risk surgery, a preoperative resting 12-lead electrocardiogram (ECG) is reasonable to establish a preoperative baseline and guide perioperative management.[1,2]
2a	B-NR	2. In patients undergoing NCS with a preoperative ECG exhibiting new abnormalities,† further evaluation is reasonable to refine assessment of cardiovascular risk.[3–8]
2b	B-NR	3. For asymptomatic patients undergoing elevated-risk surgeries without known CVD, a preoperative resting 12-lead ECG may be considered to establish a baseline and guide perioperative management.[3,9,10]
3: No benefit	B-NR	4. For asymptomatic patients undergoing low-risk surgical procedures, a routine preoperative resting 12-lead ECG is not recommended to improve outcomes.[11]

*Active symptoms and signs of CVD include chest pain, dyspnea, undiagnosed palpitations, tachycardia, syncope, or murmurs.

†Abnormalities may include ST-segment elevation, ST depression, T-wave inversions, left ventricular (LV) hypertrophy, significant pathologic Q-waves, Mobitz type II or higher atrioventricular block, bundle branch block, QT prolongation, or AF.

Synopsis

The resting 12-lead ECG may contain important prognostic information related to short- and long-term morbidity and mortality among patients with coronary heart disease undergoing NCS.[1] However, it rarely adds prognostic information beyond what can be determined with risk assessment tools. For clarification of low-, intermediate-, or high-risk surgery and associated risk assessment tools, please refer to Section 1.5 (“Definitions of Surgical Timing and Risk”) and Section 3 (“Risk Calculators”) of this guideline. For cost–value consideration, please refer to Section 11.1.2 (“Cost–Value Considerations for 12-Lead ECG”).

Recommendation-Specific Supportive Text

1. A preoperative 12-lead ECG is likely to be more valuable for patients planned for elevated-risk surgical procedures.[2,3] This is particularly true for patients with known coronary heart disease, arrhythmias, peripheral arterial disease, cerebrovascular disease, or other significant structural heart disease. Comparing a preoperative ECG with previous electrocardiographic tracings may be helpful whenever relevant abnormalities are identified, with the preoperative ECG serving as a baseline if postoperative complications develop.
2. The prognostic significance of several electrocardiographic abnormalities, including arrhythmias, significant pathologic Q-waves, LV hypertrophy, ST-segment depressions, QT_c prolongation, and bundle branch blocks has been identified in observational studies.[4,5] Most studies, however, report little to no added prognostication of ECGs beyond clinical risk assessment. The abnormalities on the ECG that should prompt the preoperative clinician to request further information, consultation, or testing are not well defined; however, notable abnormalities include significant Q-waves, LV hypertrophy, ST-segment elevation, ST depression, T-wave inversion, Mobitz type II or higher block, bundle branch blocks, AF, or QT interval prolongation.[9,12] The likelihood of abnormalities on a preoperative 12-lead ECG increases with patient age and when risk factors for heart disease are present, but a standard age or risk factor cutoff for recommending a preoperative ECG has not been defined. Likewise, the optimal time interval between obtaining a 12-lead ECG and elective NCS is unknown.
3. In general, an abnormal preoperative ECG may not substantially alter perioperative management, except for second-degree Mobitz type II or higher atrioventricular block,[13] AF with rapid ventricular response or new-onset AF, or a prolonged QT interval.[4,10,14] Recognition of a prolonged QT interval may inform the selection of anesthetics, postoperative antiemetics, or antibiotic therapy. Incidental findings of Q-waves or bundle branch block on a preoperative ECG in an asymptomatic patient may indicate coronary artery disease (CAD) but should not lead to a decision to perform coronary revascularization before NCS. Another important reason to obtain a preoperative ECG in asymptomatic patients undergoing elevated- risk NCS with increased risk of MACE is to establish a baseline ECG for comparison should a postoperative ECG be abnormal.
4. Clinical risk assessment using validated tools is more useful to guide management and predict outcomes than are the findings of a single resting preoperative ECG. Available data suggest that in low-risk patients, a routine preoperative ECG has little effect on treatment or complication rates and should be omitted from standard preoperative evaluation.[11,13] One study assessed 30 892 patients undergoing NCS with shockwave lithotripsy for nephrolithiasis, in which a preoperative ECG triggered the cancellation of 13 (0.04%) treatments in low-risk patients (1 with new AF and 12 with ischemia or previous infarction). Of these patients, only 1 had a subsequent abnormal cardiac workup, and the remaining 11 ultimately underwent NCS without complications. The study concluded that in patients at low risk for cardiac complications,

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preoperative ECG triggered very few cancellations and did not predict cardiac complications after NCS.[11] Avoiding unnecessary testing can significantly save resources.[15]

4.2. Assessment of Ventricular Function

4.2.1. Left Ventricular Function

Recommendations for Assessment of Left Ventricular Function Referenced studies that support the recommendations are summarized in the Online Data Supplement.		
COR	**LOE**	**Recommendations**
1	B-NR	1. In patients undergoing NCS with new dyspnea, physical examination findings of HF, or suspected new/worsening ventricular dysfunction, it is recommended to perform preoperative evaluation of LV function to help guide perioperative management.[1–8]
2a	C-LD	2. In patients with a known diagnosis of HF with worsening dyspnea or other change in clinical status undergoing NCS, preoperative assessment of LV function is reasonable to help guide perioperative management.[1,4,79–11]
3: No benefit	B-NR	3. In asymptomatic and clinically stable patients undergoing NCS, routine preoperative evaluation of LV function is not recommended due to lack of benefit.[12–15]

Synopsis

Abnormal LV systolic or diastolic function is associated with increased perioperative MACE in NCS.[1–8,16–18] The risk of perioperative MACE is higher with lower LV ejection fraction (LVEF), in higher surgical risk procedures, and in patients with additional comorbid risk factors.[1,7,18] In a 5% sample of Medicare beneficiaries, a preoperative diagnosis of HF conferred increased 30-day operative mortality and readmission rates after major NCS compared with control patients and patients with CAD without HF (n=1757).[2] An analysis of a US Department of Veterans Affairs database found that patients with symptomatic and asymptomatic HF, regardless of LVEF, had increased 90-day mortality compared with patients without HF.[4] A study of patients with isolated diastolic dysfunction undergoing NCS (n=2976) found a 70% higher risk of MACE in those with grade 3 compared with grades 1 to 2 diastolic dysfunction.[18] Assessment of LV function is indicated in patients with unexplained cardiac symptoms and may be reasonable in the setting of elevated preoperative BNP or NT-proBNP concentrations. Evidence is lacking to support routine preoperative assessment of LV function in stable patients.

Recommendation-Specific Supportive Text

1. HF is an established risk factor for poor outcomes after NCS.[1–4,8,16–18] In a perioperative cohort of 159 237 patients undergoing NCS, 18% of the procedures were performed in patients with HF, and 34% were performed in patients with CAD. A significantly higher risk of mortality and HF readmissions was found in patients with HF compared to patients with CAD.[1] In a retrospective analysis, 723 patients underwent preoperative 12-lead ECG, hemoglobin blood tests, and preoperative transthoracic echocardiogram (TTE).[17] After multivariate analysis, higher-risk NCS, reduced hemoglobin level, and decreased LVEF were independently associated with poorer outcomes.[17] In a prospective analysis of 570 patients who had preoperative echocardiography before NCS, risk models including the echocardiographic elements performed better than models using clinical variables alone (c statistic, 0.73 versus 0.68; $P<0.05$); however, the incremental benefit of preoperative echocardiography was observed only in the higher-risk patients.[16] Diastolic dysfunction is also associated with a higher perioperative risk of MACE in many[18–20] but not all[15] studies. In a retrospective cohort of 2976 patients undergoing NCS, TTE-detected grade 3 diastolic dysfunction had a higher risk of perioperative MACE than grades 1 to 2 diastolic dysfunction.[18]
2. The risk of perioperative mortality is higher in patients with HF compared with those without HF.[1,4] Although even asymptomatic patients with HF have been shown to have an increased risk of MACE in some studies,[4,6] symptomatic patients with lower LVEF who are undergoing higher-risk procedures have been shown to be at highest risk.[7,17] In a retrospective review of 174 patients undergoing intermediate- and high-risk procedures, severely reduced LVEF ≤30% identified with preoperative echocardiography was an independent predictor of 30-day mortality.[7] In a retrospective cohort of 609 735 patients undergoing NCS, the 90-day mortality for those with symptomatic HF was 5.49%, 4.9% for asymptomatic HF, and 1.2% for those with no history of HF history.[4] Preoperative point-of-care assessment of LV function using handheld focused cardiac ultrasound (FoCUS) has been considered in several small studies as a screening method to identify both systolic and diastolic dysfunction.[9–11] FoCUS may be considered to identify patients who may need additional preoperative evaluation to reduce perioperative risk only when performed by trained individuals. In 100 patients with known CVD or considered high risk undergoing hip surgery, perioperative management was changed in 54 patients as a result of the use of handheld ultrasound.[10] In a subsequent small RCT of 100 patients undergoing NCS, 1-year mortality rate was lower in those who had preoperative FoCUS (18.4%) compared with 29.4% in the control group.[9] Larger RCTs are needed to support the routine use of FoCUS in the preoperative evaluation, and comprehensive TTE remains the standard of care for assessment of perioperative LV function.
3. Large retrospective cohorts have not identified a benefit of preoperative assessment of LV function

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in clinically stable patients undergoing NCS, even in patients at higher risk.[12–15] In a large retrospective multicenter study of 264 823 patients undergoing intermediate- or high-risk NCS, 40 084 had preoperative echocardiography.[12] In a propensity score-matched cohort of 70 996 patients, including symptomatic and asymptomatic individuals, performance of a TTE was not associated with improved outcomes.[12] Similarly, data from a US Department of Veterans Affairs health care system reported that preoperative echocardiography (16.4%) was not associated with improved survival or shorter hospital stays after major NCS.[14] As such, there is currently insufficient evidence to recommend routine assessment of LV function in stable patients undergoing NCS. In high-risk patients undergoing high-risk NCS, physician judgment may be used when the results of LV assessment are expected to alter perioperative management or inform perioperative risk in patients undergoing elective NCS.

4.2.2. Right Ventricular Function

Synopsis

Patients with mitral regurgitation (MR), tricuspid regurgitation, and/or pulmonary hypertension (PH) can have reduced right ventricular (RV) function, which has been independently associated with adverse cardiovascular outcomes in NCS.[1,2] Echocardiography is often the first diagnostic test to assess RV function. Cardiovascular magnetic resonance imaging is considered the gold standard for quantitative assessment of RV volume and function and may be appropriate in selected cases. Routine preoperative evaluation of RV function is not recommended in asymptomatic and clinically stable patients.

4.3. Stress Testing

Recommendations for Stress Testing
Referenced studies that support the recommendations are summarized in the Online Data Supplement.

COR	LOE	Recommendations
2b	B-NR	1. For patients undergoing elevated-risk NCS with poor or unknown functional capacity and elevated risk for perioperative cardiovascular events based on a validated risk tool, stress testing may be considered to evaluate for inducible myocardial ischemia.[1]
3: No benefit	B-R	2. In patients who are at low risk for perioperative cardiovascular events, have adequate* functional capacity with stable symptoms, or who are undergoing low-risk procedures, routine stress testing before NCS is not recommended due to lack of benefit.[1–3]

*Poor functional capacity is considered <4 METs or a DASI score of ≤34.

Synopsis

The presence of reversible myocardial ischemia on a preoperative stress test is associated with increased risk for perioperative cardiac events.[1] However, the positive predictive value of an abnormal test is modest, and it is not clear that an abnormal test provides incremental prognostic value beyond standard risk assessment tools (eg, RCRI) or biomarkers (eg, natriuretic peptides).[1,4–11] Testing is also expensive and may lead to unnecessary downstream testing or delays in performing the indicated surgery.[12] Moreover, preoperative revascularization has not been shown to reduce perioperative MACE or cardiac mortality, and there is high potential for overtesting and overtreatment unless further perioperative testing is limited to patients in whom high-risk coronary lesions are likely.[3,13,14] Therefore, the goal of preoperative testing for ischemia is not to identify undiagnosed CAD but to identify patients for whom revascularization is believed to improve clinical outcomes, specifically those with left main disease or severe multivessel disease with a reduced LVEF.[13] These patients have been excluded from studies of preoperative revascularization, and the utility of revascularization in this context is unknown. Thus, in select patients in whom high-risk ischemia is suspected based on symptoms or other factors, stress testing may be useful for risk stratification and to guide management.[1,15,16] However, an abnormal stress test should not prompt coronary angiography or revascularization unless the study has high-risk features.[7,8,11,17] For cost–value consideration, please refer to Section 11.1.4 ("Cost–Value Considerations for Stress Testing").

Recommendation-Specific Supportive Text

1. Functional capacity of <4 METs (eg, patients unable to climb 1-2 flights of stairs or walk on a flat surface at ≥3 mph) is associated with increased risk for perioperative cardiac events regardless of the cause of the disability (eg, CAD, HF, or a noncardiac condition such as arthritis, chronic lung disease, or obesity).[18,19] In patients with elevated risk for perioperative cardiovascular events, as determined by a validated risk score (Section 3.1, "Cardiovascular Risk Indices"), and functional capacity <4 METs or indeterminate functional capacity, a stress test (exercise or pharmacological, with or without imaging depending on the clinical context) may be considered in select patients undergoing elevated-risk surgery, if high-risk myocardial ischemia is suspected (eg, left main disease or severe multivessel disease with reduced EF) or there is an indication for testing independent of planned surgery.[1,15,16] There is, however, limited evidence to support coronary revascularization before NCS in stable patients.[3,14,20,21] In general, an exercise stress test is preferable to a pharmacological stress test if the patient is able to exercise.[15,16] In patients unable to exercise, selection of a pharmacological stress test modality should be based on patient factors and local availability and expertise.[12,15,16]

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2. Stable patients with exercise capacity ≥4 METs are at relatively low risk for perioperative cardiac events.[2] In addition, although some observational studies have suggested that preoperative revascularization of patients with abnormal stress test findings may be associated with a reduction in postoperative ischemic complications, other studies have found no benefit.[14] In the CARP (Coronary Artery Revascularization Prophylaxis) trial, 510 patients with documented CAD (at least 1 lesion with ≥70% stenosis) were randomly assigned to coronary revascularization or medical therapy before undergoing major vascular surgery.[3] Patients in the revascularization group experienced a 36-day delay in time to vascular surgery. There was no difference in the incidence of perioperative MI at 30 days or in all-cause mortality at a median follow-up of 2.7 years.[3] More contemporary large RCTs have demonstrated that routine coronary revascularization does not reduce mortality or risk for MI.[20,22,23] Because the benefits of preoperative revascularization appear to be limited, routine preoperative stress testing should not be performed in patients with adequate functional capacity. Similarly, preoperative stress testing is not recommended in low-risk patients (eg, RCRI=0; see Section 3.1, "Cardiovascular Risk Indices") or in stable patients undergoing low-risk NCS because it is costly, may lead to a delay in surgery, and has not been shown to improve clinical outcomes. [2,14,16,24] This applies to patients with or without known or suspected CAD or cardiovascular risk factors.

4.3.1. Modality Selection for Stress Testing

Synopsis

The selection of stress testing is often driven by clinician preference[1] and should incorporate patient considerations, including their risk factors. Stress testing is generally avoided in unstable syndromes such as acute coronary syndrome (ACS), decompensated HF, severe/symptomatic aortic stenosis (AS), uncontrolled arrhythmia, severe systemic arterial hypertension (eg, ≥200/110 mm Hg), acute aortic dissection, pericarditis/myocarditis, pulmonary embolism, severe PH, or in some cases, other acute illness. Additional modality-specific considerations and contraindications are listed in Table 7. Exercise testing is preferred to pharmacological stress testing whenever functional status permits.[2] Stress myocardial perfusion imaging has a longstanding role in preoperative risk assessment.[3–5] Moderate to large reversible defects on myocardial perfusion imaging have moderate sensitivity for postoperative cardiac events, while the absence of reversible defects is an indication of lower risk for postoperative MI or death.[6] Fixed defects do not indicate additional risk for postoperative cardiac events but, as an indicator of CAD, carry prognostic and therapeutic implications for longer-term cardiac and mortality outcomes.[7,8]

Table 7. Considerations and Contraindications for Specific Stress Testing Modalities

Modality	Contraindication*
Vasodilator pharmacological stress imaging	Significant arrhythmias (eg, VT, second- or third-degree atrioventricular block), significant hypotension (SBP <90 mm Hg), known or suspected bronchoconstrictive or bronchospastic disease or use of dipyridamole or methylxanthines (eg, aminophylline, caffeine) within 12 h
Exercise stress testing (with or without imaging)	Inability to exercise
Dobutamine stress echocardiography	Critical aortic stenosis, hemodynamically significant LVOT obstruction

*In general, the following contraindications apply to all stress testing modalities: ACS, decompensated HF, severe/symptomatic aortic stenosis, uncontrolled arrhythmia, systemic arterial hypertension (eg, ≥200/110 mm Hg), acute aortic dissections, pericarditis/myocarditis, pulmonary embolism, and severe PH.[30]

ACS indicates acute coronary syndrome; HF, heart failure; LVOT, left ventricular outflow tract; PH, pulmonary hypertension; SBP, systolic blood pressure; and VT, ventricular tachycardia.

Dobutamine stress echocardiography for preoperative risk assessment before elevated-risk NCS has been evaluated in several studies, predominantly including patients at increased cardiovascular risk, with poor (<4 METs), and/or unknown functional capacity.[9–26] Overall, a positive test result for dobutamine stress echocardiography was reported in the range of 5% to 50%.[9–11,19,23,27,28] In these studies with event rates of 0% to 15%, the ability of a positive test result to predict perioperative cardiovascular events ranged from 0% to 37%, whereas the negative predictive value was typically >90%. Dobutamine stress echocardiography is appropriate for patients unable to exercise and should be avoided in patients with uncontrolled hypertension, serious arrhythmias, unstable or ACS, or hemodynamically significant LV outflow tract (LVOT) obstruction.[29] There is limited evidence for other stress testing imaging modalities, including positron emission tomography and cardiac magnetic resonance, in preoperative risk stratification before NCS.

4.4. Cardiopulmonary Exercise Testing

Synopsis

In high-risk patients undergoing elevated-risk procedures in whom objective functional capacity is reduced and where additional physiological data are needed to inform perioperative care or guide preoperative optimization, CPET may be beneficial for risk assessment of perioperative morbidity and mortality.[1,2] Reduced cardiorespiratory fitness increases the risk of postoperative complications.[3] CPET is the gold-standard assessment of the physiological response to exercise, providing an objective measure of functional capacity.[4] CPET can be used to diagnose the etiology of exercise intolerance

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(cardiac versus pulmonary pathology), guide preoperative optimization, and inform prehabilitation.[4] CPET predicts all-cause morbidity, which is more common than cardiovascular complications alone,[5] and supports risk prediction in major abdominal, vascular, bariatric, and thoracic surgery, although the definitions of morbidity differ across studies.[1,4] Most studies in perioperative CPET are retrospective and single center and vary in predictive precision.[6,7] The thresholds for identifying high-risk patients also vary between cohorts and surgical procedures. Over time, the risk threshold for reported indices has fallen (eg, the anaerobic threshold decreased from 11 to 9-10 mL/min/kg), reflecting an evolution in surgical and perioperative practice.[8] Alternative measures of functional capacity exist (eg, 6-minute-walk-test) that are also used in risk prediction.[9] These have the advantage of being easier to perform than CPET, without the need for specialized equipment. CPET and the 6-minute-walk-test demonstrate variable correlation, possibly reflecting the need for both tests to be conducted in a standardized manner by trained personnel.[9] Consensus guidance has been released on the indications, organization, conduct, and reporting of perioperative CPET.[4] Additional physiological data beyond the 6-minute-walk-test are provided by CPET that may support its use in high-risk patients with objectively reduced functional capacity undergoing elevated-risk procedures.

4.5. Coronary Computed Tomography Angiography

Recommendations for Coronary Computed Tomography Angiography Referenced studies that support the recommendations are summarized in the Online Data Supplement.

COR	LOE	Recommendations
2b	B-NR	1. For patients undergoing elevated-risk surgery with poor* or unknown functional capacity, and elevated risk for perioperative cardiovascular events based on a validated risk tool, coronary computed tomography angiography (CCTA) for the detection of high-risk coronary anatomy† may be considered.[1–4]
3: No benefit	B-NR	2. In patients who are at low risk for perioperative cardiovascular events, have adequate* functional capacity with stable symptoms, or who are undergoing low-risk procedures, routine CCTA before NCS is not recommended due to lack of benefit.[1,5]

*Poor functional capacity is considered <4 METs or a DASI score of ≤34.

†High-risk coronary anatomy is defined as patients with obstructive stenosis who have ≥50% left main stenosis or anatomically significant 3-vessel disease (≥70% stenosis).[6]

Synopsis

In patients with acute chest pain and no known CAD, CCTA may be useful to exclude atherosclerotic plaque and obstructive CAD and is recommended as an alternative to invasive angiography.[6] However, the role of CCTA in the perioperative setting before NCS is less well established. A positive CCTA has a low predictive value (ie, overestimates the risk for perioperative MACE), thereby possibly contributing to delays in surgery and potential harm.[1] Furthermore, there is no demonstrable benefit of prophylactic coronary revascularization to mitigate the risk of MACE in stable patients undergoing NCS.[5] As a result, routine preoperative risk assessment with CCTA is not recommended. Further, if a patient has a prior coronary artery calcium score of 0 within 2 years, proceeding to surgery without additional testing would be reasonable. CCTA may be considered in select patients with elevated risk or to exclude high-risk coronary anatomy in patients undergoing elevated-risk surgery.[6] Although CCTA is a cost-effective strategy for evaluating patients with chest pain compared with stress testing, the cost analysis has not been evaluated in stable patients undergoing NCS.[7] Studies using CT-based vulnerable plaque characteristics or CT perfusion imaging are currently limited to nonsurgical literature, and their role in perioperative risk assessment are not well established. CCTA is contraindicated and may be harmful in patients who require urgent or emergency surgery, as the need and urgent timing for surgery outweighs any benefit that might be obtained by performing a CCTA and delaying surgery.[1] For cost–value consideration, please refer to Section 11.1.3 (“Cost–Value Considerations for Coronary Computed Tomography Angiography”).

Recommendation-Specific Supportive Text

1. In patients with elevated risk for perioperative cardiovascular events, as determined by a validated risk score (Section 3.1, “Cardiovascular Risk Indices”) and low (<4 METs or a DASI score of ≤34) or indeterminate functional capacity, CCTA may be considered in select cases if high-risk coronary anatomy is suspected and there is a guideline-concordant indication for testing independent of planned surgery. Risk assessment by CCTA offers incremental risk assessment over clinical risk scores. The Coronary CTA-VISION (Coronary CT Angiography to Predict Vascular Events in NCS Patients Cohort Evaluation) study (N=987) showed that use of CCTA marginally improved the risk estimation for predicting postoperative cardiovascular death and nonfatal MI compared with clinical risk score alone.[1] CCTA confers a high negative predictive value for excluding perioperative cardiovascular events.[1–4] These results were confirmed in a meta-analysis including 11 studies and 3480 patients who underwent preoperative CCTA.[2] The presence, extent, and severity of coronary atherosclerosis directly correlated with risk of perioperative MACE. On CCTA, patients with single- and multivessel disease demonstrated a

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3-fold and an 8-fold increased risk of perioperative MACE, respectively.[2] However, as listed in Section 6.1.1 ("Coronary Revascularization"), evidence supporting routine coronary revascularization before planned surgery is lacking.

2. CCTA can improve risk estimation among patients who will experience perioperative MACE; however, compared with clinical risk scores, CCTA is >5 times as likely to inappropriately overestimate risk among patients who will not experience MACE.[1] This overestimation of risk may result in a delay or cancellation of surgery and unnecessary increased use of medical resources, thereby contributing to patient morbidity and mortality and increased medical expenses. Low-risk patients include those at low risk for cardiovascular events based on validated risk tools and those who are undergoing low-risk noncardiac surgical procedures (Section 3.1, "Cardiovascular Risk Indices," Section 1.5, "Definitions of Surgical Timing and Risk"). In these patients, or those with functional capacity ≥4 METs with stable symptoms, the probability of uncovering high-risk coronary anatomy that would adversely affect surgical outcomes is small. This recommendation is applicable to patients with or without known or suspected CAD or cardiovascular risk factors.

4.6. Invasive Coronary Angiography

Recommendation for Invasive Coronary Angiography		
COR	**LOE**	**Recommendation**
3: No benefit	**C-LD**	1. In patients undergoing NCS, routine preoperative invasive coronary angiography (ICA) is not recommended to improve perioperative outcomes.[1,2]

Synopsis

ICA is used to define epicardial coronary artery anatomy, diagnose atherosclerotic CAD, and assess the location, extent, and severity of obstructive coronary stenoses. ICA is necessary to determine the feasibility and necessity of percutaneous or surgical revascularization.[3] Preoperative ICA may be performed in selected patients to detect coronary stenoses that pose significant risks in the perioperative period. Data are insufficient to recommend routine coronary angiography in patients scheduled for NCS, including those undergoing elevated-risk surgery or pretransplant evaluation.[4] Even in patients undergoing vascular surgery, independent of preoperative risk, ICA is not consistently associated with improved early postoperative clinical outcomes.[1,2,5]

Recommendation-Specific Supportive Text

1. Routine invasive angiography to assess the need for coronary revascularization is not recommended in the preoperative evaluation of NCS. The CARP trial of 510 patients assessed the benefit of preoperative coronary artery revascularization among patients with chronic CAD scheduled for elective vascular surgery and reported that coronary artery revascularization before elective vascular surgery does not significantly alter long-term outcomes.[2] Two small European RCTs also evaluated routine versus selective ICA before vascular surgery. In a trial enrolling 426 patients undergoing carotid endarterectomy without a previous history of CAD, routine preoperative ICA was associated with lower rates of early postoperative MI and improved long-term survival compared with surgeries without prior ICA.[6] In a separate study of 208 patients undergoing major vascular surgery with an RCRI ≥2, in-hospital risk of MACE was not different in patients assigned to routine versus selective ICA, although routine ICA was associated with improved survival and freedom from MACE at approximately 5 years of follow-up.[5] Unfortunately, in contrast to the more robust CARP trial, these 2 trials were small, nonblinded, and management of patients assigned to the selective ICA arms was not clearly defined; these findings have not been replicated in larger, more contemporary studies. In contrast, large trials that are not specific to perioperative care indicate that in the setting of stable CAD, invasive management with coronary revascularization of CAD in epicardial vessels other than the left main does not improve short- or long-term survival versus optimal medical therapy alone.[7] Thus, ICA should be reserved for the highest-risk patients. A strategy of routine ICA with an intent to perform revascularization before elective NCS in patients with chronic coronary syndromes cannot be recommended. In general, indications for preoperative coronary angiography should be similar to those identified in nonoperative settings, such as ACS, accelerating angina despite maximal antianginal therapy, newly diagnosed moderate-severe ischemia on stress testing, and indicators of obstructive left main disease on noninvasive testing.

5. APPROACH TO PERIOPERATIVE CARDIAC TESTING

5.1. Stepwise Approach to Perioperative Cardiac Assessment

Figure 1 represents a suggested framework for perioperative risk stratification and management that incorporates best practices and recommendations described throughout this guideline. Recommendations are supported by various levels of evidence. Clinical outcomes of perioperative care guided by this algorithm have not been prospectively studied or validated and therefore should not replace clinical judgment and individualized clinical care.

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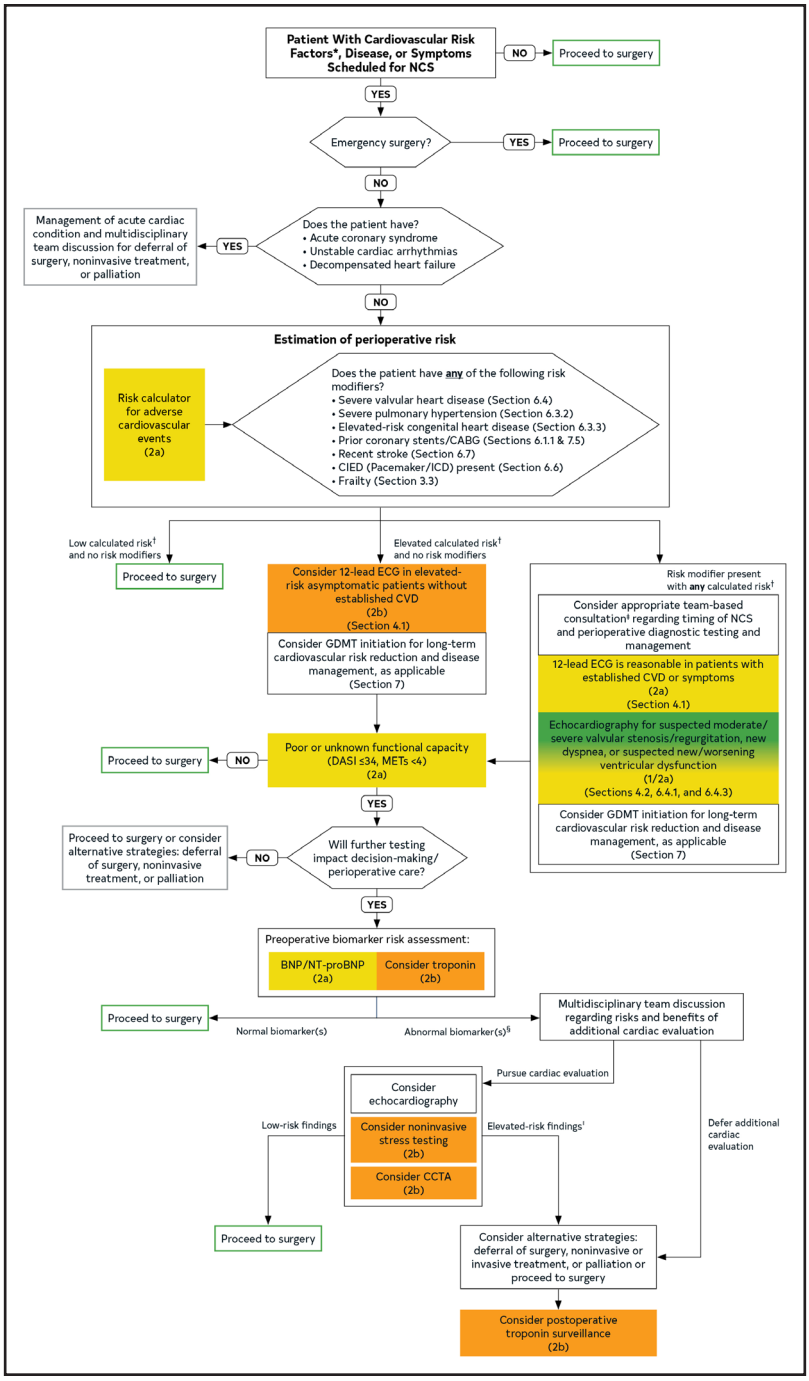


Figure 1. Stepwise Approach to Perioperative Cardiac Assessment.

*Cardiovascular risk factors: hypertension, smoking, high cholesterol, diabetes, women age >65 y; men age >55 y; obesity; family history of premature CAD. †Determining elevated calculated risk depends on the calculator used. Traditionally, RCRI >1 or a calculated risk of MACE with any perioperative risk calculator >1% is used as a threshold to identify patients at elevated risk. §Abnormal biomarker thresholds: troponin >99th percentile URL for the assay; BNP >92 ng/L, NT-proBNP ≥300 ng/L. ‡Conditions that pose additional risk for MACE. ‖Noninvasive stress testing or CCTA suggestive of LM or multivessel CAD. Colors correspond to Class of Recommendation in Table 3. BNP indicates B-type natriuretic peptide; CABG, coronary artery bypass grafting; CAD, coronary artery disease; CCTA, coronary computed tomography angiography; CIED, cardiovascular implantable electronic device; CVD, cardiovascular disease; DASI, Duke Activity Status Index; ECG, electrocardiogram; GDMT, guideline-directed management and therapy; ICD, implantable cardioverter-defibrillator; LM, left main; MACE, major adverse cardiovascular event; METs, metabolic equivalents; NCS, noncardiac surgery; NT-proBNP, N-terminal pro b-type natriuretic peptide; RCRI, Revised Cardiac Risk Index; and URL, upper reference limit.

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6. CARDIOVASCULAR COMORBIDITIES AND PERIOPERATIVE MANAGEMENT

6.1. Coronary Artery Disease

Synopsis

CAD is prevalent in approximately 18% of patients undergoing major NCS,[1] is associated with increased risk of perioperative MACE, and is a common element in preoperative risk estimation.[2–6] The location, extent, and severity of atherosclerotic CAD informs perioperative risks, and a history of an ACS confers greater perioperative risks than chronic coronary disease (CCD) does. Among >3500 patients included in the RCRI derivation and validation cohorts, a history of MI was associated with a 3.5-fold increased risk of perioperative MACE.[4]

Patients with CAD treated with coronary stents also have increased risk of MACE.[3] In a retrospective cohort of approximately 28 000 patients undergoing NCS, the odds of perioperative MACE was 2-fold higher in patients with coronary stents placed in the prior 2 years compared with matched controls without stents.[7] The risks of MACE are inversely proportional to the time interval between coronary revascularization and NCS (Section 6.1.1, "Coronary Revascularization").[8] Careful attention to optimal medical management for ASCVD is important before elective NCS in patients with CAD.[9] The perioperative diagnostic evaluation and management of patients with a history of CAD undergoing NCS is outlined in Section 3 through Section 7.

6.1.1. Coronary Revascularization

Recommendations for Coronary Revascularization
Referenced studies that support the recommendations are summarized in the Online Data Supplement.

COR	LOE	Recommendations
1	C-LD	1. In patients with ACS being considered for elective NCS, coronary revascularization as appropriate and deferral of surgery is recommended to reduce perioperative cardiovascular events.[1–9]
2a	C-LD	2. In patients with CCD and hemodynamically significant left main coronary artery stenosis ≥50% who are planning elective NCS, coronary revascularization and deferral of surgery is reasonable to reduce perioperative cardiovascular events.[10,11]
3: No benefit	B-R	3. In patients with non–left main CAD who are planned for NCS, routine preoperative coronary revascularization is not recommended to reduce perioperative cardiovascular events.*[12–15]

*Modified from the "2021 ACC/AHA/SCAI Guideline for Coronary Artery Revascularization."[16]

Synopsis

This guideline reviews the role of coronary revascularization before NCS. For further guidance on coronary revascularization, please refer to the "2021 ACC/AHA/SCAI Guideline for Coronary Artery Revascularization."[16] For patients with ACS ST-segment elevation myocardial infarction (STEMI) or high-risk non–ST-segment elevation myocardial infarction (NSTEMI) and patients with CCD involving left main CAD, preoperative revascularization can be beneficial in reducing MACE.[13–17] For patients experiencing anginal symptoms refractory to optimal GDMT, a multidisciplinary heart team approach to revascularization should be considered before planned NCS.[15,16] In general, the 2021 revascularization guideline can be applied to NCS patients as long as they are able to safely postpone the surgery to accommodate for the dual antiplatelet therapy (DAPT) recommendations. For patients undergoing organ transplant surgery, vascular surgery, and/or with multivessel CAD, multidisciplinary team input is recommended for assessing revascularization needs and timing.[16] Please refer to Section 7.5 ("Antiplatelet Therapy and Timing of Noncardiac Surgery in Patients With Coronary Artery Disease") in this guideline for antiplatelet management and timing of NCS after percutaneous coronary intervention (PCI).

Recommendation-Specific Supportive Text

1. Coronary revascularization, either with PCI or coronary artery bypass grafting (CABG), is an important treatment modality for patients with ACS. In patients with STEMI, cardiovascular outcomes are improved by immediate reperfusion therapy with primary PCI and coronary stent placement.[7,16,18] Coronary revascularization is also commonly indicated in patients with unstable angina and NSTEMI, particularly in those with (1) cardiogenic shock; (2) ACS characterized by refractory angina, intractable arrhythmias, or hemodynamic instability; or (3) GRACE (Global Registry of Acute Coronary Events) scores >140.[16] In patients with ACS who have an indication for NCS, coronary revascularization should be performed as described in the "2021 ACC/AHA/SCAI Guideline for Coronary Artery Revascularization" and, when possible, NCS should be deferred to reduce perioperative cardiovascular events.[16]
2. In patients with CCD and left main disease, the cumulative mortality and morbidity risks of both the coronary revascularization procedure and the NCS should be weighed carefully, taking into consideration the individual patient's overall health, functional status, and prognosis. Summative evidence from prior RCTs such as ISCHEMIA (International Study of Comparative Health Effectiveness With Medical and Invasive Approaches), COURAGE (Clinical Outcomes Utilizing Revascularization and Aggressive Drug Evaluation), and BARI-2D (Bypass Angioplasty Revascularization Investigation 2 Diabetes) have noted the importance of GDMT and lack of benefit from routine revascularization in most patients with CCD.[13–15] However, patients with left main CAD were excluded from these landmark RCTs. Older RCT data suggest that revascularization

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with CABG reduces mortality in patients with left main disease.[10,11] In nonrandomized patients with multivessel CAD (including left main) planned for vascular NCS, unprotected left main disease was the only angiographic subset with a survival benefit from preoperative coronary revascularization.[19] Furthermore, Bayesian methods support the concept that PCI, like CABG, improves survival for patients with unprotected left main CAD compared with medical therapy.[10] Therefore, preoperative coronary revascularization before NCS is a reasonable consideration in patients with CCD and significant left main CAD (defined as >50% stenosis).[16,17]

3. In the CARP trial, routine prophylactic coronary revascularization with either PCI or CABG before elective major vascular surgery was not associated with differences in 30-day or 1-year rates of death or MI.[12] Patients with left main CAD, LVEF <20%, or severe AS were excluded from this trial.[12] Smaller trials, including a subgroup of abdominal aortic operations from the CARP study, demonstrated potential benefits from routine coronary angiography and PCI, if indicated, before NCS.[20–22] However, a meta-analysis of 3949 patients including CARP and 6 other retrospective studies did not show any benefit from routine revascularization before NCS.[23] Coronary artery revascularization in patients undergoing vascular surgery has been noted to shift the mortality from cardiovascular to noncardiovascular causes, without an absolute reduction in mortality.[24] Bleeding complications are higher with PCI, specifically in the first 6 months after placement of a drug-eluting stent (DES).[25]

6.2. Hypertension and Perioperative Blood Pressure Management

Recommendations for Hypertension and Perioperative Blood Pressure Management Referenced studies that support the recommendations are summarized in the Online Data Supplement.		
COR	**LOE**	**Recommendations**
Preoperative Blood Pressure Management		
2a	**C-EO**	1. In most* patients with hypertension planned for elective NCS, it is reasonable to continue medical therapy for hypertension throughout the perioperative period.†
2b	**C-LD**	2. In patients undergoing elective elevated-risk surgery who have cardiovascular risk factors for perioperative complications‡ and recent history of poorly controlled hypertension (systolic blood pressure [SBP] ≥180 mm Hg or diastolic blood pressure [DBP] ≥110 mm Hg before the day of surgery), deferring surgery may be considered to reduce the risk of perioperative complications.†[1,2]
Intraoperative Blood Pressure Management		
1	**B-NR**	3. In patients undergoing NCS, maintaining an intraoperative mean arterial pressure (MAP) ≥60 to 65 mm Hg or SBP ≥90 mm Hg is recommended to reduce the risk of myocardial injury.[3–9]
Postoperative Blood Pressure Management		
1	**B-NR**	4. In patients undergoing NCS, treatment of hypotension (MAP <60-65 or SBP <90 mm Hg) in the postoperative period is recommended to limit the risk of cardiovascular, cerebrovascular, renal events, and mortality.[6]
1	**C-EO**	5. In patients with hypertension undergoing NCS, it is recommended that preoperative antihypertensive medications be restarted as soon as clinically reasonable to avoid complications from postoperative hypertension.

*Caution is advised when continuing antihypertensive therapy in patients with low or low-normal perioperative BPs, older adults (≥65 years),[10] and patients in whom the risk for perioperative hypotension is high based on an evaluation of the patient's overall clinical status, surgery type, and anesthetic plan.

†Modified from the "2017 ACC/AHA/AAPA/ABC/ACPM/AGS/APhA/ASH/ASPC/NMA/PCNA High Blood Pressure Guideline."[11]

‡One or more components of the RCRI: CAD, congestive heart failure, cerebrovascular accident, baseline serum creatinine >2.0 mg/dL, or preoperative insulin treatment.[12]

Synopsis

Perioperative hypertension affects an estimated 25% of patients who undergo major NCS and is a leading cause for postponement of elective surgery.[13] Uncontrolled hypertension contributes to increased myocardial demand via elevated LV end-diastolic pressure, leading to subendocardial myocardial ischemia. In the perioperative period, uncontrolled hypertension increases the risk of CVD, cerebrovascular events, and bleeding.[14,15] Evidence from large cohort studies indicates that intraoperative[6,8,16,17] and postoperative[6,17] hypotension also increases the risk for adverse cardiovascular and renal outcomes and death. There are comparatively fewer data that attribute the risk to intraoperative hypertension[5,16] and intraoperative BP variability.[18] However, no high-quality RCTs have shown that acute lowering of perioperative BP reduces rates of cardiovascular events or mortality and, in fact, may be harmful.[19] The most appropriate approaches to BP assessment (systolic,[2,5,6,20] diastolic,[2,5,21,22] mean,[4,5,10,23] or pulse pressure[24]), thresholds (absolute[2,4–6,10,20] or relative[4,25]), and frequency of measurement[26] to guide care have not been established.[27] In addition to baseline BP, an assessment of total cardiovascular risk, age, clinical comorbidities, surgery type, anesthetic approach, and short-term risk of complications should be considered when individualizing perioperative BP management.

Recommendation-Specific Supportive Text

1. Uncontrolled hypertension is associated with increased perioperative complications. In a retrospective analysis of 251 000 adults undergoing elective NCS from the UK Clinical Practice Research Datalink, preoperative DBP >90 mm Hg

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was associated with increased 30-day postoperative mortality.[21] Accordingly, ongoing treatment of chronic hypertension is recommended in the perioperative period. If hypertensive patients are unable to take oral medications, it is reasonable to use intravenous medications to control BP. Tight BP control mitigates long-term cardiovascular risk, but this strategy may not be appropriate for all patients in the perioperative period. Whereas maintaining an SBP >90 mm Hg may be an acceptable target for younger adults,[20] a higher target may be preferred in older adults, those with chronic hypertension, or both.[21] The decision whether to hold or continue antihypertensive medications may be specific to drug class. Certain medications (eg, beta blockers, clonidine) may be associated with rebound hypertension if discontinued abruptly,[28] whereas others have been associated with increased risk of intraoperative hypotension when continued (eg, angiotensin-converting enzyme inhibitors [ACEi], angiotensin-receptor blockers [ARBs]).[29,30] Refer to Sections 7.2 through 7.4 for further guidance on specific classes of antihypertensive drugs.

2. In patients with untreated or uncontrolled hypertension, induction of anesthesia can trigger sympathetic activity, resulting in labile BP and heart rate.[31] In a systematic review and meta-analysis of 30 observational studies, a preoperative diagnosis of hypertension was associated with a 35% increase in cardiovascular complications.[2] A single-center retrospective analysis of 58 276 patients undergoing NCS identified an association between preinduction SBP >160 mm Hg and a composite outcome (cardiac, neurological, or renal complication or in-hospital mortality) that was only significant in patients (n=10 512) with ≥1 components of the RCRI (eg, CAD, congestive HF, cerebrovascular accident, baseline serum creatinine >2.0 mg/dL, or preoperative insulin treatment).[1] However, an elevated BP on the day of surgery may represent a situational ("white coat hypertension") response.[32] Therefore, referring to patients' baseline ambulatory BP is recommended to guide management. In the absence of RCRI components,[1] there is little evidence for increased risk of perioperative complications in patients with preoperative BP of <180/110 mm Hg[2] or at any preinduction BP.
3. Intraoperative hypotension is associated with postoperative myocardial injury, acute kidney injury, and mortality.[4–6,8,23] The harm threshold in observational analyses appears to be roughly a MAP <65 mm Hg or an SBP <90 mm Hg maintained for about 15 minutes.[4,33] However, the results of 3 key trials are challenging to interpret. The multicenter, randomized INPRESS (Intraoperative Noradrenaline to Control Arterial Pressure) trial studied 298 high-risk patients and reported a roughly 25% relative risk reduction if SBP was maintained within 10% from baseline versus >80 mm Hg.[25] Another single-center trial[34] randomized 458 high-risk patients to a MAP ≥60 mm Hg versus MAP ≥75 mm Hg, and POISE-3 (Perioperative Ischemic Evaluation-3)[9] randomized 7490 patients to a hypotension-avoidance (target MAP ≥80 mm Hg) versus hypertension-avoidance (target MAP ≥60 mm Hg) intraoperative strategy. Neither of these reported benefit from a strategy targeting higher BP. However, interpretation of the INPRESS study is complicated by lack of details reported with respect to extent of hypotension, especially in the potentially harmful MAP range of 55 to 70 mm Hg. Thus, while the expert opinion is to maintain intraoperative BP targets above MAP ≥60 to 65 or SBP >90 mm Hg, there is currently insufficient trial evidence to support higher BP targets.
4. In the POISE-2 (Perioperative Ischemic Evaluation-2) substudy, there was increased risk of the composite outcome of MI and death for increasing duration of SBP <90 mm Hg through postoperative day 4 (OR, 2.83 per 10-minute increase).[6] However, anesthetic and hypotension management (eg, fluid boluses, vasoactive drugs, and mechanical support) was at the discretion of the clinical team and not controlled or reported. Closer monitoring of postoperative patients in the intensive care setting may allow for earlier recognition of hypotension.[35] A systematic review and meta-analysis on the perioperative use of vasoactive drugs (including inotropic agents and vasoconstrictors) to treat hypotension concluded that their use may reduce postoperative complications and reduce the length of stay in adult patients having major abdominal surgery.[7]
5. Postoperative hypertension can occur as a result of a variety of stimuli, including pain, inflammation, anxiety, hypoxia, volume overload, urinary retention, or as a result of withdrawal of chronic antihypertensive medications.[36] Hypertension can increase the risk for myocardial ischemia/infarction, acute decompensated HF, cerebral ischemia, and dysrhythmias.[36] Propensity-matched retrospective US Department of Veterans Affairs cohort studies found that delaying the resumption of preoperative ACEi/ARBs was associated with increased 30-day mortality risk.[37,38] Chronically taken oral antihypertensive medications should be restarted as soon as clinically reasonable to avoid complications from postoperative hypertension. However, results from a nonrandomized propensity-matched cohort study of men ≥65 years with hypertension caution against intensification of antihypertensive therapy at hospital discharge due to an increased 30-day risk of readmission and serious

adverse events without improvement in 1-year cardiovascular events.[39]

6.3. Heart Failure

Recommendations for Heart Failure Referenced studies that support the recommendations are summarized in the Online Data Supplement.		
COR	**LOE**	**Recommendations**
1	C-LD	1. In patients with HF undergoing elective NCS, sodium-glucose cotransporter-2 inhibitors (SGLT2i) should be withheld for 3 to 4 days* before surgery when feasible to reduce the risk of perioperative metabolic acidosis.[1–3]
2a	C-LD	2. In patients with compensated HF undergoing NCS, it is reasonable to continue GDMT (excluding SGLT2i) in the perioperative period, unless contraindicated, to reduce the risk of worsening HF.[4–8]

*Canagliflozin, dapagliflozin, and empagliflozin should be stopped ≥3 days and ertugliflozin ≥4 days before scheduled surgery.[3]

Synopsis

Patients with HF are at increased risk for perioperative complications.[9,10] In a study of 38 047 patients with nonischemic HF, ischemic HF, CAD, or AF, the crude 30-day postoperative mortality was significantly higher in patients with nonischemic HF (9.3%) or ischemic HF (9.2%) compared with patients with CAD (2.9%), suggesting that patients with HF have a 3-fold greater risk for perioperative death than those with CAD alone.[11] In addition, patients with active HF symptoms or signs are at higher risk for adverse outcomes than those with compensated HF or history of HF.[9] In another study of patients undergoing NCS, those with an HF diagnosis (n=47 997) had 67% higher adjusted odds of 90-day mortality compared with those without HF (n=561 738), and lower LVEF was associated with higher 90-day mortality (Table 8).[10] Accordingly, history of HF has been integrated into both the RCRI and NSQIP preoperative risk assessment indices.

There are established guideline-directed therapies for all forms of HF,[12] and there is evidence that optimizing HF treatment before elevated-risk surgery is associated with reduced risk for perioperative complications.[10] Moreover, interruption or discontinuation of HF GDMT without a specific indication to do so is associated with increased mortality.[4–7,13] However, SGLT2i have been associated with increased risk for metabolic acidosis in the perioperative period and should be withheld for 3 to 4 days before surgery when feasible.[1–3,14] In patients with advanced HF (New York Heart Association [NYHA] class III-IV) who are clinically decompensated or hemodynamically unstable, consideration should be given to postponing elective surgery and obtaining cardiology consultation to assist with perioperative management.

Table 8. Association of Heart Failure and Left Ventricular Ejection Fraction With 90-day Mortality in Patients Undergoing Noncardiac Surgery

	N	Crude Mortality	Crude OR	Adjusted OR
No heart failure	561 738	1.22%	Reference	Reference
HFpEF, LVEF ≥50%	28 742	4.88%	4.14 (3.90-4.39)	1.51 (1.40-1.62)
LVEF 40%-49%	7612	5.11%	4.34 (3.91-4.82)	1.53 (1.38-1.71)
LVEF 30%-39%	6048	6.58%	5.68 (5.12-6.31)	1.85 (1.68-2.05)
LVEF <30%	4185	8.34%	7.34 (6.56-8.21)	2.35 (2.09-2.63)

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HFpEF indicates heart failure with preserved ejection fraction; LVEF, left ventricular ejection fraction; and OR, odds ratio (with 95% CI).

Recommendation-Specific Supportive Text

1. SGLT2i have been associated with metabolic acidosis and euglycemic ketoacidosis in the perioperative period, which can lead to serious complications, prolonged hospital stay, and death.[1,2] The mechanism underlying SGLT2i-induced ketoacidosis is thought to be similar to starvation ketosis, with intensification of the normal metabolic effects of these agents by perioperative fasting. The diagnosis of euglycemic ketoacidosis may be missed because symptoms are often nonspecific, such as nausea, abdominal pain, and shortness of breath, and blood glucose levels may be normal or only mildly elevated. The diagnosis should be suspected when there is an anion gap metabolic acidosis and ketones in the blood or urine. In 2022, the US Food and Drug Administration (FDA) updated the labeling for SGLT2i to recommend discontinuing these agents 3 to 4 days before surgery when feasible.[3] This recommendation has been endorsed by the American Diabetes Association and other organizations.[14]
2. GDMT for HF with reduced EF (HFrEF) includes 4 medication classes that have been shown in multiple trials to reduce mortality and morbidity: (1) renin-angiotensin system inhibition with angiotensin receptor-neprilysin inhibitors, ACEi, or ARBs alone; (2) beta blockers; (3) mineralocorticoid receptor antagonists; and (4) SGLT2i.[12] There are also guideline-recommended therapies for HF with mildly reduced EF, HF with preserved EF, and HF with improved EF.[12] Similarly, patients with stage B pre-HF, including those with asymptomatic systolic or diastolic dysfunction, should be managed in accordance with guideline recommendations.[12] In patients hospitalized for HFrEF, discontinuation of GDMT in the absence of a direct contraindication has been associated with increased mortality

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and readmission.[4–8] Thus, continuation of medical therapy for HF is reasonable and likely to be beneficial for most patients undergoing NCS.

6.3.1. Hypertrophic Cardiomyopathy

Recommendation for Hypertrophic Cardiomyopathy		
COR	**LOE**	**Recommendation**
3: Harm	**C-LD**	1. For patients with hypertrophic cardiomyopathy (HCM) undergoing NCS, factors that aggravate or trigger dynamic outflow obstructions (eg, positive inotropic agents, tachycardia, or reduced preload) are harmful and should be avoided to reduce the risk of hemodynamic instability.[1,2]

Synopsis

HCM is a common inherited disorder (1 in 500 people in the United States) frequently accompanied by dynamic LVOT obstruction.[3] Echocardiography and cardiac magnetic resonance are the preferred diagnostic imaging modalities of HCM. Patients with HCM may be asymptomatic at rest but can decompensate from LVOT obstruction in the setting of anesthesia, tachycardia, reduced preload, or reduced afterload. Decompensation of HCM can manifest as HF, MI, ischemia, arrhythmia, or sudden cardiac death, and management of established treatment modalities (pharmacotherapy, implantable defibrillators) must be considered in the perioperative management of patients with HCM. Established negative inotropic agents should be continued into the perioperative period. Use of invasive monitoring (arterial line/central venous pressure) and/or cardiac output measurement may be considered. In most clinical situations, excessive diuresis and inotropes should be avoided to avoid the consequent increase in LV outflow gradient (Table 9). When BP support is required, vasopressors are preferred to inotropic agents. Use of transesophageal echocardiography (TEE) (Section 8.3.1, "Echocardiography") can be considered in situations of hemodynamic instability to evaluate for LVOT obstruction in patients with HCM. Sinus rhythm should be maintained where possible due to the prevalence of LV hypertrophy and decreased LV compliance in HCM.[5–7] For management of other cardiomyopathy conditions, please refer to the 2020 AHA//Multisociety HCM Guideline.[3]

Table 9. Preoperative and Intraoperative Management Considerations in Patients With Hypertrophic Cardiomyopathy

Management Considerations
Continue beta blockers and/or nondihydropyridine calcium channel blockers without interruption in the perioperative period
Avoid hypovolemia and reduced preload (can worsen LVOT obstruction)
Avoid hypotension and reduced afterload (can worsen LVOT obstruction)
Avoid tachycardia to ensure adequate LV filling
If hypotension develops: Prioritize intravenous fluid administration to correct hypovolemia Use alpha-agonists, such as phenylephrine or vasopressin,[7] rather than beta-agonists, which can worsen LVOT obstruction Consider intraoperative echocardiography to evaluate LVOT obstruction in the setting of hypotension In selected cases, intravenous beta-blockade may be necessary to reduce LV myocardial contractility and relieve LVOT obstruction

LV indicates left ventricular; and LVOT, left ventricular outflow tract.

Recommendation-Specific Supportive Text

1. There is limited evidence about perioperative risk in patients with HCM undergoing NCS. There are no studies in which intraoperative management of HCM has been addressed. Outcomes evidence is mostly derived from cohort studies and case reports, which suffer from small size, single-center composition, and from heterogeneity in patient populations and type of surgery.[1,2,4–7] These studies report either no or significantly increased perioperative risk, increased risk of developing HF, or both. A recent case-control cohort single-center observational study undertaken in an institution experienced with HCM[1] reported an increase in a composite outcome of 30-day primary events in patients with HCM, but a very low rate of death, MI, or stroke individually. Higher levels of comorbidity and higher-risk surgery, prolonged intraoperative hypotension, and higher levels of provokable LVOT obstruction appeared to be associated with greatest risk. It may be reasonable to refer patients with HCM to high-volume centers. Postoperative critical care may be indicated in patients with known obstructive HCM.[3]

6.3.2. Pulmonary Hypertension

Recommendations for Pulmonary Hypertension Referenced studies that support the recommendations are summarized in the Online Data Supplement.		
COR	**LOE**	**Recommendations**
1	**C-LD**	1. In patients receiving stable doses of targeted medical therapies* for pulmonary arterial hypertension (PAH) undergoing NCS, it is recommended to continue these agents to reduce the risk for the development of perioperative MACE.[1]
2a	**C-LD**	2. In patients with severe† PH undergoing elevated-risk NCS, referral to or consultation with a specialized PH center that can support risk assessment, optimization, and postoperative management (with consideration of intensive care after NCS) is reasonable to reduce perioperative cardiopulmonary complications.[2]
2a	**C-LD**	3. In patients with severe† PH undergoing elevated-risk NCS, invasive hemodynamic monitoring is reasonable to guide intraoperative and postoperative care.[3–5]

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Recommendations for Pulmonary Hypertension (Continued)		
COR	LOE	Recommendations
2b	C-EO	4. In patients with precapillary PH undergoing elevated-risk NCS, perioperative administration of short-acting inhaled pulmonary vasodilators (eg, nitric oxide, aerosolized prostacyclins) may be reasonable to reduce elevated RV afterload and prevent acute decompensated right HF.[6]

*For example, nitric oxide pathway mediators, endothelin receptor antagonists, prostacyclin pathway agonists, or a combination of these.

†Severe PH is defined according to hemodynamics (severe precapillary PH component by right heart catheterization and echocardiography) and additional data derived from clinical assessment, exercise tests, and laboratory biomarkers. Hemodynamically, severe PH displays a mean pulmonary artery (PA) pressure >40 mm Hg, pulmonary vascular resistance >5 Wood units, or echocardiographic evidence of significant RV dysfunction (eg, RV-to-LV diastolic diameter ratio >0.8 or RV dysfunction that is graded as moderate or severe). Although all 5 World Symposium on Pulmonary Hypertension group classifications display some degree of risk for developing severe PH, Group 1 (PAH), Group 3 (PH due to lung disease), and Group 4 (chronic thromboembolic PH) are at high risk for developing severe PH if left untreated and may be best managed and followed at a center with PH specialists.

Synopsis

The role of PH in the development of perioperative MACE in NCS remains largely defined by observational data.[1,2,7–17] A recent AHA scientific statement[6] provided comprehensive guidance related to the diagnosis, evaluation, and management of PH in patients undergoing NCS, including a thorough review of the 5 clinical group classifications of PH according to the World Symposium on PH.[17] The development of perioperative MACE is consistently higher in patients with any PH subtype compared with those without PH.[6] Perioperative risk stratification and optimization should include a review of recent preoperative right heart catheterization to determine the presence of precapillary PH (mean PA pressure >20 mm Hg, PA wedge pressure <15 mm Hg, and pulmonary vascular resistance >2 Wood units)[18] and echocardiographic data to assess the severity of RV dysfunction to inform management before, during, and after NCS.[6] Although patients with PH determined to be at elevated risk for development of perioperative MACE may benefit from invasive hemodynamic monitoring during and after surgery, the choice of invasive monitoring will vary depending on the patient, surgery, care team, and PH center.

Recommendation-Specific Supportive Text

1. For patients with Group 1 disease (PAH), it is recommended to continue targeted medical therapies during the perioperative period given the higher risk for MACE compared with patients with non-Group 1 PH undergoing NCS.[1,2] A prospective, international, multicenter, observational study of patients with PAH undergoing nonobstetric NCS at 11 specialized PH centers reported major complications in 6.1% and perioperative mortality in 3.5% of patients.[1] Mortality was 15% in emergency procedures compared with 2% in nonemergency surgeries. Although some of the risk factors for major complications were unmodifiable, this study demonstrated the importance of having specialized centers manage patients with PAH undergoing NCS. This study also supported the continuation of PAH-target medical therapies (eg, nitric oxide pathway inhibitors, endothelin receptor antagonists, prostacyclin pathway agonists) in preparation for NCS due to lower morbidity and mortality seen with well-controlled PAH.[1]
2. A study from 2004 to 2014 of almost 18 million adult hospitalizations for major NCS in the United States found that, of 143 846 patients with PH hospitalized for NCS (0.81%), PH was associated with a 43% increased odds of death, MI, or stroke and a nearly 2-fold higher risk of cardiogenic shock and cardiac arrest.[2] Compared with patients without PH, those with Group 1 disease had a 2.5-fold increase in MACE and a 5-fold greater risk for cardiogenic shock after covariate adjustment.[2] This study highlights the importance of creating a perioperative management plan for elevated-risk NCS in Group 1 patients within a specialized center that can support multidisciplinary team management. These resources are especially important if the patient is at significant risk for experiencing acute decompensated right HF from uncontrolled precapillary PH that could require extracorporeal membrane oxygenation.[6] The use of venoarterial extracorporeal membrane oxygenation as the mechanical support device of choice for PH-induced right HF, and avoidance of an RV assist device, is also supported by a previous AHA scientific statement.[19]
3. PH with a severe precapillary component is defined as mean PA pressure >40 mm Hg, pulmonary vascular resistance >5 Wood units, or evidence of significant RV morphologic alterations by echocardiography (eg, RV-to-LV diastolic diameter ratio >0.8 or RV dysfunction that is graded as moderate or severe). Patients with severe PH have a high risk for death at baseline[18] and have a higher risk for perioperative complications than those with mild or moderate disease. In a retrospective analysis of 1276 adult patients undergoing NCS with general anesthesia between 1991 and 2003, 145 patients with PAH (World Symposium on PH Groups 1, 3, or 4) displayed a mean RV systolic pressure of 68±21 mm Hg on echocardiography. Of these, perioperative complications occurred in 60 patients (42%), where NYHA functional class II or higher, RV systolic pressure-to-systemic SBP ratio ≥0.66, and intraoperative use of vasopressors were each associated with postoperative mortality.[5] Placement of a central venous catheter is based on determination of intermediate or high risk during risk

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assessment and the need for central venous pressure monitoring and anticipation of vasoactive medication use.[20] Although there are diagnostic benefits to using a PA catheter in the operating room or in the intensive care unit after NCS, incorrect interpretation of information and recognized risks to placement may temper routine use.[4]

4. The presence of isolated precapillary PH (PH attributed to the pulmonary arterial tree without the presence of pulmonary venous occlusive disease or left-heart disease) may include those with Groups 1, 3, 4, or 5 from the World Symposium on PH classification.[17] The continuous delivery of inhaled pulmonary-selective vasodilators (eg, nitric oxide, prostacyclins) in NCS has been studied mainly in obstetric patients with Group 1 disease[21] or lung transplant recipients at risk for PH-induced right HF[22] and precapillary PH contributing to primary lung-allograft dysfunction.[23] Importantly, MACE has not been evaluated as an outcome. Unlike oral or intravenous vasodilators, the use of these inhaled medications with short half-lives has the added advantage of immediately lowering RV afterload without adversely impacting systemic BP.[6] Thus, the potential benefits of selectively lowering RV afterload to avoid acute decompensated right HF may outweigh any minor theoretical risks related to nitric oxide or prostacyclins.[6] During preoperative right heart catheterization, typically for Group 1 disease, pulmonary vasodilator administration may be performed to determine vasoreactivity response (responder versus nonresponder)[17] and could help guide perioperative use as pulmonary vasodilators may not be helpful in a known nonresponder. Furthermore, these agents may only be available at specialized PH centers that can better care for patients at higher risk for perioperative MACE through the ability to provide calibrated devices and practice protocols to deliver these inhaled therapeutics.

6.3.3. Adult Congenital Heart Disease

Recommendation for Adult Congenital Heart Disease Referenced studies that support the recommendation are summarized in the Online Data Supplement.		
COR	**LOE**	**Recommendation**
1	**B-NR**	1. In patients with intermediate- to elevated-risk congenital heart disease (CHD) lesions (Table 10) undergoing elective NCS, preoperative consultation with an adult congenital heart disease (ACHD) specialist is recommended before the surgery.*[1–4]

*Modified from the "2018 AHA/ACC Guideline for Management of ACHD."[5]

Table 10. Adult Congenital Heart Disease Risk Stratification Before Noncardiac Surgery

Risk	Anatomy	Functional/Hemodynamic Status
Low Risk	Patients with isolated small CHD lesions Patients with repaired CHD lesion with no residual shunt Patients with bicuspid aortic valve disease and aortopathy	NYHA class I functional status, normal exercise capacity No chamber enlargement on imaging No residual shunt No PAH No arrhythmias
Intermediate risk	Unrepaired moderate-large shunts (ASD, VSD, PDA, AVSD) Repaired CHD with moderate to large residual shunt (ASD, VSD, PDA, AVSD) Obstructive left-sided lesions (congenital mitral stenosis, subaortic stenosis, supravalvular aortic stenosis, coarctation of aorta) except the ones described as low risk Obstructive right-sided lesion (pulmonary stenosis, branch pulmonary stenosis, repaired tetralogy of Fallot) Ebstein anomaly (disease spectrum includes mild, moderate, and severe variations) Anomalous coronary artery arising from the pulmonary artery Anomalous aortic origin of a coronary artery from the opposite sinus, especially with an interarterial or intramural course	NYHA class II-IV functional status Limited exercise capacity Presence of residual shunt Presence of PAH Presence of cardiac chamber enlargement Significant valvular dysfunction (more than mild in severity) Arrhythmias requiring treatment Presence of HF
Elevated risk	Single-ventricle patients (palliated or status post Fontan procedure), unrepaired or palliated cyanotic CHD, double outlet right ventricle, pulmonary atresia, truncus arteriosus, TGA (classic or d-TGA; CCTGA or l-TGA), interrupted aortic arch	NYHA class II-IV functional status Limited exercise capacity Significant valvular dysfunction (more than mild in severity) Arrhythmias requiring treatment Presence of PAH Presence of HF

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ASD indicates atrial septal defect; AVSD, atrioventricular septal defect; CCTGA, congenitally corrected transposition of the great arteries; CHD, congenital heart disease; d-TGA, dextro-transposition of the great arteries; HF, heart failure; L-TGA, levo-transposition of the great arteries; NYHA, New York Heart Association; PAH, pulmonary arterial hypertension; PDA, patent ductus arteriosus; TGA, transposition of the great arteries; and VSD, ventricular septal defect.

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Table 11. Adult Congenital Heart Disease Patient Management for Noncardiac Surgery

Clarify the ACHD diagnosis and review cardiac anatomy
Clarify prior procedures, residua, sequelae, and current functional status
Identify factors associated with increased risk of perioperative morbidity and mortality
Cyanosis
HF
Poor functional capacity
Pulmonary hypertension
Intermediate- to high-risk CHD lesions
Urgent/emergency procedures
Operations of the respiratory and nervous systems
Multidisciplinary team discussion to develop management strategies to minimize risk and optimize outcomes
Issues to consider
Endocarditis prophylaxis
Prevention of venous thrombosis
Monitoring of renal and liver function and appropriate drug dosing
Complications related to underlying hemodynamics
Need for hemodynamic monitoring
Periprocedural anticoagulation
Abnormal venous and/or arterial anatomy affecting venous and arterial access
Meticulous line care, including air filters for intravenous lines to reduce risk of paradoxical embolus in patients who are cyanotic because of right-to-left shunts
Arrhythmias, including bradyarrhythmias
Erythrocytosis
Pulmonary vascular disease
Adjustment of anticoagulant volume in tubes for some blood work in cyanotic patients

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ACHD indicates adult congenital heart disease; CHD, congenital heart disease; and HF, heart failure.

Synopsis

As the population with ACHD grows and ages across the world, these patients increasingly represent a larger proportion of patients undergoing NCS. Patients with ACHD are at increased risk of in-hospital mortality and longer hospitalization and are at higher risk of readmission at 30 days after high-risk NCS.[6–8] Although the risk may depend on the type and severity of ACHD, surgical procedure, and urgency of surgery, these patients present unique physiological challenges in perioperative care related to fluid balance, BP, and shunt management. Thus, preoperative consultation with an ACHD cardiovascular specialist is advised.[5] Increased intra-abdominal pressure, hypothermia, hypercapnia, metabolic acidosis, and hypovolemia should be avoided in patients with Eisenmenger syndrome or with a prior Fontan procedure to maintain optimal pulmonary vascular resistance.[2] If possible, NCS in patients with ACHD should be performed in a health care facility with an established ACHD program and with experience and expertise in perioperative management of patients with ACHD.

Recommendation-Specific Supportive Text

1. In a patient with ACHD, preoperative assessment starts with the establishment of baseline risk, which is further determined by the complexity and severity of the disease. Native anatomy, surgical repair, success of the repair and current physiology, as well as presence of HF, moderate to large residual shunt, PH, arrhythmia, hypoxemia, damage to other organs, and endocarditis can help define the baseline risk for these patients. The "2018 AHA/ACC Guideline for the Management of of Adults With Congenital Heart Disease"[5] describes the ACHD anatomic and physiological classification that is used to risk stratify this patient population. Modified from this risk classification scheme, Table 10 describes patients with ACHD with low-, intermediate-, and high-risk CHD lesions.[5] An analysis of multiple administrative databases showed that NCS carries a greater risk in patients with ACHD compared with patients without ACHD.[2,3,7,9,10] Table 11 describes the issues to be considered in the assessment and management of patients with ACHD undergoing NCS.

6.3.4. Left Ventricular Assist Devices

Recommendation for Left Ventricular Assist Devices		
COR	**LOE**	**Recommendation**
1	**C-EO**	1. In patients with a left ventricular assist device (LVAD), coordination with the LVAD care team on the appropriate timing and perioperative considerations of elective NCS is recommended to mitigate the risk of perioperative MACE.

Synopsis

LVADs implanted in the setting of advanced HF pose challenges for perioperative care among patients undergoing NCS. Patients with an LVAD require therapeutic anticoagulation to mitigate the risk of pump thrombosis and stroke and are at risk for bleeding and other major adverse events, such as major infection, right HF, cardiac arrhythmias, respiratory failure, renal dysfunction, and hepatic dysfunction.[1,2] Moreover, patients with an LVAD undergoing NCS are at greater risk of perioperative MACE, including inpatient mortality and several perioperative complications that include acute kidney injury, stroke, and gastrointestinal bleeding, compared with patients without an LVAD.[3–6] Despite extensive literature on known complications associated with LVAD recipients, there are limited data to define the optimal timing of elective NCS after LVAD placement. General

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recommendations on perioperative management of patients with an LVAD are addressed in mechanical circulatory support (MCS) guidelines.[7] Coordination with the LVAD care team on the appropriate timing of NCS and other perioperative considerations is recommended to help weigh the personalized benefits of NCS after LVAD placement against the risks of perioperative MACE and the risks associated with delaying elective NCS.

Recommendation-Specific Supportive Text

1. There are limited data on the timing of elective NCS among patients with an LVAD, and much of what is known about perioperative MACE is based on evidence collected before the contemporary generation of LVADs. The potential perioperative risks of MACE in patients with an LVAD undergoing NCS are numerous, potentially devastating, and challenging to predict. Therefore, personalized surgical benefits must be weighed along with the risk of MACE in the timing of elective NCS in patients with an LVAD. The odds of certain perioperative MACE have been shown to be greater in elective NCS <6 months versus ≥6 months after LVAD implantation[5]; however, these data reflect the timing of NCS before the contemporary era of LVAD management and the inclusion of the newer devices in registry data.[8] Coordination with the multidisciplinary LVAD team on the ideal timing of elective NCS and other considerations, including but not limited to the individual patient's recovery from initial LVAD implantation, implant strategy (eg, bridge to transplantation or destination therapy), and prior history of MACE, is recommended to help optimize the benefits and mitigate perioperative complications. To provide future recommendations with higher levels of evidence for the optimal timing of NCS after LVAD implantation, more contemporary data are needed.

6.3.5. Heart Transplantation Recipients

Synopsis

In 2022, 3668 adult heart transplants were performed in the United States, with an estimated 1-year survival of >90%, 3-year survival of >85%, and 5-year survival of >80%.[1] Patients with a history of heart transplantation have unique challenges that can increase the risks of perioperative complications, such as infection, wound-healing complications, and acute kidney injury. Acute rejection and immunosuppression-related complications, such as infection, steroid-induced hyperglycemia, and leukopenia, are more commonly encountered issues in the first year after heart transplantation.[2] The effects of chronic immune suppression and chronic rejection are more commonly seen after the first year, including cardiac allograft vasculopathy, malignancy, and chronic kidney disease (CKD).[3] Perioperative considerations for heart transplant recipients may include changes to the immunosuppression regimen if a prolonged period of oral fasting is anticipated, or if wound-healing complications might be minimized by modifying the regimen. Additional factors to consider when managing heart transplant patients include cardiac denervation of the transplanted heart, interactions between anesthetic medication and immunosuppressive agents, and transfusion decisions that minimize the risk of human leukocyte antigen allosensitization and cytomegalovirus infection.[3] Given the complexity of the perioperative management of patients with a history of heart transplantation, guidelines from the International Society for Heart and Lung Transplantation recommend preoperative assessment be performed in collaboration with the transplant team, especially for major procedures requiring general or regional anesthesia.[3]

6.4. Valvular Heart Disease

For the complete set of recommendations and specific definitions for disease severity, please refer to the "2020 ACC/AHA Guideline for the Management of Patients With Valvular Heart Disease."[1]

6.4.1. Aortic Stenosis

Recommendations for Aortic Stenosis		
COR	LOE	Recommendations
1	C-LD	1. Patients with severe AS should be evaluated for the need for aortic valve intervention before elective NCS to reduce perioperative risk.*[1,2]
1	C-EO	2. In patients with suspected moderate or severe AS who are undergoing elevated-risk NCS, preoperative echocardiography is recommended before elective NCS to guide perioperative management.*
2a	C-LD	3. In asymptomatic patients with moderate or severe AS and normal LV systolic function as assessed by echocardiography within the past year, it is reasonable to proceed with elective low-risk NCS.[3–5]

*Modified from the "2020 ACC/AHA Guideline for the Management of Patients With Valvular Heart Disease."[6]

Synopsis

Severe AS, as defined by current valvular heart disease (VHD) and echocardiography guidelines,[6,7] and including low-flow, low-gradient AS, is associated with increased risk for adverse cardiovascular outcomes in patients undergoing NCS.[5,8,9] When feasible, perioperative management of patients with severe AS should be conducted in collaboration with a multidisciplinary heart valve team (Figure 2). Perioperative risk is higher in symptomatic versus asymptomatic patients, in those with reduced LV systolic function, in those with more severe AS, concomitant PH, and in the setting of urgent/emergency versus elective NCS.[6,10] Echocardiography is

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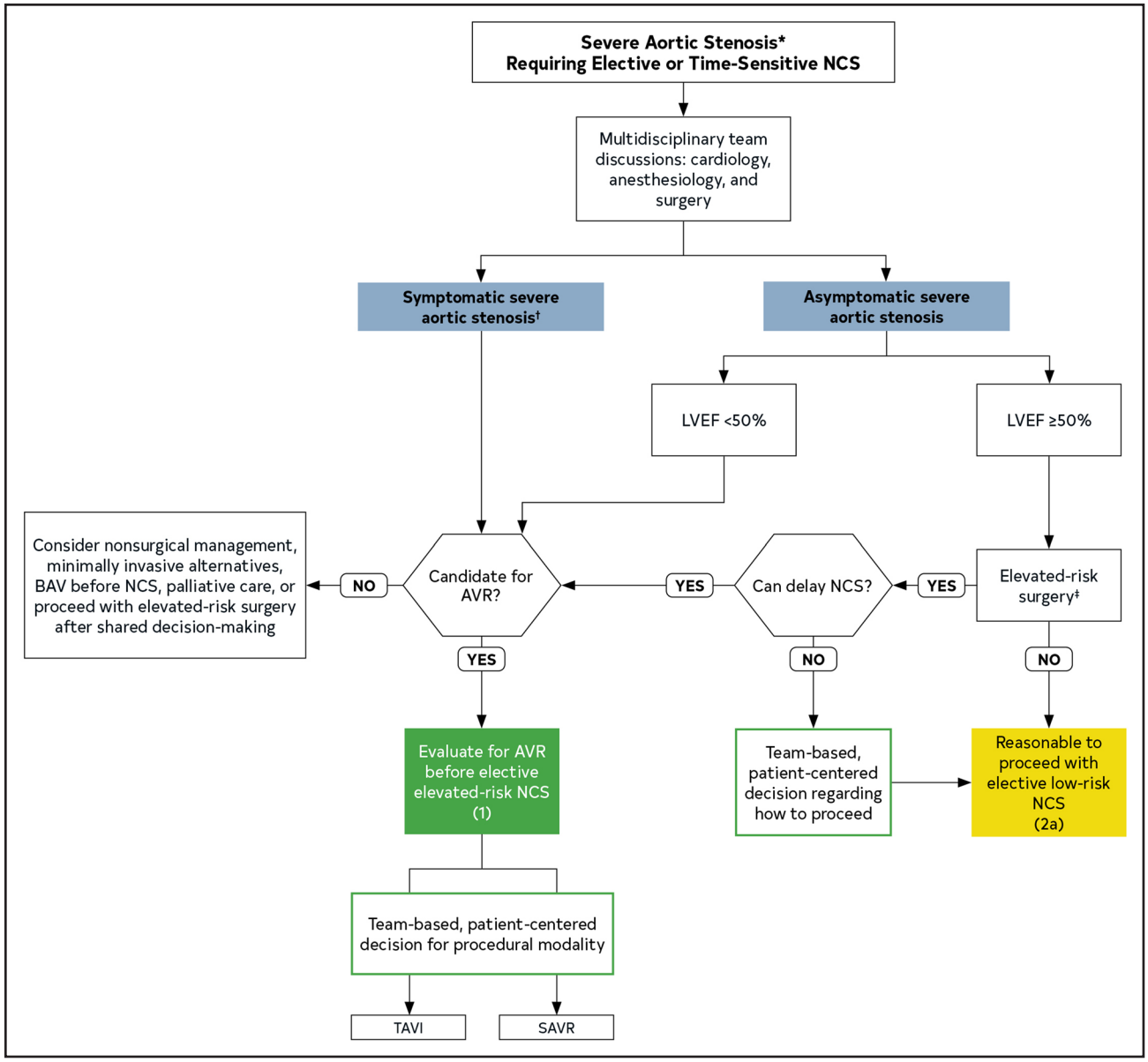


Figure 2. Management of Patients With Severe Aortic Stenosis Requiring Elective or Time-Sensitive Noncardiac Surgery.
*Severe aortic stenosis: aortic valve area <1.0 cm^2, mean aortic valve gradient ≥40 mm Hg, or peak aortic valve velocity Vmax ≥4.0 m/s. †Symptoms of exertional dyspnea, angina, heart failure, syncope, or presyncope. ‡Including elevated risk for hemodynamic instability, large volume shifts, or major bleeding. AVR indicates aortic valve replacement; BAV, balloon aortic valvuloplasty; LVEF, left ventricular ejection fraction; NCS, noncardiac surgery; SAVR, surgical aortic valve replacement; and TAVI, transcatheter aortic valve implantation. Colors correspond to Class of Recommendation in Table 3. Modified from Sorrentino et al.[15] Copyright 2022 BMJ Publishing Group. Limited by permission from BMJ Publishing Group Limited.

recommended within 1 year of elevated-risk NCS to facilitate perioperative management by defining AS severity, quantifying LV systolic and diastolic function, identifying other valvular lesions, and evaluating RV function and PA pressure.[6] In patients with severe AS who meet criteria for intervention, transcatheter or surgical aortic valve replacement (AVR) before elective NCS reduces perioperative risk.[1,2] In patients with severe AS who require urgent elevated-risk NCS, balloon aortic valvuloplasty may be considered as a bridging strategy.[3,11–13] Patients with asymptomatic severe AS and normal LV function can safely undergo elective low-risk NCS, especially in the absence of severe CAD, but patients should be monitored closely to avoid hypotension, excessive hypertension, and tachycardia.[6] Shared decision-making with the patient and family is appropriate in high-risk or otherwise challenging settings.

Recommendation-Specific Supportive Text

1. Limited data are available on the use of AVR for severe AS performed immediately before

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moderate- or high-risk NCS.[12] However, patients with severe AS who have previously undergone AVR have reduced risk for MACE after elective NCS. In 1 study, there were no perioperative deaths among 161 patients with severe AS who underwent AVR before NCS. In contrast, the 30-day mortality was 4.3% in 187 patients with untreated severe AS (P=0.008).[2] In another study of 491 patients with severe AS undergoing elective NCS, those with prior AVR (n=203) had fewer perioperative MACE compared to those with untreated AS (5.4% versus 20.5%, P<0.001).[1] In both studies, patients with symptomatic untreated AS had the worst outcomes, suggesting that AVR before elective NCS may be beneficial in these patients. Several small series have examined the utility of balloon aortic valvuloplasty before NCS.[3,6,9,11] Although the procedure can be performed safely, data are conflicting regarding the effect of balloon aortic valvuloplasty on clinical outcomes.[6,14] Due to the high risk associated with severe AS in patients undergoing elevated-risk NCS, such patients are best managed at centers capable of performing aortic valve interventions.

2. Severe AS has long been recognized as an independent risk factor for adverse cardiac events and death after NCS.[5,8,9] Although more recent studies suggest that the perioperative mortality risk associated with AS has declined, AS remains a strong predictor of nonfatal cardiac events in the perioperative period.[4] Patients with suspected moderate or severe AS who have not had an echocardiogram within 12 months before planned NCS should undergo TTE to aid in perioperative decision-making. Additional factors that should be considered in perioperative planning include the severity of AS, presence of significant CAD or other valvular pathology (especially MR), LV and RV function, PA pressure, type of surgery, and other factors associated with increased perioperative risk.[6] If the echocardiogram reveals severe AS, consultation with a heart valve team, if available, should be obtained.
3. Patients with asymptomatic severe AS undergoing NCS are at increased risk for perioperative cardiac complications, but the risk is lower than in symptomatic patients.[5,8,9] AVR before NCS could potentially reduce perioperative risk but may lead to a delay in indicated surgery (especially with surgical AVR), and it is also associated with potential complications. The available evidence, while limited, favors proceeding with low-risk NCS in patients with asymptomatic AS and preserved LVEF ≥50%, especially in the absence of severe CAD.[6] Preoperative evaluation for severe CAD may be considered in select patients.[6] Patients with asymptomatic severe AS undergoing high-risk NCS may benefit from additional preoperative evaluation (Figure 2). All patients with severe AS should be monitored closely throughout surgery and the early postoperative period to minimize the risk of hypotension, excessive hypertension, and tachycardia, as well as to avoid dehydration or volume overload.[12] Such monitoring may include invasive hemodynamic monitoring and/or intraoperative TEE. Consultation with a multidisciplinary heart team is appropriate, particularly if hemodynamic instability, large volume shifts, or high risk for bleeding is anticipated in the perioperative period.[6]

6.4.2. Mitral Stenosis

Recommendations for Mitral Stenosis
Referenced studies that support the recommendations are summarized in the Online Data Supplement.

COR	LOE	Recommendations
1	B-NR	1. Patients with severe mitral stenosis (MS) should be evaluated for the need for mitral valve (MV) intervention before elective NCS.[1–17]
2a	C-EO	2. In patients with severe MS who cannot undergo MV intervention before NCS, perioperative invasive hemodynamic monitoring is reasonable to guide management to reduce the risk of cardiovascular complications.
2b	C-LD	3. In patients with severe MS who cannot undergo MV intervention before NCS, perioperative heart-rate control (eg, beta blockers, calcium channel blockers [CCBs], ivabradine, digoxin) may be considered to prolong diastolic filling time and decrease perioperative cardiovascular complications.[18–21]

Synopsis

Patients with moderate to severe MS are at increased risk of perioperative adverse cardiovascular events. Suspected MS can be evaluated by echocardiography, and patients with severe MS may benefit from a multidisciplinary team approach at centers experienced with this higher-risk population. There is a paucity of data guiding the management of patients with MS undergoing NCS, and much has been extrapolated from pregnancy literature.[22–25] Patients with MS who meet criteria for MV intervention should receive treatment before elective NCS.[26] Criteria for MV intervention include patients with severe rheumatic MS who are symptomatic (NYHA class ≥II) or asymptomatic with elevated pulmonary pressures (PA systolic pressure >50 mm Hg). In cases where MV intervention cannot be performed before surgery (eg, emergency or urgent surgery), perioperative goals include maintaining a low-normal heart rate, a high-normal systemic vascular resistance, ensuring adequate preload, and, when applicable, a rhythm control strategy to maintain sinus rhythm.

Tachycardia decreases diastolic time and increases transvalvular MV gradients, which can lead to increased left atrial pressures, elevated pulmonary pressures, pulmonary edema, and systemic hypotension. Intensive

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monitoring could improve detection and management of tachycardia and hypotension and may reduce cardiovascular events. Recovery in the intensive care unit or longer monitoring periods in the postanesthesia care unit may be appropriate. For other recommendations regarding VHD and MS, including thresholds for intervention, please refer to Section 6 in the "2020 ACC/AHA Guideline for the Management of Patients With Valvular Heart Disease."[26]

Recommendation-Specific Supportive Text

1. In patients with symptomatic severe MS or asymptomatic severe MS with elevated pulmonary pressures or new AF, MV intervention may reduce morbidity and mortality rates.[1–17] In patients with severe MS with an indication for valve intervention in whom intervention can be successfully performed, elevated-risk elective NCS should be delayed until MS has been addressed. There may be lower-risk surgeries where clinicians may favor MV intervention before elective NCS, especially if percutaneous mitral balloon commissurotomy could be performed without delaying surgery. The decision to intervene before elective NCS should be contextualized according to the proposed MV intervention (percutaneous mitral balloon commissurotomy versus a surgical approach) and the risk of the NCS.
2. Patients with MS are at higher risk of pulmonary edema, hypotension, and arrhythmia. PH has been associated with adverse perioperative events,[27] and changes in pulmonary hemodynamics may increase cardiovascular risk in patients with MS. Perioperative conditions (eg, hypoxia, hypercapnia/hypercarbia[28]) that could worsen PH should be avoided. Longer durations of observation in the postanesthesia/recovery care unit may allow for earlier detection and intervention of complications. In settings where there may be significant intravascular fluid shifts, earlier detection and treatment of clinically significant hemodynamic changes may be possible with invasive hemodynamic monitoring, providing real-time measures to guide therapy. Invasive monitoring could include Swan-Ganz catheters, arterial lines, and TEE, but the intensity and level of monitoring should be commensurate to the risk of surgery and anesthesia technique.
3. RCTs have demonstrated that heart rate control improves patient symptoms and exercise duration.[18–21] These studies have focused on stable symptomatic outpatients with MS. There have been no RCTs examining the benefit of perioperative heart rate control in patients with MS. Heart rate control may improve symptoms in the perioperative period by increasing diastolic time and forward flow, thereby decreasing left atrial pressures and ensuring adequate cardiac output. Heart rate–controlling medications may be considered for procedures where elevated heart rates or tachycardia are anticipated.

6.4.3. Chronic Aortic and Mitral Regurgitation

Recommendations for Chronic Aortic and Mitral Regurgitation		
COR	**LOE**	**Recommendations**
1	C-EO	1. In patients with suspected moderate or severe valvular regurgitation, preoperative echocardiography is recommended before elective NCS to guide perioperative management.*
1	C-EO	2. In patients with VHD who meet indications for valvular intervention based on clinical presentation and severity of regurgitation, the need for valvular intervention should be considered before elective elevated-risk NCS to reduce perioperative risk.*[1–3]
2a	C-LD	3. In asymptomatic patients with moderate or severe MR, normal LV systolic function, and estimated PA systolic pressure <50 mm Hg, it is reasonable to perform elective NCS.*[45]
2a	C-LD	4. In asymptomatic patients with moderate or severe aortic regurgitation and normal LV systolic function (LVEF >55%), it is reasonable to perform elective NCS.*[6]

*Modified from the "2020 ACC/AHA Guideline for the Management of Patients With Valvular Heart Disease."[3]

Synopsis

Aortic and mitral valvular regurgitation are common, particularly in older adults, and may be detected during preoperative assessment for NCS.[6] Patients with valvular regurgitation can have symptoms of increasing exercise intolerance, dyspnea, paroxysmal nocturnal dyspnea, or orthopnea.[7,8] Echocardiography is the primary imaging tool to determine the presence and severity of regurgitant aortic valves and MVs.[9] In asymptomatic patients with normal LV systolic function, NCS may be safely performed in the setting of severe aortic regurgitation (AR) or MR.[2] Exercise testing can be used to confirm the lack of symptoms.[10] Valvular regurgitation is broadly classified as either primary or secondary.[11] Secondary MR results from diseases that primarily affect the LV or the left atrium, causing impaired function of the MV apparatus. It is important to understand the etiology, severity, and hemodynamic consequences of valvular regurgitation before NCS. Although there is limited evidence available, decreased LVEF and AF contribute to increased perioperative risks in patients with valvular regurgitation. Since the publication of the 2020 ACC/AHA VHD guideline,[3] no major new evidence has warranted revisions to the existing guideline recommendations.

Recommendation-Specific Supportive Text

1. Patients evaluated for NCS with known or suspected moderate or severe valvular regurgitation should undergo a comprehensive history and physical examination, 12-lead ECG, and TTE.[12] Echocardiography is important to assess the severity of valvular regurgitation, estimate right and left

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ventricular systolic and diastolic function, quantify chamber sizes, and assess PA systolic pressures.[12] An echocardiogram performed within the prior 12 months may be acceptable for preoperative evaluation if the patient's functional status and symptoms are unchanged since the previous study.[13] Preoperative recognition of the diagnosis and severity of regurgitant VHD is critical to guide perioperative management and decisions regarding the timing of surgery.

2. Although regurgitant VHD is generally better tolerated than valvular stenosis, aortic and mitral valvular regurgitation increase the cardiovascular risks during NCS.[3] Patients with MR or AR who are planned for elective elevated-risk NCS and who meet standard indications for intervention should have mitral or aortic valve surgery (repair or replacement) performed before NCS, when feasible.[3] In patients with MR with indications for repair who are not candidates for MV surgery, minimally invasive MV transcatheter edge-to-edge repair (TEER) of the MV can also be considered before NCS.[1,14]
3. Patients with moderate-severe MR undergoing NCS have increased risks of perioperative HF and MI than matched patients without MR undergoing NCS.[4] Risk factors for adverse perioperative outcomes in the setting of MR include lower EF and preexisting AF. Asymptomatic individuals with moderate or severe MR, normal LV systolic function, and a PA systolic pressure <50 mm Hg, can be considered for NCS without preoperative valve intervention.[13] In selected patients, exercise testing can be considered to confirm asymptomatic status, assessed as a normal functional capacity without dyspnea. In patients with untreated MR who undergo NCS, perioperative hemodynamic and anesthetic management strategies should include avoiding increased afterload and bradycardia. General anesthesia or, alternatively, combinations of neuraxial local anesthetics and opioids, cause vasodilation, lower systemic vascular resistance, and are generally favorable for patients with MR. Although vasodilation can be advantageous for MR, preload should be maintained.[3,15] Invasive hemodynamic and/or intraoperative TEE may permit continuous optimization of LV filling pressures in the perioperative period. Intensive monitoring should be considered for up to 24 to 72 hours after surgery.[3] In all patients with MR, careful attention to afterload and volume status is critical. In patients with asymptomatic secondary MR, perioperative considerations should also include management of the underlying heart disease.
4. Patients with severe AR undergoing NCS are at risk for hypotension, arrhythmias, HF, and death because of increased ventricular volumes and myocardial wall stress. In an analysis of patients with moderate-severe or severe AR versus those without moderate-severe or severe AR undergoing NCS, patients with AR had more perioperative hemodynamic instability, excess morbidity from pulmonary edema and prolonged endotracheal intubation, and higher in-hospital mortality than matched controls. LV systolic dysfunction, serum creatinine >2 mg/dL, and intermediate- or high-risk NCS were associated with excess risks of mortality in patients with AR.[6] Careful attention to volume status is critical in patients with AR. To minimize the adverse hemodynamic effects of AR, bradycardia should be avoided in the perioperative period to minimize diastolic filling times. Invasive systemic arterial and venous catheters and/or TEE may help guide perioperative management.[3,13] Intensive monitoring is appropriate in the immediate postoperative period.

6.4.4. Previous Transcatheter Aortic Valve Implantation or Mitral Valve Transcatheter Edge-to-Edge Repair

Recommendations for Patients With Previous Transcatheter Aortic Valve Implantation or Mitral Valve Transcatheter Edge-to-Edge Repair Referenced studies that support the recommendations are summarized in the Online Data Supplement.

COR	LOE	Recommendations
2a	B-NR	1. For patients who undergo successful transcatheter aortic valve implantation (TAVI), it is reasonable to perform NCS early* as clinically indicated.[1–3]
2a	C-EO	2. For patients who undergo MV TEER, it is reasonable to perform NCS after the successful MV intervention as clinically indicated.[4]

*Evidence supports the safety of NCS within 30 days of TAVI, if indicated.

Synopsis

With an increasing number of TAVI procedures being performed in the United States and globally, NCS in patients with previous TAVI is being encountered in clinical practice with increasing frequency. Available evidence on the safety of NCS after TAVI is limited to small case series[1,2] and 1 prospective TAVI registry of patients at the tertiary care University Hospital in Bern, Switzerland.[3] The available evidence suggests that NCS may be performed early after successful TAVI with acceptable outcomes. In general, lifelong single antiplatelet therapy is recommended after TAVI, and DAPT with aspirin and clopidogrel for up to 6 months is commonly used in patients with sinus rhythm after MV TEER; however, there are no evidence-based recommendations for antiplatelet/anticoagulant therapy after the TEER procedure.[5–8]

Recommendation-Specific Supportive Text

1. NCS may be performed safely early after successful TAVI as defined by the 2020 ACC/AHA VHD guideline.[8] In a cohort study of 300 patients undergoing NCS after TAVI, suboptimal performance,

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such as prosthesis-patient mismatch and paravalvular regurgitation, was associated with increased risk of adverse outcomes after NCS.[3] Twenty-one percent of patients underwent surgery within 30 days of TAVI, with no excess risk of adverse outcomes in this cohort compared with longer delays to surgery. Based on these data, surgery early (eg, within 30 days) after successful TAVI appears to have acceptable perioperative outcomes. Aspirin therapy should ideally be continued in the perioperative period of NCS in patients with prior TAVI to reduce thrombotic risks.[7]

2. Clinical studies have demonstrated reductions in the severity of primary MR, LV and left atrial volumes, and improved exercise capacity and QOL in patients treated with MV TEER.[4,9] Although there is a lack of data on timing and safety of NCS after MV TEER, NCS may be performed early (eg, within 30 days) after a successful valve intervention if residual MR is no longer severe. Please refer to the 2020 ACC/AHA VHD guideline for the definition of a successful MV TEER procedure.[8] The TRAMI (Transcatheter Mitral Valve Interventions) registry was the largest real-world cohort of patients treated with TEER and confirmed lasting clinical improvements and low intervention rates. The strongest predictor of long-term mortality in the TRAMI registry was a history of prior TAVI; other predictors of mortality were NYHA class IV HF, prior HF decompensation, CKD, and LVEF <30%.[4]

6.5. Atrial Fibrillation

Recommendations for Atrial Fibrillation		
COR	**LOE**	**Recommendations**
Perioperative		
2a	**C-LD**	1. In patients with rapid AF identified in the setting of NCS, it is reasonable to treat potential underlying triggers contributing to AF and rapid ventricular response (eg, sepsis, anemia, pain).*[1–5]
2a	**C-LD**	2. In patients with new-onset AF identified in the setting of NCS, initiation of postoperative anticoagulation therapy can be beneficial after considering the competing risks associated with thromboembolism and perioperative bleeding.*[4,6]
Postdischarge		
1	**C-LD**	3. In patients with new-onset AF identified in the setting of NCS, outpatient follow-up for thromboembolic risk stratification and AF surveillance are recommended given a high risk of AF recurrence.*[7–11]

*Adapted from the "2023 ACC/AHA/ACCP/HRS Guideline for the Diagnosis and Management of Atrial Fibrillation."[12]

Synopsis

AF is the most common arrhythmia, with an estimated prevalence of undiagnosed AF in 2009 of approximately 13% of the US population.[13,14] Patients with preexisting AF undergoing NCS have higher risks of all-cause mortality, HF, and ischemic stroke within 30 days of surgery than patients without preexisting AF.[15] If hemodynamically stable, patients with AF who are planned for NCS generally do not require any changes in medical management other than interruption of oral anticoagulation (OAC) (Section 7.6, "Oral Anticoagulation").[16] According to the "2023 ACC/AHA/ACCP/HRS Guideline for the Diagnosis and Management of Atrial Fibrillation," patients with preoperative AF and poor rate control should have medical management optimized before surgery.[12] New-onset perioperative/postoperative AF (POAF) in the setting of NCS is also common, with an incidence that varies widely depending on the type of surgery and patient population.[17,18] POAF can be asymptomatic or can lead to hemodynamic instability. Management of new-onset POAF requires identifying and treating known triggers (eg, pain, sepsis, anemia) and consideration of rate and/or rhythm control strategies to optimize patient hemodynamics. POAF is associated with increased risk of short- and long-term stroke and mortality, and anticoagulation should be considered to reduce thromboembolic risks.[5,18,19] Patients with paroxysmal POAF have a high risk of recurrent AF after discharge. Future studies are needed to address optimal surveillance and long-term management of POAF after NCS.[20] For additional information on AF and associated recommendations, please refer to the 2023 ACC/AHA/ACCP/HRS AF guideline.[12]

Recommendation-Specific Supportive Text

1. The postoperative development of pain, anemia, electrolyte imbalance, fluid shifts, and sepsis in NCS patients can contribute to new-onset POAF and a rapid ventricular response. Aggressive management of these underlying triggers is an essential component of POAF management. Hemodynamically stable patients with POAF may require specific therapy to achieve an optimal heart rate (<110 bpm). Medications that block atrioventricular nodal conduction, such as beta blockers or CCBs, can be used for ventricular rate control, and digoxin can be considered as an adjunct or if other agents are contraindicated.[21–24] Among patients with AF refractory to rate control with atrioventricular nodal blockers, rhythm control with synchronized electrical direct current cardioversion or pharmacological cardioversion with antiarrhythmic drugs can be considered. Exclusion of left atrial appendage thrombus before implementing rhythm control may be indicated in patients with a prolonged duration (>48 hours) of AF or in patients at high risk for thromboembolism. Synchronized direct current cardioversion is recommended for hemodynamically unstable AF with a rapid ventricular response associated with hypotension.

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2. New-onset POAF after NCS is associated with thromboembolic risks comparable to those in nonsurgical patients with AF.[6,19] In a meta-analysis of 2 458 010 patients, POAF was associated with a 62% increased risk of early stroke and a 44% increased risk of early mortality within 30 days of surgery versus patients without POAF.[6] POAF was also associated with a 37% increased risk of long-term stroke and a 37% increased risk of long-term mortality.[6] In subgroup analyses, POAF was more strongly associated with stroke in patients undergoing NCS (hazard ratio [HR], 2.00 [95% CI, 1.70-2.35]) than in patients undergoing cardiac surgery (HR, 1.20 [95% CI 1.07-1.34]).[6] It is unclear whether stroke mechanisms are the same in patients with POAF compared with those with nonsurgical AF. In patients with POAF after NCS, anticoagulation should be considered based on a patient's thromboembolic stroke risk (eg, CHA_2DS_2-VASc score) and bleeding risk. In a Danish registry analysis of patients with AF after NCS, use of OAC initiated within 30 days postdischarge was associated with a 48% reduced risk of thromboembolic events compared with no anticoagulation therapy.[4] The use of oral nonvitamin K anticoagulant or no anticoagulation in patients with new-onset AF in the postoperative period after NCS is being tested in ASPIRE-AF (Anticoagulation for Stroke Prevention in Patients with Recurrent Episodes of Perioperative AF after NCS), an ongoing RCT.[19]
3. In a longitudinal database of 10 723 patients with newly diagnosed AF (age 68±10 years, 41% women), 15% developed POAF after NCS. POAF after NCS was associated with a 39% risk of AF recurrence at 5 years, with an increased risk of HF and death.[20] Given these findings, POAF after NCS warrants timely outpatient follow-up to coordinate AF surveillance, determine the need for anticoagulation, optimize risk factors, titrate medications for rate control, and consider rhythm control. More intensive monitoring, such as with 1- to 2-week ambulatory electrocardiographic monitoring, 30-day electrocardiographic event monitoring, or implantable cardiac monitoring in selected patients, may be warranted. In cardiac surgery patients, continuous monitoring postsurgery is associated with a higher detection of AF.[7–9] This is consistent with previous studies showing higher sensitivity of AF detection with longer-term monitoring.[10,11] Although the optimal frequency, duration, and type of rhythm monitoring with postoperative AF remains unclear, outpatient follow-up within 3 to 6 months of NCS to evaluate the incidence of AF after NCS is recommended.[25]

6.6. Cardiovascular Implantable Electronic Devices

Recommendations for Preoperative Management of Patients With Cardiovascular Implantable Electronic Devices
Referenced studies that support the recommendations are summarized in the Online Data Supplement.

COR	LOE	Recommendations
1	B-NR	1. Patients with cardiovascular implantable electronic devices (CIED) having elective NCS should have a management plan developed before surgery if electromagnetic interference (EMI) is anticipated, including identification of the type of CIED (eg, pacemaker, implantable cardioverter-defibrillator [ICD], implantable monitor), manufacturer, and model.[1–6]
1	B-NR	2. Patients who are pacemaker-dependent having surgeries above the umbilicus with anticipated EMI should have the pacemaker reprogrammed or have a magnet placed on the generator to provide an asynchronous mode to avoid pacing inhibition.[1,7]
1	B-NR	3. Pacemaker-dependent patients with a transvenous ICD undergoing surgery above the umbilicus with anticipated EMI should have the device reprogrammed*; if the patient is not pacemaker-dependent, then either reprogramming or a magnet placed on the generator can be used to inhibit tachytherapies or inappropriate shocks.[8,9]
1	B-NR	4. Patients who have a pacemaker or ICD reprogrammed to asynchronous pacing or have tachytherapies programmed off before surgery should have device functioning restored in the postoperative period before hospital discharge.[10]
1	C-LD	5. Patients with leadless pacemakers who are pacemaker-dependent having surgeries with anticipated EMI above the umbilicus should have their pacemakers reprogrammed to an asynchronous mode.[11]
2a	C-LD	6. For patients with subcutaneous ICD having noncardiac or nonthoracic surgery with anticipated EMI above the groin, it is reasonable to reprogram the device or use a magnet to temporarily disable tachytherapies.[12]

*For pacemaker-dependent patients with an ICD, tachytherapies should be disabled and the device should be reprogrammed to an asynchronous mode to avoid pacing inhibition.

Synopsis

A CIED may be identified by history and physical examination, review of records, and chest radiography. The closer the electrosurgery unit (ESU) is to the pulse generator or leads of the CIED, the more likely EMI will occur.[9] The risk of EMI dissipates with distance away from the CIED.[9] An ESU below the umbilicus is unlikely to cause EMI with transvenous devices.[2,13,14] Failure to identify a CIED can lead to adverse outcomes from EMI, inhibition of pacing, inappropriate tachycardia detection, inappropriate shocks, and damage to the device.[1,2] Use of intermittent, irregular bursts of monopolar ESU at the lowest feasible energy can limit EMI. Bipolar ESU and ultrasonic scalpels are unlikely to cause EMI.[14] Even if EMI is not anticipated, there may be circumstances when patient movement from an CIED shock is undesirable, such as during intracranial, intraspinal, or intraocular surgeries. EMI may obscure pacing spikes and QRS complexes on

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the ECG. Magnets should not be relied on without preoperative confirmation of their effects on CIEDs.[1] Some devices have programmable magnet responses that have effects other than forcing asynchronous pacing. It is important to ensure the CIED is functioning properly before surgery.[15] Patients with CIED frequently have cardiac diseases that are equally important to evaluate, such as arrhythmias, structural or congenital heart disease, ischemic and nonischemic cardiomyopathies, and HF. For emergencies with anticipated EMI, a magnet should be used, and the CIED type, manufacturer, and programmed parameters should be identified as soon as possible. A magnet will not force asynchronous pacing in an ICD.

Recommendation-Specific Supportive Text

1. The type of CIED, the manufacturer, the model, primary indication for placement, pacing dependency, effects of a magnet, and proper functioning of the CIED must be determined.[1,5] Information is obtained from medical records, patient identification cards, the CIED management team, interrogation reports, or a preoperative interrogation.[3] Clinicians should confirm battery status through recommended interrogations (every 12 months for a pacemaker, every 6 months for an ICD).[1] A plan for reprogramming or use of a magnet should be developed before beginning procedures, with input from the CIED professionals, anesthesiologists, and surgeons. Institutions should have a CIED protocol in place (Figures 3 and 4).[5,16] Management plans should incorporate the procedure details, patient positioning (eg, prone), and the type of anticipated EMI. Recommendations should state specific programming changes if needed, response to a magnet, patient pacemaker dependency, battery life, and history of serious arrhythmias.[1,5] Recommendations and changes need to be included in the medical record and accessible to all perioperative clinicians.[1–5]
2. Magnet pacing rates vary by manufacturer and battery status. With ample battery supply, devices pace

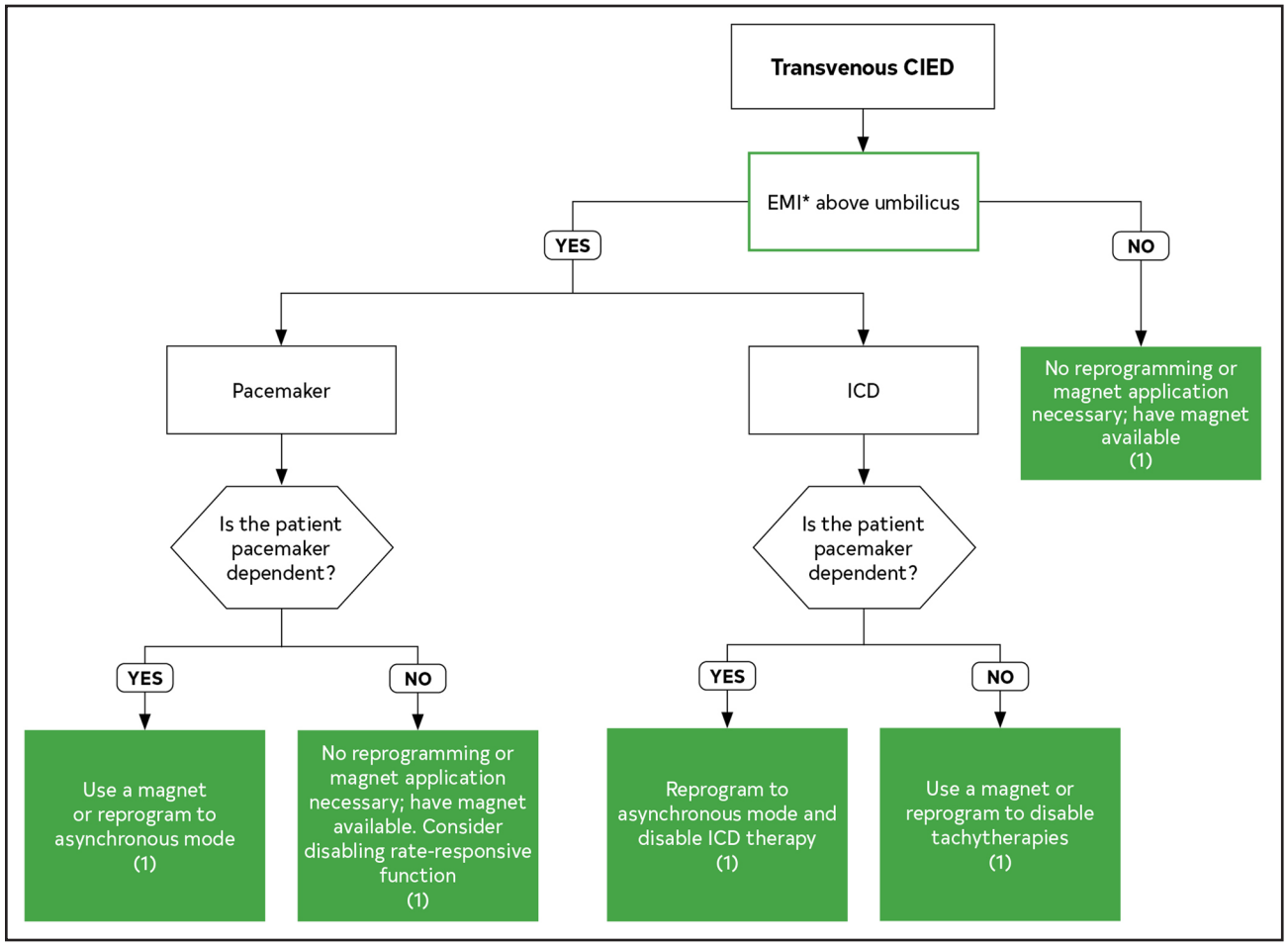


Figure 3. Patients With Transvenous CIEDs.
*EMI is considered a significant risk when the source is <15 cm from the CIED generator. External pacing and/or defibrillation must be available. Clinicians must confirm device magnet capabilities are enabled and individual magnet responses are known. Consider consulting a CIED team for cardiac resynchronization therapy devices. Colors correspond to Class of Recommendation in Table 3. CIED indicates cardiovascular implantable electronic device; EMI, electromagnetic interference; and ICD, implantable cardioverter-defibrillator.

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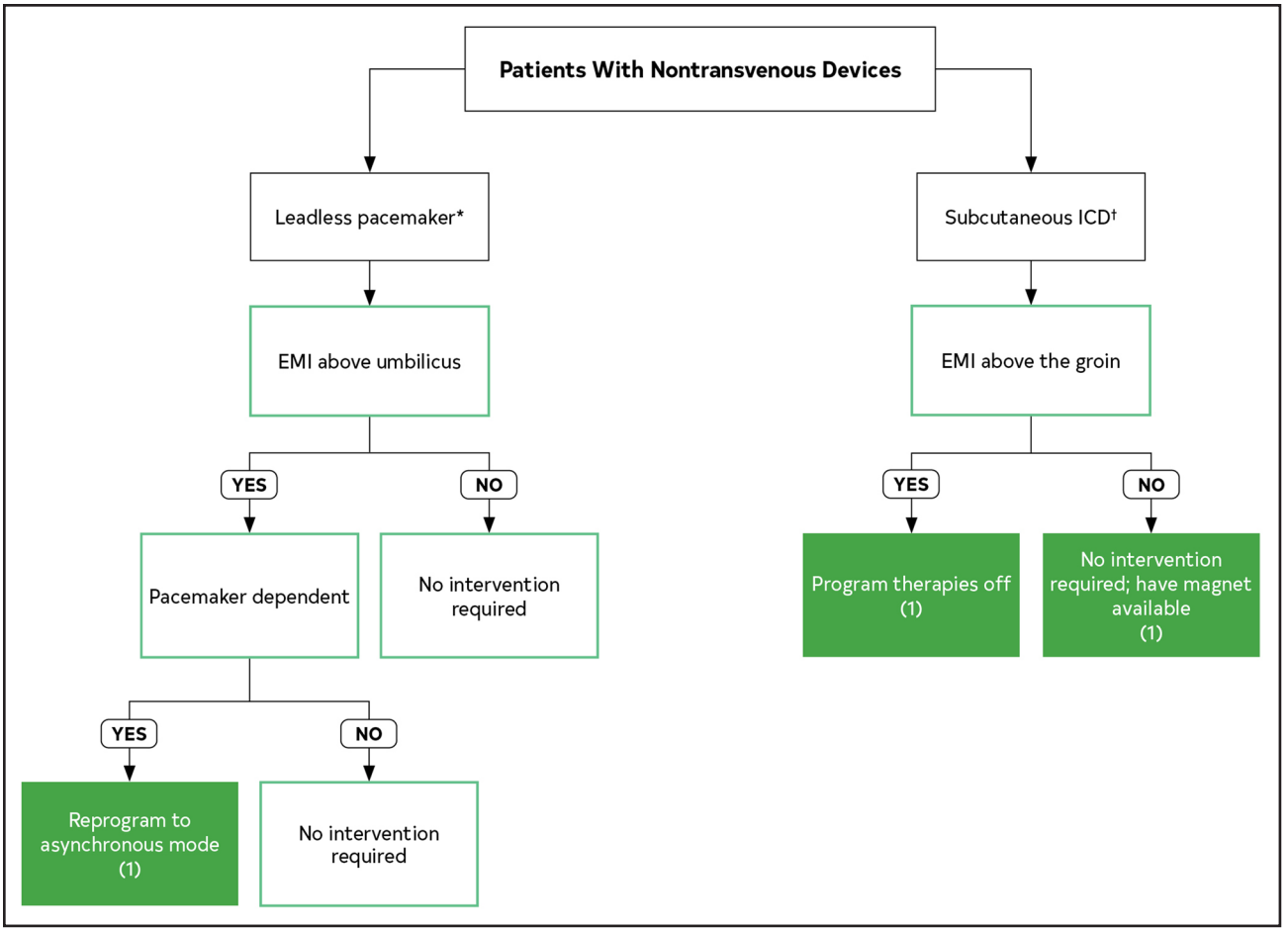


Figure 4. Patients With Nontransvenous Devices.

*For patients with a leadless pacemaker, a magnet will not force asynchronous pacing. †A subcutaneous ICD does not currently provide pacing. A magnet, if used, should be secured with adhesive tape. If the patient is in a position other than supine, or extensive EMI is anticipated when performing the surgery above the diaphragm, consider reprogramming. A magnet placed over the subcutaneous ICD will emit an R wave synchronous beep, indicating that the magnet is correctly positioned. If the tone is not audible, reprogramming is necessary. Colors correspond to Class of Recommendation in Table 3. EMI indicates electromagnetic interference; and ICD, implantable cardioverter-defibrillator.

at 85 to 100 bpm.[15] Magnet rates decrease with battery depletion. It is important to confirm asynchronous (VOO or DOO) pacing at the expected rate with magnet use. Magnet use with some pacemakers only forces asynchronous pacing for 10 beats and then reverts to programmed settings.[17] These devices must be reprogrammed to avoid EMI. Magnets may not be effective in obese or prone patients, or if continuous generator contact cannot be ensured.[1,12] EMI from ESU, monitors, bone saws, or patient movement can trigger rate-responsive functions, resulting in undesirable tachycardia that may cause unwanted hemodynamic effects or may be misinterpreted.[7] Deactivating the rate adaptive function is recommended during lithotripsy or electroconvulsive therapy. Monopolar ESU require a dispersive electrode to divert current away from the CIED to avoid damage. EMI is more common with monopolar than bipolar ESU and with coagulation versus cutting mode.[13,14] The dispersive electrode is positioned as far as possible from the generator and the heart. The current path should not cross the generator or the leads.[9] There is a risk of EMI even with ESU below the umbilicus with underbody dispersive electrodes, and practitioners need to use a magnet or reprogram the CIED.[9,18]

3. ICDs need to be programmed to asynchronous pacing in pacemaker-dependent patients. ICDs will misinterpret EMI as a tachyarrhythmia, thus triggering tachytherapies. Antitachyarrhythmia functions are disabled to avoid inappropriate therapies. Removal of a magnet rapidly restores tachytherapies if needed.[8] Some, but not all, devices emit a tone with application of a magnet. Comments regarding ESU and dispersive electrodes noted previously for pacemakers apply to ICDs.
4. If external cardioversion or defibrillation is not an option during a procedure, transcutaneous pacing or defibrillator pads should be on the patient when CIED functions are disabled. When ICDs

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have been reprogrammed, the devices need to be interrogated and reprogrammed to their original or recommended settings before the patient is discharged to an unmonitored setting or to home.[10] Patients with sudden death have been reported to registries after failure to reactivate tachytherapies.[10] Patients with CIED can play a role in safe care and appropriate CIED functionality by sending a remote transmission upon discharge.

5. Leadless pacemakers are miniaturized, fully self-contained devices that are nonsurgically implanted in the RV via a catheter.[11,19] The pacemaker may or may not be magnet responsive and is manufacturer specific. Identification of the correct placement of a magnet can be difficult given that these devices are fully intracardiac.
6. Subcutaneous ICDs are more susceptible to ESU above the groin, likely due to their large surface area and location along the left chest wall.[12]

6.7. Previous Stroke or Transient Ischemic Attack

Recommendation for Previous Stroke or Transient Ischemic Attack Referenced studies that support the recommendation are summarized in the Online Data Supplement.		
COR	**LOE**	**Recommendation**
2a	**B-NR**	1. In patients with a history of stroke or transient ischemic attack, it is reasonable to delay elective NCS for ≥3 months after the most recent cerebrovascular event to reduce the incidence of recurrent stroke, MACE, or both.[1,2]

Synopsis

Patients with prior stroke or transient ischemic attack are at higher perioperative risk of a recurrent stroke or worsening of neurological deficits.[3] This increased risk appears to diminish over time, with reduction of inflammation, decreased hemorrhage risk, and reestablishment of cerebral autoregulation.[4] However, there is limited observational evidence that determines the optimal time interval to delay elective NCS after a stroke. Prior studies compared elective noncardiac surgical patients with and without prior stroke, rather than prior stroke with and without NCS; patients with prior stroke have a baseline 5-year risk of recurrence of 12%.[5] For management of stroke risk, please refer to the 2021 AHA/ASA stroke prevention guideline.[5]

Recommendation-Specific Supportive Text

1. When compared with patients without prior stroke, an analysis from a large Danish registry found an increased risk of recurrent stroke, MI, and cardiovascular death in patients with recent stroke, particularly <3 months after the event (OR, 14.23), compared with 3 to 6 months (OR, 4.85), 6 to 11 months (OR, 3.04), or ≥12 months of the index event (OR, 2.47).[2] The odds of a postoperative ischemic stroke within the first 3 months of a prior stroke were high. However, over the ensuing months, this marked elevated risk waned and plateaued at 9 months but did not approach baseline risk, even at 12 months postinfarction (OR, 8.2). A more recent analysis of a Medicare database of ~6 million patients undergoing elective noncardiac and non-neurological surgery found a far lower overall rate of secondary strokes compared with those with no prior stroke for operations performed <30 days or performed between 61 and 90 days after prior stroke (OR, 8.0 [95% CI, 6.37-10.10] and OR, 5.0 [95% CI, 4.0-6.29], respectively).[1] Importantly, there was only a very small decrement in risk between 61 and 90 days and 6 and 12 months (OR, 4.76 [95% CI, 4.26-5.26]). Based on this new evidence, delaying NCS for ≥6 months does not appear to provide additional protection against the occurrence of recurrent stroke.

6.8. Obstructive Sleep Apnea

Recommendation for Obstructive Sleep Apnea Referenced studies that support the recommendation are summarized in the Online Data Supplement.		
COR	**LOE**	**Recommendation**
2a	**B-NR**	1. In patients scheduled for NCS, obstructive sleep apnea (OSA) screening using validated questionnaires is reasonable to assess the risk of perioperative complications.[1–3]

Synopsis

The pathophysiology of OSA is complex, multifactorial, and associated with several cardiovascular complications, including hypertension, AF, HF, CAD, stroke, PH, metabolic syndrome, diabetes, and cardiovascular mortality.[4,5] Approximately 34% of men and 17% of women between the ages of 40 and 60 years meet the diagnostic criteria for OSA.[4] In a recent meta-analysis of 22 studies evaluating outcomes of NCS in patients with (n=184 968) and without OSA (n=2 848 846),[6] a preoperative diagnosis of OSA was associated with an increased incidence of a composite of postoperative cardiac and cerebrovascular complications. In comparison to patients without OSA, patients with OSA had a 2.5-fold greater risk of developing postoperative pulmonary complications. A diagnosis of OSA was also associated with an increased incidence of perioperative MI and AF but not HF. In a separate meta-analysis of 46 studies, OSA was associated with risks of postoperative pulmonary complications and cardiac complications that increased with greater OSA severity. Specifically, OSA was associated with an increased incidence of MI, AF, and HF but not an increased incidence of stroke.[7] Among patients

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with a diagnosis of OSA who require the use of noninvasive positive airway pressure ventilation before surgery, positive airway pressure should be restarted postoperatively as early as possible.[8–10] In patients with OSA undergoing NCS, regional anesthesia is reasonable to reduce the use of systemic opioids, sedatives, and the risk of pulmonary complications.[2,10]

Recommendation-Specific Supportive Text

1. A prospective multicenter study analyzed the preoperative sleep study results of 1218 patients without a prior diagnosis of OSA who were scheduled for major NCS.[3] Among these patients, 67.6% were assigned a new diagnosis of previously recognized OSA, 30.5% had at least moderate OSA, and 11.2% had severe OSA. For those patients with severe OSA, there was an increased risk of the composite outcome of myocardial injury, cardiac death, HF, thromboembolism, AF, and stroke within 30 days of surgery.[3] In a prospective study of 2877 adults who completed OSA risk screening questionnaires during preoperative assessment before NCS,[11] 23.7% were identified as high risk for OSA. Few patients identified as high risk had a prior OSA diagnosis, and among 207 who elected to undergo a home sleep study, 170 (82.1%) were found to have OSA (mild, n=97; moderate, n=40; severe, n=33).[11] Another prospective study enrolled 245 adults with ≥2 risk factors for OSA scheduled for NCS. All patients were screened with the STOP-Bang questionnaire, and among them 182 patients underwent a preoperative level III polysomnogram.[1,12] Seventy patients (38%) were diagnosed with OSA, including 11 patients (6%) with moderate to severe OSA. Although prospective evidence to support routine OSA screening before surgery is lacking, the increased prevalence of OSA in surgical patients with CVD and potential for benefit with OSA treatment provide a reasonable rationale for OSA screening before NCS.

7. PERIOPERATIVE MEDICAL THERAPY

7.1. Statins

Recommendations for Statins
Referenced studies that support the recommendations are summarized in the Online Data Supplement.

COR	LOE	Recommendations
1	B-NR	1. In patients currently on statins and scheduled for NCS, continuation of statin therapy is recommended to reduce the risk of MACE.[1–3]
1	B-R	2. In statin-naïve adult patients who meet criteria for statin use based on ASCVD history or 10-year risk assessment and are scheduled for NCS, perioperative initiation of statin is recommended with intention of long-term use.[4,5]

Synopsis

The use of long-term lipid-lowering therapies for primary and secondary prevention of atherosclerotic cardiovascular events is well established. Hydroxymethyl glutaryl coenzyme A reductase inhibitors (statins) reduce atherogenic low-density lipoprotein-cholesterol, confer pleiotropic anti-inflammatory effects, and may confer benefits to patients in the perioperative period and beyond. Multiple small RCTs, observational cohorts, and meta-analyses demonstrate that perioperative statin use is safe and may reduce cardiovascular outcomes, particularly in patients undergoing major vascular surgery. However, the benefit of routine preoperative administration of statins remains uncertain in patients undergoing nonvascular surgery, as compelling observational data and meta-analyses are counterbalanced by a small but more scientifically rigorous RCT in which statin use did not confer benefit.[2,3,6–10] The LOAD (Lowering the Risk of Operative Complications using Atorvastatin Loading Dose) trial, the largest RCT to date, randomly assigned 648 statin-naïve patients to atorvastatin 80 mg loading (within 18 hours preoperatively) followed by 40 mg daily for 7 days versus placebo and evaluated the composite of all-cause mortality, nonfatal MI, and stroke at 30 days.[10] There was no difference in short-term perioperative MACE; long-term benefits of therapy were not evaluated in this study. Future large RCTs are needed to elucidate the role of perioperative statin initiation on outcomes in lower-risk patients or procedures, as well as the ideal timing and dosing regimens (eg, reloading), before routine statin initiation can be recommended. Of note, the measurement of low-density lipoprotein-cholesterol concentrations to guide initiation of statin therapy in patients with appropriate indications, should not delay surgery; however, the NCS setting is an excellent opportunity to initiate therapies with the objective to improve long-term outcomes.

Recommendation-Specific Supportive Text

1. Among patients receiving statin therapy who are planned for NCS, large cohorts report safety and possible reductions in cardiovascular complications associated with continued use of lipid lowering throughout the perioperative period.[1] In a large US cohort (n=780 591), 9.9% of patients receiving perioperative lipid-lowering therapy had lower surgical mortality overall and after propensity matching than those who did not receive lipid-lowering therapy.[1] Although these data favor continuation of home-dose statins, the benefits of statin reloading or intensification before surgery are uncertain. One study randomly assigned 500 consecutive patients who were receiving statins and were admitted for urgent or emergent NCS to either reloading of atorvastatin or continuation

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of home statin.[11] In this study, statin reloading was associated with a 5.6% absolute risk reduction in perioperative MACE at 30 days, as well as reductions in AF and length of stay. Additional RCTs are needed to determine the benefits of statin intensification, reloading, or both in the perioperative period of NCS.

2. In a single-center RCT, 100 patients planned to undergo vascular surgery were randomly assigned to atorvastatin 20 mg daily for 45 days or placebo. Vascular surgery was performed an average of 30 days after statin initiation, and statins were continued long term in patients in whom low-density lipoprotein-cholesterol was ≥100 mg/dL. The primary endpoint, the composite of death from cardiac causes, nonfatal MI, stroke, and unstable angina at 6 months, occurred in 4 patients (8.0%) assigned to atorvastatin and 13 patients (26%) assigned to placebo (P=0.031).[4] Furthermore, in a 2018 systematic review and meta-analysis, statin therapy appeared to reduce perioperative MACE and improve survival after vascular surgery.[5] Long-term use of statin therapy is important to reduce primary and secondary atherosclerotic events in at-risk patients.[12] Evaluation practices outlined in the AHA/ACC guidelines may help to identify patients whose long-term cardiac outcomes would be improved by adherence to GDMT. However, given the lack of benefit in the LOAD trial, short-term use to lower perioperative risk requires further evaluation. As such, NCS should not be delayed if low-density lipoprotein-cholesterol is not already available.[10]

7.2. Renin-Angiotensin-Aldosterone System Inhibitors

Recommendations for Perioperative Renin-Angiotensin-Aldosterone System Inhibitors
Referenced studies that support the recommendations are summarized in the Online Data Supplement.

COR	LOE	Recommendations
2b	B-R	1. In select* patients on chronic renin-angiotensin-aldosterone system inhibitors (RAASi) for hypertension undergoing elevated-risk NCS, omission 24 hours before surgery may be beneficial to limit intraoperative hypotension.[1–6]
2a	C-EO	2. In patients on chronic RAASi for HFrEF, perioperative continuation is reasonable.†[1,2]

*Patients with controlled BP and undergoing elevated-risk surgical procedures.
†Modified from the "2022 AHA/ACC/HFSA Guideline for the Management of Heart Failure."[7]

Synopsis

ACEi and ARBs are widely used for their antihypertensive and cardiac benefits; therefore, the safety and efficacy of the perioperative use of RAASi is of importance. RCTs comparing omission to continuation of RAASi have enrolled a variety of low- to intermediate-risk patients undergoing major NCS. In these studies, intraoperative hypotension (MAP <60 mm Hg) occurred more commonly when these agents were continued; however, continuation compared with omission did not result in worse clinical outcomes (eg, myocardial injury after NCS [MINS]). Of note, patients with high (SBP >160 mm Hg) or low (SBP <105 mm Hg) BP are often excluded from RCTs, and there has been limited enrollment of high-risk patients including those with HFrEF. No data currently exist regarding the perioperative role (harm or benefit) of the angiotensin receptor/neprilysin inhibitor, sacubitril/valsartan. Given the important role of RAASi in preventing MI, stroke, HF, and decline in kidney function, larger RCTs are still needed before recommending routine interruption of RAASi in all patients before planned surgery; thus, an individualized approach to perioperative management of ACEi or ARBs is warranted.

Recommendation-Specific Supportive Text

1. Intraoperative hypotension, particularly prolonged episodes, may increase postoperative myocardial injury and mortality.[8] However, while omitting RAASi before surgery has been shown to reduce intraoperative hypotension, RCTs have failed to prove this strategy improves clinical outcomes.[1,2,9] The PREOP-ACEI (Prospective Randomized Evaluation of Perioperative Angiotensin-Converting Enzyme Inhibition) study for patients stable on ACEi for at least 6 weeks before planned major noncardiac nonvascular surgery observed that fewer episodes of intraoperative hypotension (SBP <80 mm Hg) occurred in patients randomized to omit the final preoperative ACEi dose compared with patients continuing use. Major adverse cardiovascular endpoints were not different, nor was postanesthesia unit recovery time or length of stay.[1] These findings are corroborated by the meta-analysis of earlier studies that included data from 6022 patients in whom ACEi or ARB was omitted or continued before planned NCS.[2] Although intraoperative hypotension was more common in patients who continued ACEi/ARB, there was no difference in MACE. Ongoing studies, including STOPorNOT (Impact of RAASi Continuation on Outcome after Major Surgery), will seek to answer questions about the clinical impact of continuation or omission of RAASi before planned surgery.[10,11] Recently published results from POISE-3 demonstrated no difference in major vascular events (MINS, vascular death, stroke, or cardiac arrest at 30 days) in nearly 7500 patients with vascular disease or risk factors randomized to hypotension-avoidance or

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hypertension-avoidance perioperative BP strategies.[12] In this study, antihypertensive agents were either withheld or continued based on the BP management strategy. Notably, 72% of patients in both groups were taking an ACEi/ARB at the time of randomization, with no excess adverse events in the group randomly assigned to continue their home BP regimen on the morning of surgery.[12]

2. The role of RAASi in HFrEF, HF with mildly reduced ejection fraction, and HF with preserved ejection fraction is supported by clinical guidelines.[7] RAASi confer a significant reduction in mortality and even dose-dependent reduction in outcomes such as hospitalizations for HF, particularly in patients with LVEF <40%.[7] The complexity of HF medication regimens and goals of care warrant careful consideration and ideally, minimal interruption. In our review of existing data, RCTs of perioperative omission of RAASi have largely excluded patients with moderate to severe HF or had limited inclusion.[1] Further, a meta-analysis in 2018 found only 1 study reporting the influence of RAASi interruption on HF outcomes.[2]

7.3. Calcium Channel Blockers

Synopsis

CCBs comprise a heterogenous class of medications that can be subdivided into nondihydropyridine (verapamil, diltiazem) and dihydropyridine agents (eg, amlodipine, felodipine, nifedipine extended release). Dihydropyridines are largely used to manage hypertension, while nondihydropyridines are important for management of cardiac dysrhythmias, and both play a role in symptom relief in patients with chronic stable angina. Perioperative CCB administration has been explored in small RCTs. In 2003, a meta-analysis of 11 RCTs encompassing 1007 patients evaluated the benefit of perioperative CCBs versus placebo on perioperative MACE.[1] Most trials tested perioperative intravenous diltiazem or intravenous verapamil. Initiation of CCBs failed to reduce perioperative mortality or perioperative MI, although they were associated with reductions in the composite of MI and death, as well as postoperative supraventricular tachycardia. Significant hypotension and bradycardia were observed in individual studies but not in the overall pooled analysis, possibly owing to the varying medication and dosage regimens chosen. A more recent meta-analysis evaluated CCBs (largely dihydropyridines), compared with other antihypertensive agents, to treat postoperative hypertension.[2] Of the 14 studies included, no significant differences in postoperative hemodynamics were noted.[2] Although these data do not support the benefit of perioperative CCB initiation, continuation may be reasonable with recognition of the potential for intraoperative hypotension (for dihydropyridines) and/or bradycardia (for nondihydropyridines).[3]

7.4. Alpha-2 Receptor Agonists

Recommendation for Perioperative Alpha-2 Receptor Agonists Management Referenced studies that support the recommendation are summarized in the Online Data Supplement.		
COR	**LOE**	**Recommendation**
3: No benefit	**B-R**	1. In patients undergoing NCS, initiation of low-dose clonidine perioperatively is not recommended to reduce cardiovascular risk.[1]

Synopsis

A single large, well-designed RCT showed no benefit of initiation of clonidine to prevent perioperative MACE. This same trial raised concerns regarding the safety of this approach. New administration is thus not recommended; however, perioperative continuation of chronic therapy has not been addressed in RCTs. Chronic use of clonidine, and other alpha-2 receptor agonists, is reserved for patients with severe resistant hypertension or special populations (eg, CKD, impulse control disorders). Abrupt discontinuation can lead to norepinephrine surge and resultant rebound hypertension.[2] Short-term interruption for surgery has not been studied.

Recommendation-Specific Supportive Text

1. The POISE-2 trial was a blinded RCT of 10010 patients undergoing major NCS, randomized to low-dose clonidine or placebo 2 to 4 hours before surgery, to evaluate the impact on 30-day risk of death or nonfatal MI and included patients were ≥45 years old and at high risk of cardiovascular complications (history of ASCVD event or ≥3 traditional risk factors).[1] If baseline SBP was ≥105 mm Hg and heart rate was ≥55 bpm, patients received 0.2 mg of clonidine orally and application of a transdermal 0.2 mg per day clonidine patch or placebo for 72 hours. At 30 days, no difference was seen in the primary outcome, composite of death or nonfatal MI, or key secondary endpoints. Patients treated with clonidine were significantly more likely to experience nonfatal cardiac arrest and clinically significant bradycardia or hypotension. Results of POISE-2, as well as 23 additional RCTs in NCS, were included in a 2018 meta-analysis that reported nonsignificant differences in all-cause mortality, cardiac mortality, and MI.[3] There was, however, moderate-to-high quality evidence to demonstrate significant increased risk of hypotension and bradycardia. Importantly, in addition to clonidine, these studies included dexmedetomidine and mivaserol, which were never approved in the United States.[3]

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7.5. Antiplatelet Therapy and Timing of Noncardiac Surgery in Patients With Coronary Artery Disease

Recommendations for Antiplatelet Therapy and Timing of Noncardiac Surgery in Patients With Coronary Artery Disease Referenced studies that support the recommendations are summarized in the Online Data Supplement.		
COR	**LOE**	**Recommendations**
1	B-NR	1. For patients with CAD undergoing elective NCS, management of perioperative antiplatelet therapy and timing of surgery should be determined by a multidisciplinary team with shared decision-making to weigh the risks of bleeding, thrombosis, and consequences of delayed surgery.[1–7]
Timing of NCS After PCI		
1	C-LD	2. In patients with recent coronary artery balloon angioplasty without stent placement, elective NCS should be delayed for a minimum of 14 days to minimize perioperative MACE.[8,9]
1	B-NR	3. In patients with DES-PCI placed for ACS who require elective NCS with interruption of ≥1 antiplatelet agents, surgery should ideally be delayed ≥12 months to minimize perioperative MACE.[5,10–15]
2a	B-NR	4. In patients with DES-PCI placed for CCD who require elective NCS with interruption of ≥1 antiplatelet agents, it is reasonable to delay surgery for ≥6 months after PCI to minimize perioperative MACE.[16–24]
2b	B-NR	5. In patients with DES-PCI who require time-sensitive NCS with interruption of ≥1 antiplatelet agents, NCS may be considered ≥3 months after PCI if the risk of delaying surgery outweighs the risk of MACE.[5,23,24]
3: Harm	B-NR	6. In patients with a recent (≤30 days) bare-metal stent (BMS) or DES-PCI, elective NCS requiring interruption of ≥1 antiplatelet agents is potentially harmful due to a high risk of stent thrombosis and ischemic complications.[6,9,22,25,26]
Perioperative Antiplatelet Management Post PCI		
1	B-R	7. In patients with prior PCI undergoing NCS, it is recommended to continue aspirin* (75-100 mg), if possible, to reduce the risk of cardiac events.[27–30]
1	B-NR	8. In patients with CAD who require time-sensitive NCS within 30 days of PCI with BMS or <3 months of PCI with DES, DAPT should be continued unless the risk of bleeding outweighs the benefit of the prevention of stent thrombosis.[23,31]
1	B-NR	9. In patients with prior PCI in whom OAC monotherapy must be discontinued before NCS, aspirin should be substituted when feasible in the perioperative period until OAC can be safely reinitiated.[27–29]
2b	B-NR	10. In select patients after PCI who have a high thrombotic risk, perioperative bridging with intravenous antiplatelet therapy may be considered <6 months after DES or <30 days after BMS if NCS cannot be deferred.[32,33]
Perioperative Antiplatelet Management in Patients Without Prior PCI		
2b	B-R	11. In patients with CCD without prior PCI undergoing elective NCS, it may be reasonable to continue aspirin in selected patients when the risk of cardiac events outweighs the risk of bleeding.[27,34,35]
3: No benefit	B-R	12. In patients with CAD but without prior PCI who are undergoing elective noncarotid NCS, routine initiation of aspirin is not beneficial.[27,36]

*Platelet adenosine diphosphate receptor (P2Y12) monotherapy may be considered if surgical bleeding risks are acceptable or if aspirin is not tolerated.

Synopsis

Management of antiplatelet therapy in the perioperative period of NCS is complex, particularly for patients with CAD and prior PCI, as the timing of antiplatelet interruption must be balanced against competing risks of thrombotic complications (Table 12 and Figure 5). The risk of perioperative stent thrombosis is greatest in the first 4 to 6 weeks post-PCI, with excess risks that decline over time but persist to 6 months. For most patients with CCD, DAPT is recommended for 6 months, followed by single antiplatelet therapy (either with aspirin or P2Y12 inhibitor).[37–39] Selected patients may be eligible for shorter durations of DAPT (28-31 days or 90 days) post-PCI based on recent data,[40–42] but the safety of this approach in patients planned for NCS requires further study. Patients with PCI performed for MI have nearly 3-fold higher risks of postoperative MACE versus those with CCD as the indication for PCI.[16,17] Ideally, NCS should be postponed ≥1 year after PCI for ACS, although NCS can be considered ≥6 months after DES placement for CCD[12,15] and after 3 months for time-sensitive NCS if the benefits of surgery outweigh the risk of MACE. If a patient requires urgent NCS requiring interruption of DAPT, balloon angioplasty without stents may be considered, with NCS delayed for a minimum of 14 days due to higher perioperative MACE risk very early after PCI.[15,43]

Table 12. Duration of Antiplatelet Therapy Effect

Antiplatelet Agent	Minimum Time From Drug Interruption to Restoration of Platelet Function
Aspirin	4 d
Clopidogrel	5-7 d
Prasugrel	7-10 d
Ticagrelor	3-5 d

Minimum times from drug interruption to noncardiac surgery should be guided by pharmacokinetic data, restoration of platelet function after drug withdrawal, and drug-specific FDA-prescribing information.[67–71]

Recommendation-Specific Supportive Text

1. The decision to perform NCS in a patient with CAD should involve the patient, the surgeon, the anesthesiologist, and the cardiologist managing the

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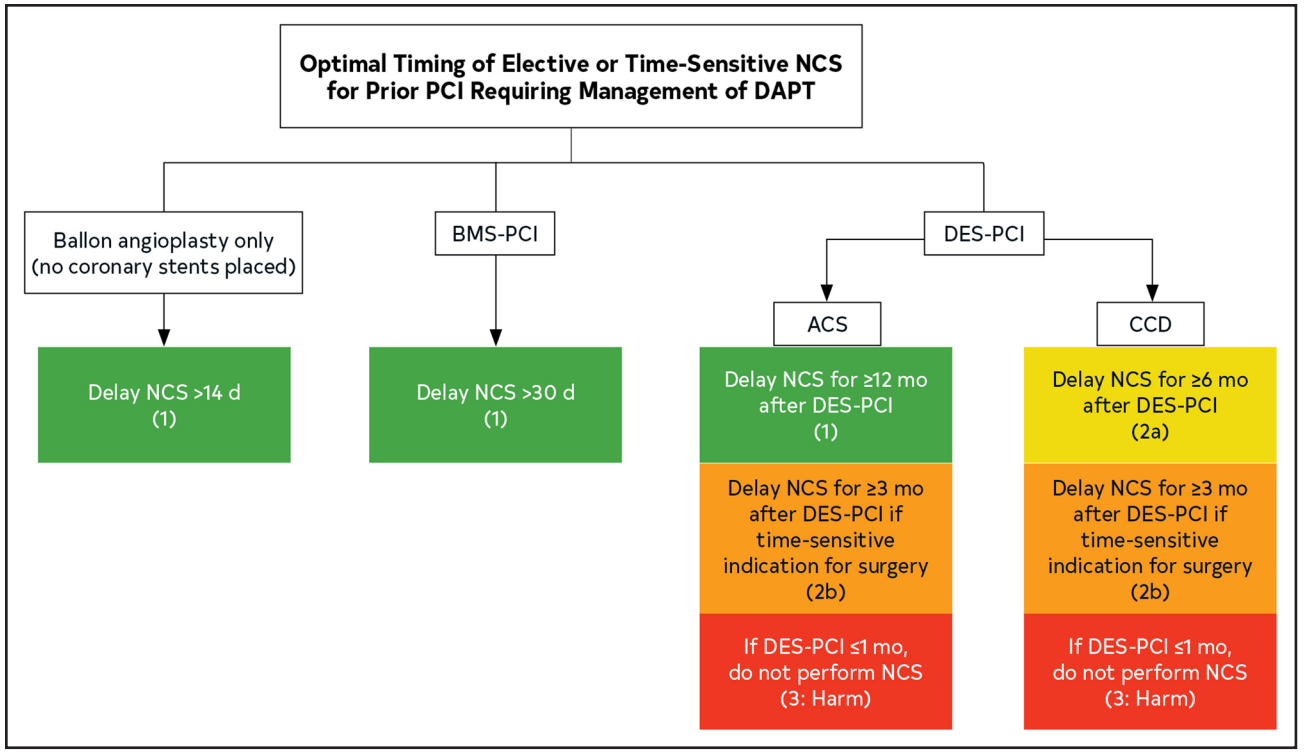


Figure 5. Optimal Timing of Elective or Time-Sensitive NCS for Prior PCI Requiring Management of DAPT.
Colors correspond to Class of Recommendation in Table 3. ACS indicates acute coronary syndrome; BMS, bare-metal stent; CCD, chronic coronary disease; DAPT, dual antiplatelet therapy; DES, drug-eluting stent; NCS, noncardiac surgery; and PCI, percutaneous coronary intervention.

patient's antiplatelet therapy and ischemic risk.[5–7,44] Antiplatelet therapy is frequently indicated for the prevention of ischemic cardiac events in patients with CAD. Temporary discontinuation of antiplatelet therapy can be safe depending on the timing of NCS relative to any prior PCI and time-independent indications for the procedure. The risk of antiplatelet therapy interruption should be individualized to balance MACE risks with optimal surgical timing.[7] Decisions for continuation or cessation of aspirin, P2Y12 inhibitor, or both in the perioperative period of NCS should be undertaken by multidisciplinary team members and should involve the patient and their family.[44] The use of aspirin for primary prevention has decreased based on evidence that it does not reduce cardiovascular risks, and multidisciplinary team consensus may not be required for perioperative interruption of aspirin when it is prescribed for primary cardiovascular prevention.[45] Multidisciplinary input may be considered in those receiving aspirin or other antiplatelet therapy for secondary prevention or noncardiovascular indications.

2. Elective NCS after balloon angioplasty alone without placement of a stent can proceed after ≥14 days of uninterrupted DAPT; however, high-quality data to inform management of these patients are limited.[8,9]
3. In patients with prior DES-PCI, the optimal timing of elective NCS requiring interruption of antiplatelet therapy requires careful consideration. Multiple studies have identified a continuum of declining perioperative MACE risk after PCI.[12] However, a large retrospective analysis of >20 000 patients corroborated smaller studies identifying that prior PCI remains a risk factor for perioperative MACE and bleeding to 1 year.[14,15] A small retrospective cohort identified that perioperative cardiac events still occur 6 months after DES-PCI.[13] Perioperative risks of NCS are particularly high within the first year after PCI when coronary stent placement occurs for the treatment of acute MI.[11,16,17] In patients with DES-PCI performed for ACS, elective NCS should be delayed ≥12 months after PCI. A 12-month delay between PCI and NCS may also be appropriate for patients undergoing complex DES-PCI (eg, bifurcation stents, long stent lengths, multivessel PCI) or when details regarding prior DES-PCI are unavailable.[17]
4. In a matched cohort study from US Department of Veterans Affairs hospitals, perioperative MACE events were highest during the first 6 months after PCI and stabilized thereafter at 1%.[16] A retrospective analysis of 221 379 hospital admissions for NCS found high rates of perioperative MI (4.7%), bleeding (32%), and mortality (4.4%)

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within 6 months of PCI.[5] Stent type (BMS versus DES) was not associated with perioperative MACE at 6 months in a large cohort study.[12] Similarly, another registry showed no significant differences in perioperative MACE between those patients with BMS or DES, only identifying PCI for ACS as an independent MACE risk factor.[11] However, a multicenter prospective registry (approximately 40 000 patients) identified stent type as a risk factor for MACE events, with older-generation DES associated with higher risk of events at any time point compared with BMS.[21] In a Canadian study (approximately 8000 patients), the incidence of MACE associated with major elective NCS performed >6 months after DES-PCI was 1.2%, with risk approaching that of intermediate-risk surgical patients without prior PCI.[6] The variation seen in these analyses emphasizes that stent type, time from PCI, and indication for PCI represent important factors in shared decision-making regarding consideration of surgery at 6 months post-PCI.

5. In patients with prior PCI and a time-sensitive indication for NCS (eg, resection of malignancy), a risk assessment balancing the potential delay of surgery against perioperative MACE should be performed. Risks of perioperative MACE after NCS appear highest when surgery is performed within the first 3 months after PCI.[17] A previous study found lower incidence of MACE when NCS was performed >3 months (2.8%) compared with <30 days (10.5%) after BMS-PCI.[8] The incidence of perioperative MACE after NCS was also lowest if surgery was performed >3 months after DES-PCI.[46] In a prospective study evaluating perioperative MACE and bleeding, event rates were high in the first 30 days after PCI, with time from stent implantation to surgery <3 month as an independent risk factor for bleeding.[24] Finally, in a large pooled analysis of nonsurgical patients post-PCI, DAPT discontinuation at >3 months was not associated with excess stent thrombosis.[47] Taken together, these data suggest that, in selected patients, it may be reasonable to undergo NCS ≥3 months post-PCI if the benefit of surgery outweighs the risk of MACE.
6. Elective NCS should not be performed <30 days of PCI. Early case series reported a high incidence of bleeding and MACE after NCS scheduled within 30 days of PCI.[48] Larger studies subsequently confirmed excess risk of perioperative MACE within this timeframe post-PCI.[5,8,9,23,49] Catastrophic outcomes of NCS within 30 days of PCI have been reported, with risks of MI, stent thrombosis, bleeding, and mortality.[8,48,49] Surgical trauma leads to catecholamine surges, inflammatory cytokines, activation of the clotting cascade, enhanced platelet activation, and decreased fibrinolysis, all of which contribute to the thrombotic milieu, and consequently surgery should be delayed after PCI.[22] A prospective study of patients post-PCI found that those undergoing NCS at <35 days from PCI had a 2-fold higher risk of complications compared with those undergoing surgery >90 days after PCI.[26] Another study found that NCS <1 month post-PCI had a higher incidence of MI (7.2% versus 0.5%), cardiac death (5% versus 0.4%), and all-cause mortality (9% versus 2.1%) than those undergoing surgery within the first 12 months after PCI.[23] Elective NCS after PCI with BMS can proceed after ≥30 days of uninterrupted DAPT, although BMS are rarely placed in the contemporary era.[8,9]
7. In patients with prior PCI with coronary stent placement undergoing NCS, aspirin use was associated with lower rates of death and nonfatal MI (absolute risk reduction, 5.5%), with comparable major and life-threatening bleeding.[29] Although the risks of bleeding with DAPT are higher than those with aspirin alone,[25,48,50–53] in a meta-analysis of 46 studies including >30 000 patients undergoing NCS, both single and double antiplatelet therapy were associated with a modest increased risk of bleeding without additional thrombotic risk compared with placebo or interruption of antiplatelet therapy.[54] A systematic review found limited data to support either continuation or discontinuation of DAPT before NCS as a strategy to reduce thrombotic risk, bleeding, or mortality.[35] In patients planned for NCS that requires interruption of DAPT, aspirin monotherapy should be continued whenever possible.
8. The risk of stent thrombosis is highest in the first 4 to 6 weeks after PCI with BMS and in the first 3 months after DES implantation.[6,9–12,25,48,52,55–58] In a Danish national registry from 2005 to 2012, NCS within 1 month of PCI-DES was associated with a 13-fold higher risk of cardiac death and a 4-fold higher risk of all-cause mortality.[23] When time-sensitive NCS is necessary within 30 days of BMS-PCI or within 3 months of DES-PCI, DAPT should be continued in the perioperative period, if feasible, from a surgical bleeding perspective.
9. In patients with prior PCI in whom oral anticoagulation monotherapy is planned to be interrupted before NCS, initiation of aspirin monotherapy is reasonable to reduce risks of stent thrombosis and ischemic complications. After NCS, aspirin may be discontinued, and oral anticoagulation monotherapy may be reinitiated as surgical bleeding risks permit.
10. In patients who are within 1 to 6 months of PCI and continue to need DAPT, use of intravenous antiplatelet therapy as a bridge for nondeferrable surgery has been inadequately studied.[4] The BRIDGE

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(Bridging Antiplatelet Therapy With Cangrelor in Patients Undergoing Cardiac Surgery) trial studied oral P2Y12 inhibitor discontinuation and subsequent use of cangrelor versus placebo.[59] This study of patients undergoing CABG demonstrated greater platelet inhibition with cangrelor without excessive risk of major bleeding. The MONET BRIDGE (Maintenance of Antiplatelet Therapy in Patients with Coronary Stenting Undergoing Surgery) trial is currently underway for evaluating cangrelor as a bridging strategy in patients undergoing NCS within 12 months of PCI.[60] There are no established data on the use of glycoprotein IIB/IIIA inhibitors as a bridging strategy.[61,62]

11. In observational studies of patients undergoing NCS, aspirin continuation was associated with a 1.5-fold greater risk of nonserious bleeding events.[34] Withdrawal of aspirin preceded up to 10% of perioperative acute cardiovascular syndromes.[34] In a small RCT of 220 patients undergoing NCS, perioperative aspirin was associated with a 7.2% absolute risk reduction for postoperative MACE.[63] In a meta-analysis of >30 000 patients with and without prior PCI undergoing NCS, antiplatelet therapy was associated with minimal bleeding risk and no increase in thrombotic complications.[54] In the prespecified stratum of POISE-2 (n=4382) trial, aspirin continuation did not reduce death or nonfatal MI compared with aspirin interruption (7.7% versus 7.8%; HR, 1.00 [95% CI, 0.81-1.23]).[27] Although aspirin should not be routinely continued in the perioperative period of NCS, continuation may be reasonable in selected patients after consideration of individualized thrombotic and bleeding risks.[35]
12. The POISE-2 trial randomly assigned 10 010 patients planned for NCS and at risk for cardiovascular complications to perioperative aspirin versus placebo.[27] Administration of aspirin before surgery and for 30 days postoperatively did not reduce the composite of death or nonfatal MI (7.0% versus 7.1%; HR, 0.99 [95% CI, 0.86-1.15]; *P*=0.92) but was associated with a 23% increased hazard for major bleeding. Findings were consistent regardless of aspirin use before trial enrollment.[27] Among patients in POISE-2 undergoing vascular surgery, perioperative withdrawal of chronic aspirin therapy was not associated with increased cardiovascular events.[64]

In the POISE-3 trial, among patients undergoing NCS, the incidence of the composite bleeding outcome was significantly lower with tranexamic acid than with placebo.[65] The net clinical benefit of tranexamic acid appears patient-specific; that is, it is worthwhile for those at increased risk for bleeding outcomes but harmful for those at increased risk for adverse cardiovascular events.[66]

7.6. Oral Anticoagulants

Recommendations for Oral Anticoagulants Management
Referenced studies that support the recommendations are summarized in the Online Data Supplement.

COR	LOE	Recommendations
OAC Management		
1	B-NR	1. For patients with CVD receiving OAC who require elective NCS, a multidisciplinary team-based approach to time-based* interruption is recommended to balance the competing risks of thromboembolism and perioperative bleeding (Tables 13 and 14).[1–7]
OAC Bridging		
2a	C-LD	2. In patients with CVD and high thrombotic risk (Table 14) undergoing NCS where interruption of vitamin K antagonist (VKA) is required, preoperative bridging with parenteral heparin can be effective to reduce thromboembolic risk.[8–10]
3: Harm	C-LD	3. In most patients with CVD who are undergoing elective NCS where OAC interruption is warranted, routine periprocedural bridging is not recommended due to increased bleeding risk.[8,11]
OAC Resumption		
2a	C-LD	4. In patients with preoperative OAC interruption, resumption of OAC is reasonable after hemostasis is achieved.[9]

*Timing of preoperative interruption is based on patient-specific factors (eg, thrombotic risk, age, sex, body weight, renal clearance), surgical bleeding risk, and drug factors (eg, pharmacokinetics, dosing, drug interactions).

Synopsis

Both major bleeding and thrombosis (eg, stroke and venous thromboembolism) are important surgical outcomes and key contributors to death in NCS.[12] Balancing these perioperative risks is particularly challenging in patients receiving chronic OAC, including VKA and direct oral anticoagulants (DOAC). Development of a perioperative plan for elective NCS should include evaluation of patient-specific factors (eg, age, thrombotic risk, renal function, history of bleeding), procedural factors (eg, timing of surgery, bleeding risk), and drug properties (eg, dosing, drug interaction, onset/offset).[12,13] Whenever feasible, multidisciplinary assessments (eg, OAC prescriber, cardiologist, vascular specialist, hematologist, surgeon, anesthesiologist) should be performed to better understand patient characteristics and surgical risk. Such approaches, applied as part of a standardized preoperative screening process, may greatly improve patient safety.[14] Finally, guidance on monitoring for residual drug effects and hemostasis as well as approaches to OAC reversal is highlighted, particularly when surgical interventions must occur urgently.

Recommendation-Specific Supportive Text

1. It is generally safe to perform surgeries with minimal bleeding risk without interrupting OAC therapy (Tables 13 and 14).[1–3,15–17] For NCS with greater

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Table 13. Perioperative Management of Direct Oral Anticoagulants and Vitamin K Antagonists

Preoperative DOAC Schedule												
		Preoperative Interruption						Surgery/ Procedure	Postoperative Resumption			
	Procedure Bleeding Risk	Day -6	Day -5	Day -4	Day -3	Day -2	Day -1	Day 0	Day +1	Day +2	Day +3	Day +4
Apixaban, edoxaban, rivaroxaban	High	*	*	*	*	†	†	†	†	†	*	*
	Low/Moderate	*	*	*	*	*	†	†	*	*	*	*
	Minimal	*	*	*	*	*	*	*	*	*	*	*
Apixaban, edoxaban, rivaroxaban with renal impairment (CrCl <30 mL/min)	High	*	*	*	†	†	†	†	†	†	*	*
	Low/Moderate	*	*	*	*	†	†	†	*	*	*	*
	Minimal	*	*	*	*	*	*	*	*	*	*	*
Dabigatran CrCl ≥50 mL/min	High	*	*	*	*	†	†	†	†	†	*	*
	Low/Moderate	*	*	*	*	*	†	†	*	*	*	*
	Minimal	*	*	*	*	*	*	*	*	*	*	*
Dabigatran CrCl <50 mL/min	High	*	*	†	†	†	†	†	†	†	*	*
	Low/Moderate	*	*	*	*	†	†	†	*	*	*	*
	Minimal	*	*	*	*	*	*	*	*	*	*	*
VKA Schedule												
		Preoperative Interruption						Surgery/ Procedure	Postoperative Resumption			
	Procedure Bleeding Risk	Day -6	Day -5	Day -4	Day -3	Day -2	Day -1	Day 0	Day +1	Day +2	Day +3	Day +4
Warfarin in low/moderate thrombotic risk	High	*	†	†	†	†	†	†	*	*	*	*
	Low/ Moderate	*	†	†	†	†	†	†	*	*	*	*
	Minimal	*	*	*	*	*	*	*	*	*	*	*
Warfarin in high thrombotic risk	High	*	†	†	‡	‡	‡	†	*	*	*#	*#
	Low/ Moderate	*	†	†	‡	‡	‡	†	*	*#	*#	*#
	Minimal	*	*	*	*	*	*	*	*	*	*	*

Management for perioperative bleeding risk and DOAC or VKA schedule should incorporate team-based decision-making, especially in high thrombotic risk patients or when undergoing procedures with higher risks of adverse outcome, should bleeding occur (eg, neuraxial anesthesia). Minimal bleeding risk = 30-day risk of major bleeding 0% (eg, cataract surgery, minor dental/dermatological procedures). Low/moderate bleeding risk = 30-day risk of major bleeding <2% (eg, complex dental, gastrointestinal, breast surgery, procedures using large-bore needles). High bleeding risk = 30-day risk of major bleeding ≥2%.

*Administer DOAC or VKA.

†Withhold DOAC or VKA.

‡While withholding VKA in select very high thrombotic risk patients, preoperative bridging with parenteral heparin once INR is less than desired therapeutic range.

#Resuming postoperative LMWH bridge at either full dose or prophylaxis dose until INR is within therapeutic range is a team-based decision that weighs the risks and benefits.

CrCl indicates creatinine clearance; DOAC, direct oral anticoagulants; INR, international normalized ratio; LMWH, low-molecular-weight heparin; and VKA, vitamin K antagonist.

bleeding risks, time-based interruption ("time reversal") of OAC is advised.[5,18–20] A DOAC interruption protocol tested in 3007 patients with AF in the PAUSE (Perioperative Anticoagulation Use for Surgery Evaluation) study[7] resulted in low rates of major bleeding or thromboembolism (Table 13). Findings were similar in the prospective, observational, EMIT-AF/VTE (Edoxaban Management in Diagnostic and Therapeutic Procedures) study.[6]

In select patients with recent thromboses and high residual thrombotic risk, delaying elective NCS may permit safer interruption of OAC. Time reversal of OAC is always preferred, but this may not be feasible for urgent or emergency procedures with moderate or high bleeding risk.[21] The measurement of coagulation parameters, drug levels, or both may identify ongoing drug effects. In the absence of altered coagulation parameters or detectable drug levels, OAC reversal agents may not be necessary.[22–24] Otherwise, rapid reversal of OAC can be achieved with prothrombin complex concentrates,[25,26] andexanet alfa for factor Xa inhibitors (rivaroxaban, apixaban, or edoxaban), or idarucizumab for dabigatran (Table 15).[27,28]

Procedures with higher bleeding risks (eg, neuraxial anesthesia) should be performed with complete interruption of OAC.[29] When minimal drug effect is desired, anticoagulants should be held

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Table 14. Thromboembolic Risk for Common Oral Anticoagulant Indications

Risk Category	Venous Thromboembolism	Atrial Fibrillation	Mechanical Valve	Other Anticoagulation Indications
Low	VTE >12 mo	CHA_2DS_2-VASc 1-4 (without prior history of stroke)	Bileaflet mechanical AVR without major risk factors for stroke*	
Moderate	VTE ≤3-12 mo Recurrent VTE	CHA_2DS_2-VASc 5-6	Bileaflet mechanical AVR with major risk factors for stroke*	Nonsevere coagulopathy (heterozygous factor V Leiden or prothrombin gene G20210A mutation) Active cancer
High	Recent VTE (<1 mo or <3 mo)	CHA_2DS_2-VASc ≥7 (or 5-6 with recent stroke or TIA) AF with rheumatic valvular heart disease	Mechanical mitral valve Caged ball or tilting-disk valve Mechanical heart valve in any position with recent stroke or TIA (<3 mo)	Recent cardioembolic stroke (<3 mo)† Active cancer associated with high VTE risk LV thrombus (within past 3 mo) Severe thrombophilia† Antiphospholipid antibodies

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*Major risk factors for stroke include AF, multiple prior strokes/TIAs (≥3 months), prior perioperative stroke, or prior valve thrombosis.

†Deficiency of protein C, protein S, or antithrombin; homozygous factor V Leiden or prothrombin gene G20210A mutation or double heterozygous for each mutation, multiple thrombophilias.

AF indicated atrial fibrillation; AVR, aortic valve replacement; CHA_2DS_2-VASc, congestive heart failure, hypertension, age ≥75 (doubled), diabetes mellitus, prior stroke or transient ischemic attack or thromboembolism (doubled), vascular disease, age 65 to 74 years, sex category; LV, left ventricular; OAC, oral anticoagulant; TIA, transient ischemic attack; and VTE, venous thromboembolism.

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for ≥5 half-lives (Table 13), ≥3 days for factor Xa inhibitors (rivaroxaban, apixaban, edoxaban), and ≥4 days for dabigatran (5-6 days, if creatinine clearance <50 mL/min).[30]

2. In high thrombotic risk patients who are receiving VKA (Table 13), bridging with parenteral anticoagulation is a common practice; however, data supporting efficacy (ie, prevention of thromboembolism) or safety (ie, bleeding) are not available. A meta-analysis of patients with venous thromboembolism reported the incidence of recurrent thromboembolism to be low, regardless of perioperative management strategy or baseline thromboembolic risk, and that bridging increased the incidence of bleeding.[8] A systematic review and meta-analysis of NCS perioperative

Table 15. Pharmacokinetic Characteristics, Monitoring, and Reversal of Vitamin K Antagonist and Direct Oral Anticoagulants

	Warfarin	Apixaban	Rivaroxaban	Edoxaban	Dabigatran
Mechanism of action	VKORC1 (vitamin K-dependent factors)	Factor Xa inhibitor	Factor Xa inhibitor	Factor Xa inhibitor	Factor IIa inhibitor (direct thrombin inhibitor)
Bioavailability	>95%	50%	100% (66% without food)	62%	3%-7%
Time to Cmax	2-6 h	3-4 h	2-4 h	1-2 h	1.25-3 h
Plasma half-life ($t_{1/2}$)	36-48 h	9-14 h	6-9 h (11-13 h in older persons)	10-14 h	12-15 h
Duration of action	~5 d (beyond normalization of INR)	24 h	24 h	24 h	24 h
Renal clearance (%)	0	27	33	37-59	85 (partially dialyzable)
Drug interaction		CYP p450 3A4, p-glycoprotein	CYP 450 3A4/2J2, p-glycoprotein	CYP 450 3A4 (<5%), p-glycoprotein	p-glycoprotein
Altered anticoagulation parameters		PT, aPTT, ACT	PT, aPTT, ACT	PT, aPTT, ACT	aPTT, ACT, PT/INR, DTT
Monitor for presence of drug effect	PT/INR	Anti-Xa* (DOAC)	Anti-Xa* (DOAC)	Anti-Xa* (DOAC)	ECT (DOAC)
Antidote/reversal[34]	Vitamin K, 4F-PCC, FFP	4F-PCC, andexanet alfa	4F-PCC, andexanet alfa	4F-PCC, andexanet alfa	4F-PCC, idarucizumab

*Quantitative assessment requires drug-specific calibrators. With no therapeutic levels, use can indicate ongoing drug effect.

4F-PCC indicates 4-factor prothrombin complex concentrate; ACT, activated clotting time; Anti-Xa, assay to measure anticoagulation activity; aPTT, activated partial thromboplastin time; CYP, cytochrome; DOAC, direct oral anticoagulant; DTT, diluted thrombin time; ECT, ecarin clotting time; FFP, fresh frozen plasma; INR, international normalized ratio; and PT, prothrombin.

bridging in patients with mechanical heart valves (35.8% of patients with mechanical mitral valves) identified 15 studies with 2453 bridging episodes and found that bridging increased overall bleeding, with near significant differences in major bleeding, and without the benefit of lowering thromboembolism; however, both noted the majority of results were based on poor-quality cohorts overall.[10] The PERIOP-2 (Postoperative Low Molecular Weight Heparin Bridging Treatment for Patients at High Risk of Arterial Thromboembolism) study enrolled 1471 patients on VKA requiring NCS (79% AF, 14% mechanical heart valve, 7% with both).[9] All patients had warfarin held 5 days before NCS and received low-molecular-weight heparin for 3 days preoperatively followed by postoperative randomization to placebo or low-molecular-weight heparin at either a prophylactic or full dose based on procedural bleeding risk. Thromboembolism was similar across all patient populations, and secondary outcomes of bleeding were increased with postoperative bridging. Although further RCTs are warranted, available data support limiting the use of bridging to very high thrombotic risk (eg, mechanical mitral valves) patients on VKA, with careful consideration of bleeding risk (eg, HAS-BLED,[31] previous personal bleeding history, and perioperative bleeding risk) to determine an individualized strategy.

3. The BRIDGE trial enrolled 1844 patients with AF on VKA and randomized them to low-molecular-weight heparin bridge therapy or placebo starting 3 days preoperatively and continued 5 days postoperatively. All patients had warfarin held from preoperative day 5 through postoperative day 1. Bridging anticoagulation was noninferior to placebo for prevention of thromboembolism, but bridging increased the risk of major bleeding.[11] Subsequent analysis showed bridge therapy, along with history of renal disease and procedures with high bleeding risk, to be a baseline predictor of major bleeding.[32] The pharmacokinetic properties of DOAC therapy allow for a more rapid onset and offset of anticoagulant effects and thus shorter perioperative interruptions. A simple DOAC interruption strategy without heparin bridging results in minimal time off DOAC, low bleeding, and low thromboembolic risk in patients with AF.[7] Data from phase 3 AF studies support these findings. Some patients who required procedures in these studies (approximately 11% of DOAC-treated patients) received unfractionated heparin or low- molecular-weight heparin bridging, which resulted in increased risk of bleeding without reduction in thromboembolic risk.[18–20] Based on these studies, most patients with AF will not benefit from bridging anticoagulation.
4. When restarting VKA after interruption, it can take several days to achieve full anticoagulant effect. Therefore, once hemostasis is achieved after a low or moderate bleeding risk procedure, it is reasonable to restart VKA as early as 12 to 24 hours postoperatively. It is suggested to resume VKA at the previous therapeutic dose, bearing in mind that additional monitoring may be required because concomitant medications (eg, antibiotics, nonsteroidal anti-inflammatory drugs, acetaminophen), nutrition, and drug clearance may be altered during the perioperative period. After initiation of DOAC, in most patients, peak levels and a therapeutic anticoagulation effect are achieved in ~2 to 3 hours. Therefore, DOACs should be resumed when full anticoagulation is clinically appropriate, which may be as early as 6 hours postoperatively if hemostasis has occurred. In the PAUSE trial, DOACs were resumed 48 to 72 hours after high bleeding risk procedures, with overall low bleeding and thrombotic events.[7,33]

7.7. Perioperative Beta Blockers

Recommendations for Perioperative Beta Blockers
Referenced studies that support the recommendations are summarized in the Online Data Supplement.

COR	LOE	Recommendations
1	B-NR	1. In patients on stable doses of beta blockers undergoing NCS, beta blockers should be continued through the perioperative period as appropriate based on the clinical circumstances.[1,2]
2b	B-NR	2. In patients scheduled for elective NCS who have a new indication for beta blockade, beta blockers may be initiated far enough before surgery (optimally >7 days) to permit assessments of tolerability and drug titration if needed.[3]
3: Harm	B-R	3. In patients undergoing NCS and with no immediate need for beta blockers, beta blockers should not be initiated on the day of surgery due to increased risk for postoperative mortality.[4]

Synopsis

Initial optimism regarding the efficacy of perioperative beta blockers on ischemia and subsequent major cardiac events was significantly tempered by large RCTs, suggesting that their moderate benefit of reducing ischemic cardiac events and atrial arrhythmias was offset by harm (eg, stroke) and was associated with increased all-cause mortality. As a result, the practice of perioperative beta blockers to reduce perioperative risk is not advised.[3,5] There are no large RCTs of adequate size or power to determine the optimal timing of beta-blocker initiation in the perioperative period, an approach to dose titration pre- or postoperatively, whether specific patient subgroups benefit (eg, based on RCRI), or whether surgery alone is an indication for beta-blockade outside of

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acceptable indications (eg, HF, history of CAD). Absent this evidence, an optimal strategy should restrict the use of beta blockers in patients with clear long-term or acute indications, initiating beta blockers at least 1 week before surgery, managing chronic beta blockers as appropriate to patients' perioperative hemodynamics, and ensuring they are continued at discharge.

Recommendation-Specific Supportive Text

1. Early studies of beta-blockade suggesting benefit may have produced their results by withdrawing beta blockers in patients who had been on them long term.[6] Acutely discontinuing beta blockers for long-term indications is harmful[1,2,7] and should be avoided. Clinical judgment should be used to titrate beta blockers as appropriate during the perioperative period, with a focus on ensuring the medication is continued through the hospital stay and at discharge unless clear contraindications arise.
2. Results from POISE indicate that initiating beta blockers on the day of surgery is harmful, particularly if the medication is started at higher doses.[8] Contemporaneous studies focused on initiating beta-blockade weeks in advance and titrated to physiological effect showed clinical benefit, but these results have since been called into question.[9] A large observational study of beta-blocker initiation before NCS suggested higher risks of death if beta blockers were initiated <7 days before surgery[3] compared with patients who initiated beta blockers >31 days earlier. Patients who initiated beta blockers between 8 and 30 days did not have excess mortality, nor did they show any perioperative benefits. Thus, if a patient requires initiation of beta blockers before surgery, the medication should be initiated ≥7 days before the surgery.
3. Initial evidence for perioperative beta blockers was derived from several relatively underpowered RCTs and a large observational study suggesting benefit from perioperative beta blockers. These were followed by the large multicenter POISE study,[8] which demonstrated mixed benefits (eg, moderate reduction in MACE) balanced by harms (eg, hypotension, stroke, with a net increase in all-cause mortality) when high-dose beta blockers were administered to beta blocker–naïve patients immediately before surgery and maintained throughout the perioperative period.[9,10] Similar to the systematic review for the "2014 ACC/AHA Guideline on Perioperative Cardiovascular Evaluation and Management of Patients Undergoing Noncardiac Surgery,"[11] this guideline excludes a group of perioperative beta-blocker trials from consideration because of concern for unreliable data leading to spurious results. Evidence from 3 meta-analyses was concordant regarding potential harms of perioperative beta-blocker administration; however, the results of each of these studies were heavily influenced by the large POISE-1 sample size.[4,11,12] Although large observational studies have suggested higher potential benefit of beta-blockade in patients at increased risk as defined by the RCRI, these results have not been replicated in clinical trials.[13,14]

7.8. Perioperative Management of Blood Glucose

Recommendations for Perioperative Management of Blood Glucose
Referenced studies that support the recommendations are summarized in the Online Data Supplement.

COR	LOE	Recommendations
2a	B-NR	1. In patients with or at risk for diabetes who are scheduled for elective NCS, preoperative hemoglobin A1c (HbA1C) testing is reasonable if it has not been performed in ≤3 months.[1–4]
1	C-LD	2. In patients scheduled for NCS, SGLT2i should be discontinued 3 to 4 days* days before surgery to reduce the risk of perioperative metabolic acidosis.[5–7]
2a	C-LD	3. In patients with diabetes or impaired glucose tolerance, continuation of metformin during the perioperative period is reasonable to maintain glycemic control.[8–12]

*Canagliflozin, dapagliflozin, and empagliflozin should be stopped ≥3 days and ertugliflozin ≥4 days before scheduled surgery.[13]

Synopsis

In the United States, 34.1 million adults have diabetes, representing 13% of the population.[14,15] Additionally, undiagnosed diabetes is present in 7.3 million adults, or 2.8% of the population.[14] It is estimated that up to 20% of general surgery patients have diabetes, and 23% to 60% have prediabetes or undiagnosed diabetes.[5] Patients with diabetes have an increased prevalence of ASCVD, including CAD, CKD, and HF. Diabetes confers increased risks of perioperative cardiovascular events and surgical site infections. The finely regulated balance between hepatic glucose production and glucose utilization in peripheral tissue is altered by the stress of anesthesia and surgery, thereby affecting regulatory hormones and inflammatory cytokines.[15,16] Thus, management of perioperative hyperglycemia is imperative; however, the optimal blood glucose targets for intraoperative glycemic control are not well-defined.[17]

Emerging data suggest that glucagon-like polypeptide-1 (GLP-1) agonists, increasingly used for the management of diabetes, can cause clinically significant gastroparesis and delayed gastric emptying.[18] A recent consensus statement from the ASA recommends that weekly formulations of GLP-1 agonists be held >1 week before elective NCS for weekly dosed GLP-1 agonists and the day before for daily dosed GLP-1 agonists to reduce the risk of pulmonary aspiration of gastric contents at the time of surgery.

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Recommendation-Specific Supportive Text

1. If not obtained within 3 months of NCS, it is reasonable to check the preoperative hemoglobin A1c before surgery.[5,15,19] Multiple studies have assessed hemoglobin A1c and surgical outcomes, but it remains controversial whether elevated levels are linked to poor postoperative outcomes or are just a marker of poor perioperative glucose control.[1–4] At this time, there is no evidence that deferring surgery to achieve better glycemic control improves cardiovascular outcomes. Although there are no validated hemoglobin A1c risk thresholds, it may be reasonable to postpone an elective surgery if hemoglobin A1c is higher than 8%.[1] Emergent or time-sensitive procedures should not be delayed to achieve a target hemoglobin A1c; instead, the focus should be on optimizing perioperative glucose control. A retrospective study of preoperative blood glucose levels in patients undergoing noncardiac and nonvascular surgery found glucose concentrations ≥200 mg/dL to be associated with a >2-fold higher all-cause mortality rate and a >4-fold cardiovascular mortality rate compared with patients with normal blood glucose levels.[20] This study also demonstrated that preoperative patients undergoing treatment for diabetes had lower all-cause and cardiovascular mortality.[20,21]
2. SGLT2i, noninsulin glucose–lowering agents that facilitate glycemic control by inhibiting renal glucose reabsorption and thus promoting glycosuria, must be discontinued 3 to 4 days before surgery.[5] A rare complication of these agents is euglycemic diabetic ketoacidosis, which is a serious postoperative complication defined as normoglycemia (blood glucose <250 mg/dL) in the presence of metabolic acidosis (pH <7.3), total decreased serum bicarbonate (<18 mEq/L), and elevated serum and urine ketones.[5–7,22] There are no clear guidelines regarding restarting SGLT2i after surgery. Ideally, they should not be recommended until the patient is clinically stable and has resumed a normal diet.
3. Prior recommendations to discontinue metformin in the perioperative period stemmed from the concern that lactic acidosis could be precipitated in the setting of physical stressors; however, more recent data suggest that metformin is not associated with lactic acidosis. A population-based cohort of >10 600 patients with type 2 diabetes identified 163 patients who had been hospitalized with lactic acidosis. When compared with sex- and age-matched controls, current use of metformin was not associated with a risk of lactic acidosis.[9]

   There have been several studies demonstrating cardiovascular risk reduction in nonoperative patients taking metformin.[8,10–12] The UKPDS (United Kingdom Prospective Diabetes Study) showed that, in addition to lowering blood glucose, metformin reduced cardiovascular mortality in patients with obesity and type 2 diabetes. The prespecified subgroup analysis showed risk reductions of 32% for any diabetes-related endpoint, 42% for diabetes-related death, and 36% for all-cause mortality.[23] These findings were further supported by a 10-year follow-up that showed significant risk reduction persisted in the metformin group for any diabetes-related endpoint (21%), MI (33%), and death from any cause (27%).[24]

8. ANESTHETIC CONSIDERATIONS AND INTRAOPERATIVE MANAGEMENT

8.1. Choice of Anesthetic Technique and Agent

Recommendations for Choice of Anesthetic Technique and Agent
Referenced studies that support the recommendations are summarized in the Online Data Supplement.

COR	LOE	Recommendations
2a	A	1. In patients undergoing NCS, use of a volatile-based anesthetic agent or total intravenous anesthesia is reasonable for general anesthesia with no apparent difference in associated cardiovascular events (eg, MI, ischemia).[1–3]
2a	B-R	2. In patients undergoing NCS where neuraxial is feasible, either neuraxial or general anesthesia is reasonable with no apparent difference in associated cardiovascular events.[4–6]

Synopsis

Broadly, there are 4 major classes of anesthesia: local anesthesia, regional anesthesia (eg, neuraxial blockade and peripheral nerve block), monitored anesthesia care (sedation with or without local anesthesia), and general anesthesia (either volatile or intravenous anesthesia). A combination of anesthetic class agents is frequently used. Neuraxial anesthesia can be performed as a primary anesthetic technique alone or with sedation or as a supplement to general anesthesia. An evaluation of risk factors (other than cardiac), including type and duration of surgical procedure, comorbidities, patient preference, and coagulation status, is crucial for determining the risk versus the benefits of each type of anesthetic technique.

The concentration of oxygen administered has also been studied in the perioperative period. Several studies investigated the impact of 30% versus 80% of fraction of inspired oxygen on myocardial injury and infarction during surgery. Two separate RCTs independently reported that oxygen concentration was not associated with increased risk of myocardial injury within 3 days or postoperative release of NT-proBNP.[7,8] These results confirm those of a previously published retrospective analysis including 1617 surgical patients that

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demonstrated no association between increased oxygen concentration and incidence of myocardial injury, cardiac arrest, and 30-day mortality.[9]

Recommendation-Specific Supportive Text

1. Over the past few decades, several studies have indicated a possible myocardial protective benefit of volatile anesthetic agents over total intravenous anesthesia, most commonly propofol, in surgical patients undergoing cardiac surgery. In 2009, a meta-analysis including >6000 surgical patients undergoing NCS failed to demonstrate a difference in rates of MI among patients who received anesthesia with sevoflurane or propofol.[10] Several subsequent studies, including 4 RCTs, failed to identify any significant advantage to inhaled versus intravenous anesthesia.[1–13,11] In 2011, 88 patients were randomized to sevoflurane versus propofol, with no difference in detectable cardiac troponin I elevation or in median peak release of cardiac troponin I.[11] In 2012, 385 surgical patients at cardiovascular risk undergoing major NCS were randomized to sevoflurane or propofol.[2] The incidence of myocardial ischemia, postoperative release of NT-proBNP, MACE, or delirium was not decreased with the use of sevoflurane. In 2013, 193 surgical patients scheduled for elective abdominal aortic surgery were randomized to either sevoflurane or propofol/remifentanil.[1] Again, sevoflurane did not decrease postoperative release of cardiac troponin T, postoperative complications, nonfatal coronary events, or mortality when compared with propofol and remifentanil. In 2017, another trial randomized 120 older patients with established CAD to sevoflurane versus propofol/remifentanil, with no difference observed in release of cardiac troponin T or BNP 8 or 24 hours after surgery.[3]
2. A large nationwide retrospective cohort study in Denmark was performed in surgical patients undergoing first-time open inguinal and infrainguinal arterial reconstruction procedures.[4] A significant benefit in terms of reduction of mortality and cardiac morbidity (MI, HF, dysrhythmias) was observed with regional anesthesia (including neuraxial and peripheral anesthesia) when compared with patients under general anesthesia.[4] In contrast, another retrospective analysis examined a large dataset of patients undergoing above knee amputation.[6] After propensity matching, there was no observed difference in either 30-day mortality or any secondary outcomes, including cardiac complications.[6] In a recent randomized trial of 1600 surgical patients receiving spinal or general anesthesia for surgical management of hip fracture,[5] no difference was reported between groups in primary outcome, a composite of death, or an inability to walk 10 feet independently or with a walker or cane approximately 60 days after surgery. Other outcomes were examined, including MI, nonfatal cardiac arrest, and stroke, but no significant difference between groups was detected.[5] These results are in accordance with a previous meta-analysis in patients after hip fracture that reported no 30-day mortality benefit.[12] Evidence related to neuraxial anesthesia for postoperative pain control is discussed in Section 8.2 ("Perioperative Pain Management").

8.2. Perioperative Pain Management

Recommendations for Perioperative Pain Management
Referenced studies that support the recommendations are summarized in the Online Data Supplement.

COR	LOE	Recommendations
2a	B-R	1. For patients undergoing major abdominal surgery, the use of epidural analgesia for postoperative pain relief is reasonable to decrease the incidence of perioperative cardiac events.[1,2]
2b	B-R	2. For patients with a hip fracture waiting for surgical repair, epidural analgesia may be considered to decrease the incidence of preoperative cardiac events.[3]

Synopsis

Pain is a common experience after surgery, and physiological manifestations, such as tachyarrhythmias and hypertension, can have serious consequences in patients with preexisting cardiac disease. In patients with CAD, increased myocardial oxygen demand from sympathetic effects of acute pain could lead to the development of type 2 MI (supply-demand imbalance without acute atherothrombotic plaque disruption).[4] Intravenous or regional administration of analgesics are the mainstay of pain control in the postoperative period. Epidural analgesia and catheter-based regional anesthetics allow for medication administration for acute pain relief up to several days after surgery. Thoracic epidural analgesia (TEA) is preferred for most abdominal incisions, while lumbar epidural analgesia is commonly used for hip fractures and lower extremity orthopedic injuries. The benefits of TEA for the prevention of postoperative MI after abdominal surgery have been demonstrated.[1,2] Enhanced recovery after NCS protocols are increasingly using TEA as part of a multimodal pain management strategy to reduce both intravenous and oral administration of opioid-based analgesics.[5] The use of gabapentin or pregabalin as adjunct medications has been less successful in promoting an opioid-sparing technique, with adverse effects that include visual disturbances, dizziness, respiratory depression,[6,7] and postoperative delirium in patients ≥65 years of age.[8]

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Recommendation-Specific Supportive Text

1. TEA remains a cornerstone for anesthetic technique in major abdominal surgery to treat pain in the perioperative period. An updated 2016 Cochrane review in patients undergoing abdominal aortic surgery concluded there was a decreased incidence of MI associated with epidural analgesia compared with intravenous systemic opioid-based pain management.[1] A recent RCT of patients undergoing abdominal surgery (gastrectomy, Whipple, distal esophagectomy) comparing TEA (n=60) with intravenous analgesia (n=60) demonstrated a lower rate of postoperative myocardial injury (8.33% versus 36.67%) and supraventricular tachyarrhythmia (11.66% versus 36.67%) in the TEA cohort.[2] A large, retrospective NSQIP database analysis of >8000 patients demonstrated the benefit of epidural analgesia compared with intravenous analgesia in open abdominal surgery for preventing cardiopulmonary complications (OR, 0.58). However, there is a lack of high-quality evidence from RCTs comparing TEA with intravenous analgesia within enhanced recovery after NCS protocols, making it difficult to assess primarily for perioperative MI and other MACE after major abdominal surgery.
2. In patients with hip fractures, lumbar epidural analgesia for pain control appears to decrease the incidence of perioperative MACE. A systematic review and meta-analysis from 2022 that included 4 RCTs published between 2000 and 2014 (n=221 patients) supported the use of epidural analgesia for the prevention of perioperative MACE (to include combined events of cardiac death, MI, unstable angina, HF, or new-onset AF).[3]

8.3. Intraoperative Monitoring Techniques

8.3.1. Echocardiography

Recommendations for Echocardiography Referenced studies that support the recommendations are summarized in the Online Data Supplement.		
2a	C-LD	1. In patients with unexplained hemodynamic instability undergoing NCS, the emergency use of perioperative TEE or FoCUS is reasonable to determine the cause if expertise is readily available.[1–4]
3: No benefit	C-LD	2. In patients undergoing NCS without risk factors or procedural risks for significant hemodynamic compromise, the routine use of intraoperative TEE is not recommended to screen for cardiac abnormalities or to monitor for myocardial ischemia.[5–8]

Synopsis

Echocardiography has the capacity to assess biventricular and valvular function, intracardiac structures, the pericardial space, and the thoracic aorta.[9–11] Different echocardiographic modalities (eg, TTE, TEE) are used during NCS, mostly as diagnostic tools in the setting of persistent, unexplained hemodynamic instability that occurs more frequently in the intraoperative or postoperative period.[1,2,11–13] However, TEE has been increasingly used as an intraoperative monitoring tool in patients with high-risk factors or undergoing high-risk noncardiac procedures.[7,8,14–17] In addition, TEE is widely used in cardiac surgery and lung transplantation.[8] Although TEE is a low-risk procedure overall, complications may still occur; therefore, the benefits and risks must be considered.[18,19] FoCUS using TTE is an evolving field in perioperative medicine[3,4,12,13,20,21] that comprises limited, standard cardiac views and is used to coarsely identify pathology in the setting of hemodynamic instability. If additional echocardiographic information is needed to rule out a cardiac-related cause, a comprehensive examination should be performed.[20,21] The choice of the echocardiographic modality used depends on the circumstances, the availability of equipment and expertise, and the indication for the examination (eg, the left atrial appendage and the thoracic aorta are better evaluated with TEE).

Recommendation-Specific Supportive Text

1. The emergency use of perioperative TEE to determine the cause of unexplained, severe hemodynamic instability that persists despite attempted corrective therapy is appropriate where available.[1,2,11,16,22] Clinical practice guidelines for the appropriate use of TEE have been developed by the American Society of Anesthesiologists, the Society of Cardiovascular Anesthesiologists, and the American Society of Echocardiography.[10,11,22] A systematic review showed that intraoperative FoCUS with TTE may be a useful, noninvasive tool to diagnose the cause of unexplained hypotension and to guide treatment.[3] The evidence was of low quality, most likely reflecting the challenges in designing high-quality studies such as RCTs involving situations of unpredictable hemodynamic instability.[4] Recommendations suggest appropriately trained practitioners perform the TEE or FoCUS examinations.[10–13,22]
2. Limited evaluation data exist on the effectiveness of routine use of intraoperative TEE during noncardiac procedures, in screening for regional myocardial function and its association with perioperative cardiovascular outcomes.[5,6] In addition, the data to recommend routine TEE monitoring are insufficient in terms of predictive accuracy, cost-effectiveness, or safety. However, TEE is used routinely as a monitoring tool in cardiac and lung transplantation cases and is also more commonly used in other procedures with high risk for hemodynamic instability.[7,8]

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8.3.2. Body Temperature

Recommendation for Body Temperature Referenced studies that support the recommendation are summarized in the Online Data Supplement.		
COR	**LOE**	**Recommendation**
2a	**B-R**	1. In patients with CVD undergoing NCS, maintenance of normothermia is reasonable to avoid perioperative complications overall.[1–5]

Synopsis

Hypothermia has been associated with several perioperative complications, including wound infection, MACE, immune dysfunction, coagulopathy, increased blood loss, death, and transfusion requirements.[1,6–14] Emerging literature suggests that mild intraoperative hypothermia (35.5°C)[2] is not correlated with postoperative cardiac events.[1,2] Likewise, mild intraoperative hypothermia (>35.5°C) in nonobese patients with preserved renal function is not correlated with postoperative cardiac events.[2] Hypothermia has been reported to be proarrhythmogenic by increasing sympathetic nervous system activity. Hypothermia can also induce shivering, which can lead to perioperative cardiac injury due to an imbalance of oxygen supply and demand.[6,15–17]

Recommendation-Specific Supportive Text

1. A multicenter trial in 2010 that randomized 1000 patients with subarachnoid hemorrhage to either normothermia (36.7°C±0.5°C) or hypothermia (33.3°C±0.8°C) demonstrated no increased incidence of perioperative cardiovascular events in the hypothermia group.[3] In a prospective study of 8841 patients undergoing orthopedic surgery, a body temperature of ≥36°C was associated with significantly lower risks for cardiac or cerebral events, or both, in the arthroplasty subgroup but not in the general orthopedic surgery cohort.[4] In 2022, a multicenter, superiority trial randomized 5056 patients to be warmed to a core temperature of 37°C or to receive routine management to a temperature of 35.5°C. The incidence in 30-day composite of major cardiovascular outcomes did not significantly differ between the 2 groups.[2]

8.3.3. Temporary Mechanical Circulatory Support

Recommendation for Temporary Mechanical Circulatory Support		
COR	**LOE**	**Recommendation**
2b	**C-LD**	1. In patients with acute, severe hemodynamic instability and cardiopulmonary dysfunction undergoing urgent or emergency NCS, temporary MCS devices may be used preemptively or as rescue therapy.[1–5]

Synopsis

Temporary MCS devices may be used to help maintain adequate organ perfusion during procedures that would otherwise be hemodynamically challenging.[3,5,6] Another use of temporary MCS is to allow time for diagnostic evaluation, treatment, and patient participation in the management decision-making process.[6,7] Currently, no high-quality evidence exists to support the routine use of MCS in patients at risk for cardiogenic shock undergoing NCS. The emergency use of MCS has increased in recent years,[1–4] calling renewed attention to this rare and challenging perioperative clinical scenario.[8,9]

Recommendation-Specific Supportive Text

1. Case reports have described the prophylactic use of temporary MCS devices in high-risk cardiac patients before urgent NCS, the intention being to show the benefit of using these devices to hemodynamically support patients when their cardiac condition could not be corrected before surgery.[10–15] A retrospective study showed no increase in mortality in patients requiring the use of temporary MCS before heart transplantation compared with patients who did not require temporary MCS.[16] Emergency use of temporary MCS devices, including intra-aortic balloon pump counterpulsation, extracorporeal membrane oxygenation, and percutaneous ventricular assist devices, has been described as a rescue treatment for unexpected cardiogenic shock when pharmacological treatment fails.[4,8,9,17–19] This allows time for diagnosis and treatment or recovery while also providing hemodynamic support.[6] Several series have reported outcomes in patients with MCS undergoing noncardiac procedures.[20–26] A multidisciplinary approach that includes expert guidance on anticoagulation strategies, MCS management, hemodynamic monitoring, and infection prevention strategies is essential to the perioperative management of these patients. Specific recommendations are addressed in the American Association for Thoracic Surgery/International Society for Heart and Lung Transplantation clinical practice guidelines for MCS.[22,26]

8.3.4. Pulmonary Artery Catheters

Recommendations for Pulmonary Artery Catheters Referenced studies that support the recommendations are summarized in the Online Data Supplement.		
COR	**LOE**	**Recommendations**
2b	**C-LD**	1. In patients with CVD undergoing NCS, the use of PA catheterization may be considered when underlying medical conditions that significantly affect hemodynamics (eg, decompensated HF, severe valvular disease, combined shock states, PH) cannot be corrected before surgery.[1,2]
3: No benefit	**A**	2. In patients with CVD undergoing NCS, routine use of PA catheterization is not recommended to reduce morbidity or mortality.[3]

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Synopsis

The theoretical basis for better outcomes with the routine use of PA catheterization in NCS is derived from an improved understanding of perioperative hemodynamics by clinicians.[4] However, there are no large RCTs proving its use improves patient outcomes,[3,4] and pulmonary catheter placement is an invasive and costly procedure. Some have argued that the PA catheter is a monitoring device and, thus, patient outcomes should be based on the appropriate interpretation of the data provided as well as the therapeutic protocols implemented.[5] Despite a decline in its use over the past years, PA catheterization remains the preferred method for monitoring hemodynamically unstable patients. In severely injured trauma patients with severe shock, advanced age, or acute HF, PA catheterization was associated with a survival benefit.[1,2]

Recommendation-Specific Supportive Text

1. A retrospective data analysis of 53312 patients admitted to intensive care units found that severely injured patients in shock, with advanced age, or with acute HF benefited from PA-guided management.[1] Another prospective, observational multicenter cohort study reported that appropriate use of PA catheters decreased mortality in patients in acute HF, especially in hypotensive patients or those receiving inotropes.[1]
2. Clinical trial data regarding the benefit of routine use of PA catheterization in NCS are sparse. One trial randomly allocated patients at high surgical risk, defined by an ASA risk score of III or IV, to medical management with or without the use of PA catheters.[6] There were no differences found in mortality or morbidity, except for an increase in pulmonary embolism noted in the pulmonary artery catheter arm.[6] In 2013, a systematic review and meta-analysis of 5 studies (n=2395) concluded the preoperative optimization and hemodynamic management guided by a PA catheter did not alter patient perioperative outcomes when compared with central venous pressure catherization.[3] The types of surgeries included vascular,[7,8] abdominal, thoracic, orthopedic,[6] abdominal reconstructive surgeries,[9] as well as high-risk surgical patients.[10] Similar results were reported in an additional study involving patients undergoing aortic reconstruction surgery.[11]

8.4. Perioperative Anemia Management

Recommendations for Perioperative Anemia Management Referenced studies that support the recommendations are summarized in the Online Data Supplement.		
COR	**LOE**	**Recommendations**
2a	A	1. In patients having NCS with expected blood loss, tranexamic acid is reasonable to reduce intraoperative blood loss, reduce transfusions, and avoid anemia.[1–3]
2a	B-R	2. In patients with iron deficiency anemia having elective NCS, iron therapy (either oral or intravenous) administered preoperatively is reasonable to reduce blood transfusions and to increase hemoglobin.[4–18]

Synopsis

Even mild preoperative anemia is an independent risk factor for postoperative morbidity and mortality, including respiratory, urinary, wound, septic, and thromboembolic complications.[10,19–22] Patients with CKD, diabetes, CVD, and HF have a high prevalence of anemia.[23–26] Limited tissue oxygen delivery is a common mechanism of adverse outcomes in patients with anemia.[27] Anemia may contribute to myocardial ischemia, particularly in patients with CAD.[20] Postoperative hemoglobin is associated with myocardial injury, type 2 MI, and mortality.[20,28] The World Health Organization defines anemia as a hemoglobin concentration <13 g/dL in men and <12 g/dL in women. Up to 64% of surgical patients have anemia,[19,29] more than half of which is moderate to severe.[30] Iron deficiency is responsible in 40% to 50% of cases.[15,29–31] A ferritin concentration <100 ng/mL, transferrin saturation <20%, and/or microcytic hypochromic red cells (mean corpuscular volume <80 fL, mean corpuscular hemoglobin concentration <27 g/dL) are indicative of iron deficiency. A screening system in which anemia automatically triggers evaluation for iron deficiency using previously collected blood identifies iron-deficiency anemia far better than clinicians using normal procedures.[31] Most anemias are correctable within 2 to 4 weeks. Anemia management programs decrease the rate of transfusions, complications, and mortality.[9]

Recommendation-Specific Supportive Text

1. Bleeding is associated with mortality.[32] Preoperative and intraoperative anemia is associated with stroke, MI, and acute kidney injury that is proportional to the lowest preoperative and intraoperative hemoglobin concentration.[10,33,34] Higher rates of pulmonary, septic, wound, thromboembolic complications, as well as acute kidney injury, longer length of stay, and infections are associated with receiving a transfusion compared with not receiving a transfusion.[7,35–38] Intraoperative transfusions are associated with an increased risk of death.[36,37,39] A restrictive transfusion threshold of 8 g/dL for orthopedic surgery patients and those with CVD is recommended by the Association for the Advancement of Blood & Biotherapies. A transfusion threshold of 7 g/dL is likely comparable to 8 g/dL, but evidence is lacking.[7] A meta-analysis of patients with ACS found no differences in mortality, MACE, recurrent ACS, HF at 30 days, or reductions in transfusions and costs using transfusion thresholds of hemoglobin

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≤8 g/dL compared with ≤10 g/dL.[22] Tranexamic acid is an orally, intravenously, or topically administered synthetic lysine antifibrinolytic analog that impedes the binding of plasminogen to fibrin, thus safely decreasing intraoperative bleeding.[1–3] Even in high-risk patients undergoing lower extremity arthroplasty with a history of venous thromboembolism, MI, seizures, ischemic stroke, transient ischemic attack, renal disease, and AF, tranexamic acid was associated with fewer transfusions and was not associated with venous thromboembolism, MI, seizures, strokes, or transient ischemic attack.[2]

2. Iron supplementation is underused in the preoperative period.[30] The use of intravenous iron in patients with iron deficiency is safe and efficacious to reverse anemia.[8,12,14,30,40,41] Oral iron therapy is minimally effective if administered only 1 to 2 weeks preoperatively and therefore is not adequate for rapid preoperative treatment of iron deficiency anemia due to its low bioavailability, lack of tolerance, and long duration of treatment. Intravenous iron, even in a single dose, is more effective than oral iron to increase hemoglobin concentrations and iron stores and reduce transfusion and readmission rates.[4,11,12,16–18,40] With an anemia management approach for patients undergoing NCS, the number-needed-to-treat to prevent 1 complication is only 6 and to prevent 1 complication-related death is 25.[6] Postoperative intravenous iron to treat iron deficiency anemia improves hemoglobin and reduces postoperative transfusions, infections, and length of stay.[5,14,16] Ferric carboxymaltose, ferric derisomaltose, and ferumoxytol consist of iron surrounded by a carbohydrate shell, which allows for a slower release of the iron, and higher doses can be administered in a single infusion. Iron sucrose is less stable and is administered in lower doses, with a maximum dose of 200 to 300 mg per infusion.

9. PERIOPERATIVE SURVEILLANCE AND MANAGEMENT OF MYOCARDIAL INJURY AND INFARCTION

9.1. Myocardial Injury After Noncardiac Surgery Surveillance and Management

Recommendations for Myocardial Injury After Noncardiac Surgery Surveillance and Management
Referenced studies that support the recommendations are summarized in the Online Data Supplement.

COR	LOE	Recommendations
MINS Surveillance		
2b	B-NR	1. In patients with known CVD, symptoms of CVD, or age ≥65 years with cardiovascular risk factors undergoing elevated-risk NCS, it may be reasonable to measure cTn at 24 and 48 hours after surgery to identify myocardial injury.[1–4]

Recommendations for Myocardial Injury After Noncardiac Surgery Surveillance and Management (Continued)

COR	LOE	Recommendations
3: No benefit	B-NR	2. In patients undergoing low-risk NCS, routine postoperative screening with cTn levels is not indicated without signs or symptoms suggestive of myocardial ischemia or MI.[5,6]
MINS Management		
2a	B-NR	3. In patients who develop MINS, especially in those not previously known to have excess cardiovascular risk, outpatient follow-up is reasonable for optimization of cardiovascular risk factors.[4,7–10]
2b	C-LD	4. In patients who develop MINS, antithrombotic therapy may be considered to reduce thromboembolic events.[4,11]

Synopsis

Perioperative myocardial injury occurs in approximately 20% of patients undergoing NCS and spans a spectrum of clinical presentations from asymptomatic myocardial injury to overt postoperative MI, defined by ischemic symptoms or electrocardiographic changes, pathologic Q-waves, or evidence on imaging of a loss of viable myocardium (Figure 6).[1,4,12–14] MINS encompasses both type 1 and type 2 MI, including asymptomatic myocardial injury, because surgical patients may be unable to report symptoms due to anesthesia, analgesia, or distracting pain at the surgical site.[4,14] A diagnosis of MINS requires >1 elevated cTn (>99th percentile of the upper reference limit) of presumed ischemic origin (excluding nonischemic etiologies such as pulmonary embolism, stroke, and sepsis) and is associated with adverse short- and long-term outcomes.[1,12,14–17] Overall, 30-day mortality associated with MINS is high (approximately 10%),[9] with risks proportional to the peak cTn concentration (17% in the highest quartile versus 1% in the lowest)[15] and a 34% population attributable risk of 30-day postoperative mortality.[1,16] Even among the 80% to 90% of patients with MINS without ischemic signs or symptoms, 30-day mortality is substantial.[1,4,14] Predictors of MINS include cardiovascular risk factors and disease, kidney disease, and urgent or emergent surgery.[9,16,17] Although mechanisms of MINS may be heterogeneous, atherosclerotic CAD is the presumed etiology in most cases and medical therapy may be warranted in patients with MINS to mitigate postoperative cardiovascular risks. For additional details, see the AHA scientific statement "Diagnosis and Management of Patients With Myocardial Injury After Noncardiac Surgery."[12]

Recommendation-Specific Supportive Text

1. Troponin surveillance may be reasonable in patients with known CVD, cardiovascular risk factors, and in individuals undergoing high-risk surgery to identify patients at elevated risk of postoperative events.[14] In a prospective cohort study of 21 842 patients

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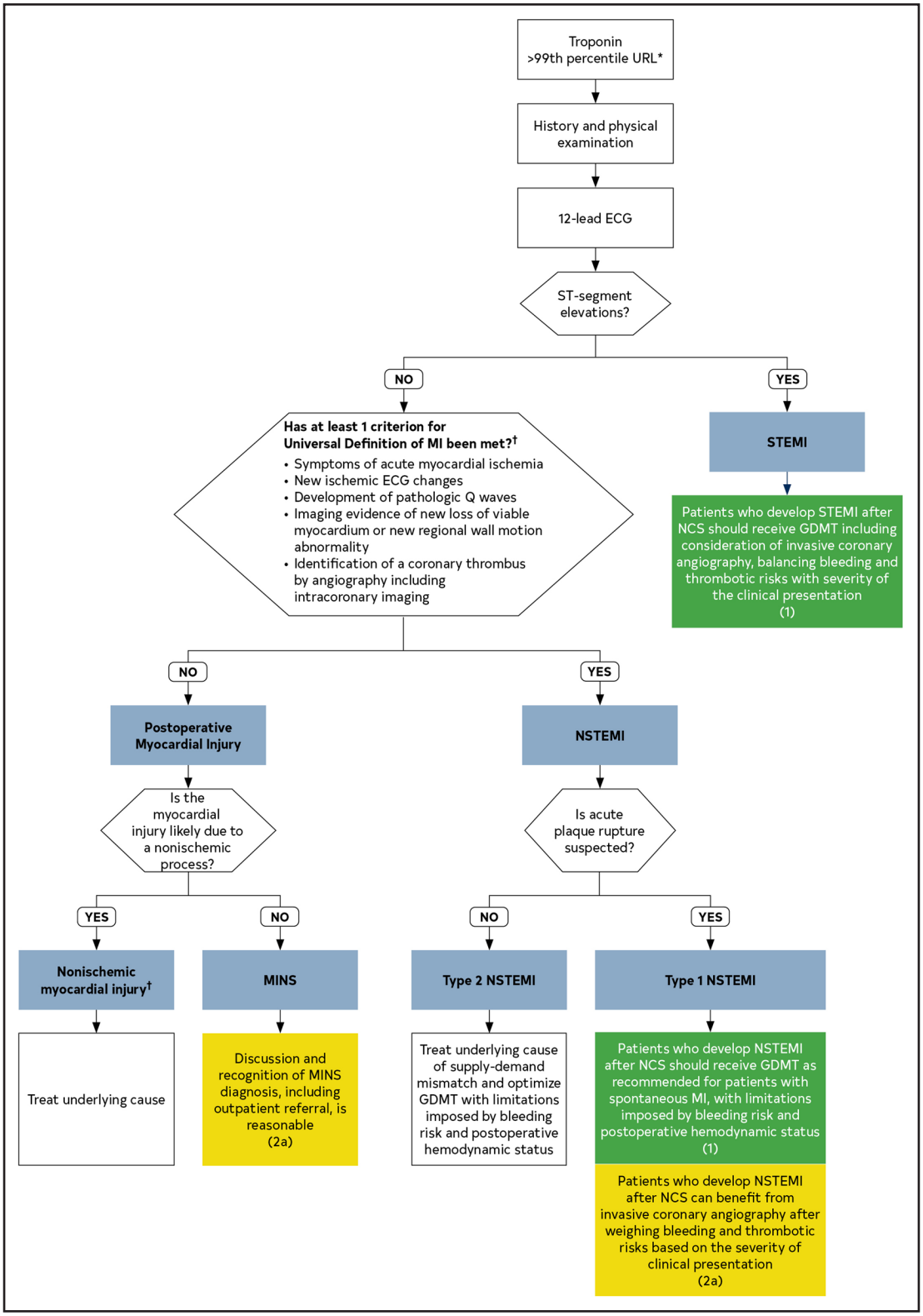


Figure 6. Evaluation of an Abnormal Troponin Obtained for Postoperative Surveillance.
*Presumes a rise and fall of troponin consistent with acute myocardial injury. Troponin may be measured using a conventional fourth-generation or a high-sensitivity assay. †Nonischemic myocardial injury encompasses pulmonary embolism, sepsis, acute decompensated heart failure, or acute stroke. Colors correspond to Class of Recommendation in Table 3. ECG indicates electrocardiogram/electrocardiographic GDMT, guideline-directed management and therapy; MI, myocardial infarction; MINS, myocardial injury after noncardiac surgery; NCS, noncardiac surgery; NSTEMI, non–ST-segment-elevation myocardial infarction; STEMI, ST-segment-elevation myocardial infarction; and URL, upper reference limit.

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aged ≥45 years undergoing high-sensitivity troponin T surveillance after NCS, elevated postoperative cTn without an ischemic feature was independently associated with a 3-fold greater hazard of 30-day mortality, while an elevated postoperative cTn with an ischemic feature was associated with a 5-fold greater hazard of 30-day mortality compared to patients without MINS.[1,15] Evaluating elevated-risk patients for MINS with serial troponin is recommended in the Fourth Universal Definition of MI and suggested in a recent AHA scientific statement.[12,13,18] To properly interpret elevated postoperative troponin concentrations, a baseline preoperative value, or serial postoperative measures, are useful to determine whether myocardial injury is acute or chronic. Based on availability, conventional fourth-generation or high-sensitivity cTn assays may be used for perioperative surveillance. Although surveillance of cTn is effective at identifying patients at >20% risk of cardiac events, the optimal management of patients with MINS remains uncertain and requires further study.[19] In elevated-risk patients with established ASCVD who are already receiving maximal GDMT for CAD, it is unclear whether a diagnosis of MINS will change the clinical management. A well-defined management strategy is urgently needed to inform effective approaches to postoperative cTn surveillance.

2. Data on troponin surveillance after NCS in low-risk populations are limited.[5,6] Given the low likelihood of perioperative cardiovascular events, troponin surveillance in asymptomatic individuals undergoing low-risk NCS is unlikely to identify myocardial injury or confer clinical benefit. Therefore, surveillance in low-risk populations should not be routinely performed.
3. Although the optimal management to reduce adverse cardiovascular events in patients with a diagnosis of MINS is uncertain, the prognostic impact is clear. Elevated postoperative cTn concentrations consistently identify surgical patients at increased risk for short- and long-term mortality. A single-center study of approximately 5000 patients found that patients with MINS who received cardiology consultation or transfer to a cardiology department had lower mortality in the first 30 days.[7] Another study identified early referral for cardiology consultation after a diagnosis of MINS to be associated with a significant reduction in early death.[8] Patients should be made aware of the MINS diagnosis during their surgical encounter. The optimal medical therapy for MINS is uncertain. In a small observational study of patients with MINS, intensification of cardiovascular medical therapy was associated with lower MACE at 1 year.[20] Data to support the use of antiplatelets and statins for presumed CAD in patients with MINS are based solely on observational cohorts. A post hoc analysis of the POISE study reported that among patients with perioperative MI, the use of aspirin and statins was associated with reduced 30-day mortality.[9] In another observational study (n=5109), postoperative statin use was associated with lower mortality at 1 year.[10] A role for statins in MINS may also be extrapolated from trials of nonsurgical patients with CVD and spontaneous MI.[21,22] In a prospective study, less than one-third of patients with MINS had intensification of GDMT for CVD.[14] Establishing the optimal medical therapy for MINS is an important evidence gap that requires further investigation.
4. Postoperative administration of DOACs may decrease the risk of long-term cardiovascular events. The MANAGE (Management of Myocardial Injury After Noncardiac Surgery) trial, the only RCT evaluating medical therapy for MINS, randomly assigned 1754 postsurgical patients to anticoagulation with dabigatran 110 mg twice daily versus placebo within 35 days of MINS. In this trial, dabigatran significantly decreased the composite of major vascular events without increasing major bleeding but was associated with excess minor and gastrointestinal bleeding. Furthermore, nearly one-half of all patients in both arms discontinued the study drug before study termination, and there was a post hoc change in the primary study outcomes due to slow enrollment and a reduced sample size. In a propensity-matched retrospective observational analysis of patients with MINS, antiplatelet therapy at hospital discharge was associated with a reduced risk of 1-year mortality.[11] Because increased preoperative expression of platelet- and coagulation-related genes has been identified as a risk factor for subsequent MINS, there is a plausible mechanistic hypothesis for the role played by antithrombotic agents.[23] Further investigation is needed to understand the pathophysiological mechanisms of MINS and to confirm the role of postoperative antithrombotic therapy in these patients.

9.2. Management of Postoperative STEMI/NSTEMI

Recommendations for Management of Postoperative STEMI/NSTEMI
Referenced studies that support the recommendations are summarized in the Online Data Supplement.

COR	LOE	Recommendations
1	B-NR	1. Patients who develop STEMI after NCS should be considered for GDMT, including consideration of ICA, balancing bleeding and thrombotic risks with the severity of the clinical presentation.[1–3]

Recommendations for Management of Postoperative STEMI/NSTEMI (Continued)		
COR	LOE	Recommendations
1	C-EO	2. Patients who develop NSTEMI after NCS should receive medical therapy as recommended for patients with spontaneous MI but after consideration of postoperative bleeding risks and hemodynamic status.
2a	C-LD	3. Patients who develop NSTEMI after NCS can be considered for ICA, balancing bleeding and thrombotic risks with the severity of clinical presentation.[2,3]

Synopsis

The incidence of perioperative MI ranges widely from 0.9% to 15% depending on the definitions, patient risk factors, and surgical type.[2,4–8] Patients presenting with perioperative MI after NCS are more likely to present with type 2 MI due to supply-demand mismatch compared with type 1 MI (eg, acute plaque rupture).[1,9,10] Recognition of MI may be difficult in the perioperative period because sedation and analgesia can limit patients' symptoms, the ability to report them, or both.[11] Patients with perioperative STEMI and NSTEMI have a substantial mortality risk, with nearly one-third of patients either dying or being readmitted at 30 days.[4,6,11–16] Risk factors for mortality include the peak cTn concentration, bleeding events, and the presence of peripheral artery disease.[13] Ideally, management of perioperative type 1 MI should include medical therapy as recommended for patients with spontaneous MI due to ASCVD. In patients with suspected type 2 MI, management should address the underlying cause of supply-demand mismatch (eg, hypertension, hypotension, tachycardia, anemia). Cardiac troponin elevation may also occur due to nonischemic causes, such as HF, sepsis, or pulmonary embolism. ICA may be indicated when acute coronary occlusion is suspected, after individualized risk stratification that accounts for factors including residual bleeding risk, type of surgery, and time since surgery. See Figure 6 for an algorithm depicting the diagnosis and management of patients with myocardial injury or infarction after NCS.

Recommendation-Specific Supportive Text

1. Perioperative STEMI due to acute plaque rupture occurs in a minority of patients with perioperative MI but is associated with in-hospital mortality of 30% to 35%.[1,2,11] GDMT for patients with perioperative STEMI should be promptly initiated, balancing the postoperative risks, which include bleeding and hypotension. Emergent ICA should be strongly considered, weighing bleeding and thrombotic risks with the severity of the clinical presentation. Patients with perioperative STEMI should have management decisions made in a team-based manner, including the surgeon, anesthesiologist, and cardiologist.
2. Patients with perioperative NSTEMI should receive GDMT as recommended for nonsurgical patients with spontaneous MI. In some cases, GMDT may need to be tailored based on hemodynamic status and bleeding risks. Medical therapy should include at least 1 antiplatelet, provided the benefits outweigh the bleeding risks, and initiation of a high-intensity statin. In patients whose hemodynamic status permits, beta blockers, ACEi, and nitrates may be considered for both symptomatic relief from angina and long-term cardiovascular risk reduction.
3. ICA may be appropriate in selected perioperative patients with postoperative NSTEMI. In retrospective observational analyses, invasive management of MI was associated with lower in-hospital mortality compared with conservative management.[2] However, given the potential need for systemic anticoagulation and longer-term antiplatelet therapies after PCI, the decision to pursue invasive treatment should be balanced with the risk of residual postoperative bleeding, type of surgery, and time since surgery. The severity of clinical presentation, peak cTn concentration, presence of ischemic electrocardiographic changes, and other patient-specific factors should also be considered.[3] Individuals with ongoing symptoms not responsive to GDMT, evidence of hemodynamic instability, persistent biomarker elevation, or imaging evidence of new regional wall motion abnormalities or reduced ventricular function may derive the greatest benefit from urgent ICA in the perioperative period. Decisions to pursue invasive management of MI after NCS should be undertaken in a team-based manner, involving the surgeon, anesthesiologist, and cardiologist.

10. SPECIAL POPULATIONS

10.1. Preoperative Evaluation Before Liver and Kidney Transplantation

Synopsis

Patients with end-stage kidney or liver disease have a higher prevalence of cardiovascular risk factors and CAD than the general population[1–6] and are at risk for other cardiovascular conditions, such as HF and PH.[7] Recent studies suggest that a targeted approach to preoperative screening for CAD before kidney transplantation appears to be associated with similar postoperative outcomes than with routine preoperative testing for CAD. Data from the US Renal Data System and Medicare claims reported that more frequent invasive or noninvasive CAD testing in the year before kidney transplantation was not associated with lower rates of 30-day posttransplant death or acute MI.[8] In the ISCHEMIA-CKD (International Study of Comparative Health Effectiveness With Medical and Invasive

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Approaches–Chronic Kidney Disease) trial, which enrolled nonsurgical adults with advanced CKD, CCD, and moderate to severe ischemia on stress testing, an initial invasive approach of coronary angiography with revascularization plus medical therapy did not reduce the risk of death or MI versus initial medical therapy alone at a median follow-up of 2.2 years.[9] The 2022 AHA scientific statement "Emerging Evidence on Coronary Heart Disease Screening in Kidney and Liver Transplantation Candidates"[1] summarizes the contemporary data and defines approaches to screening and management of CAD in candidates for kidney and liver transplantation.

10.2. Obesity and Bariatric Surgery

Synopsis

Obesity is a growing global epidemic and affects more than one-third of the US adult population.[1–3] Bariatric surgery is the most effective and long-lasting weight loss intervention for patients with body mass index ≥35 kg/m^2, resulting in significant weight loss and the improvement or resolution of obesity-related diseases, including type 2 diabetes, hypertension, and dyslipidemia.[4–6] In a population-based retrospective cohort study (n=2638), bariatric surgery was associated with a lower incidence of MACE in patients with CVD and obesity over a median 4.6-year follow-up.[7] Bariatric surgery patients tend to be young and may be selected for lower-risk features; however, bariatric surgery is not without risks. In large meta-analyses, perioperative MI was identified in 0.37% of bariatric surgeries, and the all-cause mortality rate was reported in 0.08%.[7–9] In a retrospective, multicenter study (n=494 611) of patients who underwent Roux-en-Y gastric bypass or sleeve gastrectomy,[10] prior cardiac history was associated with greater risks of perioperative cardiac arrest and 30-day mortality. In this study, sleeve gastrectomy was associated with fewer adverse events than Roux-en-Y. Another observational study of patients with obesity undergoing bariatric surgery reported that a history of ACS or HF was associated with increased risks of perioperative cardiovascular complications.[11] Thus, careful attention to history and risk factors during preoperative assessments is essential. Patients with obesity are increasingly prescribed GLP-1 receptor agonists to achieve weight loss. Considerations regarding the discontinuation of these drugs before NCS are addressed in Section 7.8 ("Perioperative Management of Blood Glucose").

11. COST–VALUE CONSIDERATIONS

11.1. Cost–Value Considerations

Health economics seeks to assess the value (eg, cost versus health benefit) associated with use of medical technology. For medical therapies, the relationship between technology use and value is direct; however, for diagnostic tests, the relationship is indirect and contingent. This is because diagnostic tests produce data that must be used by clinicians to create value.[1] The value of a diagnostic test may be substantially affected by variations in the clinical context of patient and surgical risk levels in which the medical test is performed. In some contexts, clinicians can use the medical test results to improve patient health. Here, value is driven by tradeoffs between the cost of the medical test and the resulting improvements in patient health (ie, cost-effectiveness). In other contexts, a clinician's knowledge of the test result does not lead to improvements in patient health, and in this instance, value may be created by not performing the test. Last, there are contexts in which administration of the diagnostic test may lead to patient harm (eg, incidental findings leading to additional testing, which may expose patients to additional risk or delays in treatment). These are also contexts in which value may be created by not performing the test. Thus, the key cost–value considerations for diagnostic tests are the cost of the medical test, the context of administration, and the extent to which clinicians can use the test results to improve patient health.

11.1.1. Cost–Value Considerations for Biomarkers

B-Type Natriuretic Peptide and N-Terminal Pro B-Type Natriuretic Peptide

Preoperative BNP or NT-proBNP levels can be used to evaluate perioperative risk for patients undergoing elevated-risk NCS with known CVD, CVD symptoms, or age ≥65 years with cardiovascular risk factors. However, there have been no studies that evaluated whether this information can be used by clinicians to improve patient outcomes and impact health care costs.[1] For this reason, the use of preoperative BNP or NT-proBNP for these patients has uncertain value (ie, relationship between medical cost and health benefit cannot be determined). Similarly, there is no evidence that measuring preoperative BNP or NT-proBNP levels for patients without CVD or cardiovascular risk factors scheduled for low-risk NCS will improve patient outcomes and impact health care costs. Besides the immediate cost savings, eliminating low-value BNP or NT-proBNP testing will eliminate the cascade of subsequent diagnostic testing.

Cardiac Troponin

Preoperative cTn levels can be used to evaluate perioperative risk for patients undergoing elevated-risk NCS with known CVD, CVD symptoms, or age ≥65 years with cardiovascular risk factors. However, there have been no studies that evaluated whether this information can be used by clinicians to improve patient outcomes and impact health care costs. For this reason, the use of preoperative cTn testing for patients undergoing elevated-risk NCS has uncertain value (ie, relationship between medical cost and health benefit cannot be determined).

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11.1.2. Cost–Value Considerations for 12-Lead ECG

The 12-lead ECG is an inexpensive diagnostic tool ($14.57 per 2022 Medicare reimbursement), and its use is considered cost-effective if it leads to modest improvements in patient health.[1] For patients undergoing elevated-risk NCS with active CVD symptoms or increased risk of MACE, the preoperative ECG is predictive of short-term mortality and MACE.[2–6] However, the value of ECGs in these situations is determined by whether it adds incremental risk assessment beyond the history and physical and whether clinicians are able to use electrocardiographic results to improve patient health. Although 1 study of 2967 patients undergoing NCS reported that the ECG did not improve postoperative death and MI prediction beyond risk factor information in the patient history, no studies have reported whether knowledge of electrocardiographic results in improved physician decision-making or leads to improvements in long-term patient clinical and economic outcomes.[4] For these reasons, the use of preoperative ECG for patients undergoing elevated-risk NCS has uncertain value (ie, relationship between medical cost and health benefit cannot be determined). In contrast, many studies agree that a routine preoperative ECG in low-risk patients undergoing low-risk NCS has little effect on patient outcomes and its elimination would be cost-saving.[7–10] Besides the immediate cost savings, a cascade of care is eliminated when a preoperative 12-lead ECG is not performed.[11,12]

11.1.3. Cost–Value Considerations for Coronary Computed Tomography Angiography

Although CCTA offers anatomic information for assessing myocardial ischemia, it has been associated with increased interventional coronary angiography and greater health care costs versus functional stress testing.[1] The PROMISE (A Randomized Comparison of Anatomic versus Functional Diagnostic Testing Strategies in Symptomatic Patients with Suspected Coronary Artery Disease) trial evaluated CCTA versus functional testing in symptomatic patients with suspected CAD and reported that CCTA did not improve clinical outcomes versus functional testing over a median of 2 years follow-up.[2] Average diagnostic testing costs were: exercise electrocardiography, $174; CCTA, $404; stress echocardiography: pharmacological, $501, exercise, $514; and nuclear testing: exercise, $946, and stress, $1132.[3] At 90 days, average costs were similar (CCTA, $2494 versus functional testing, $2240; difference, $254; 95% CI, −$634, $906), with CCTA resulting in more interventional cardiac procedures. Cumulative 3-year costs were also similar (CCTA, $7213; functional testing, $6586; difference, $627; 95% CI, −$463, $1609). A Markov microsimulation model study using PROMISE trial patient data compared CCTA supplemented with noninvasive functional flow reserve with functional testing and reported that CCTA with functional flow reserve was more efficient in ICA selection.[4] Over a patient's lifetime, CCTA with functional flow reserve versus functional testing provided greater quality-adjusted life years (25.15 versus 24.68; difference, 0.46; 95% CI, 0.44-0.49) and lower costs ($7222 versus $7989; difference, −$767; 95% CI, −$805 to −$729). Although important insights are provided by the PROMISE data, the study did not enroll patients undergoing evaluation before NCS, and caution must be used when extrapolating these findings to testing performed before NCS.

11.1.4. Cost–Value Considerations for Stress Testing

Although stress echocardiography has greater accuracy than electrocardiographic exercise testing (exercise ECG), it also costs more per use.[1] An RCT of diagnostic testing modalities in stable patients with suspected angina (not limited to NCS) with similar pretest CAD probabilities reported significant differences in test results. Exercise electrocardiographic results were 55.7% negative, 7.2% positive, and 37.1% inconclusive, whereas stress echocardiography results were 94.8% negative, 4.7% positive, and 0.5% inconclusive.[2] Stress echocardiography was associated with fewer clinic and emergency visits, less coronary angiography (6.3% versus 13.4%; P=0.02), lower mean costs (P=0.04), and no difference in the composite of death, MI, unplanned revascularization, and hospitalization for chest pain (3.7% versus 3.2%; P=0.38) at 3 years.[3] Patients with good functional capacity and stable symptoms as well as low-risk patients undergoing low-risk NCS do not benefit from preoperative stress testing.[4,5] The PROMISE Minimal Risk Tool has been used to identify low-risk patients for diagnostic test deferral.[6,7] Simulated results demonstrate that deferral of diagnostic testing in low-risk patients may be associated with greater patient health benefits and lower costs.[7] Cost savings were −$749 (95% CI, −$1647 to −$158) in the PROMISE patients with 10% lowest risk and −$677 (95% CI, −$1333 to −$71) in the patients with 20% lowest risk. Although PROMISE data provide important insights, the study did not enroll patients undergoing evaluation before NCS, and caution must be used when extrapolating these findings to testing performed before NCS.

12. EVIDENCE GAPS AND FUTURE RESEARCH DIRECTIONS

Since the 2014 guideline was published, there have been numerous advancements in the perioperative management of patients undergoing NCS. However, a number of key questions in perioperative medicine remain, and knowledge gaps that should serve as areas of future research are described below.

Approaches to Perioperative Care Delivery and Assessment of Risk

- Few multidisciplinary care delivery models have been rigorously studied to assess the impact on perioperative testing (eg, appropriate use of noninvasive stress testing) or cardiovascular outcomes. Specifically, further study is required regarding the use of remote visits/telemedicine for preoperative assessments and for the coordination of specialty care for higher-risk patients.
- Evidence is lacking to support the use of one perioperative risk index over another. Additional data are needed to determine how risk scores may be best used to guide perioperative management and reduce postoperative MACE.

Perioperative Management

- Optimal approaches to BP assessment, thresholds, and measurement frequency most appropriate to guide perioperative care have not been established. High-quality RCTs are needed to identify specific perioperative BP thresholds associated with a reduced incidence of adverse cardiovascular outcomes.
- There are no RCTs evaluating perioperative rate versus rhythm control strategies in patients with new-onset AF undergoing NCS. Additional studies are needed to address the optimal surveillance and management of postoperative AF.
- There is limited evidence to support coronary revascularization before NCS in stable patients, nor are there RCTs documenting improved outcomes in high-risk patients undergoing revascularization before major NCS.
- Limited data are available to guide the optimal timing of NCS after LVAD implantation.
- In patients with recent stroke, the optimal time delay before elective NCS is uncertain. The excess cardiovascular and cerebrovascular risks imposed by NCS in patients with recent stroke are not well-defined.

Preoperative Evaluation

- In the absence of indications beyond an isolated preoperative elevation in troponin concentration, there is no evidence that further testing (eg, stress test or coronary artery catheterization) is beneficial.
- No studies have reported whether knowledge of electrocardiographic results improve clinician decision-making or lead to improvements in long-term patient clinical and economic outcomes.
- Data are lacking to support routine preoperative assessment of LV function (eg, routine use of FoCUS, echocardiography) in stable patients undergoing NCS.

Perioperative Medical Therapy

- There are limited high-quality data regarding DAPT management for patients who have had elective NCS after balloon angioplasty alone without placement of a stent, after TAVI, or after TEER.
- The efficacy and safety of shorter durations of DAPT after PCI in patients undergoing NCS requires further study.
- Large RCTs are needed to elucidate the role of perioperative statin initiation on long-term outcomes, in lower-risk patients or procedures, and to define the ideal timing, medication, and dosing regimens (eg, reloading).
- No data currently exist regarding the perioperative role (harm or benefit) of the angiotensin receptor/neprilysin inhibitor, sacubitril/valsartan. Given the important role of RAASi in preventing MI, stroke, HF, and declines in kidney function, large RCTs are needed to determine preoperative management of RAASi for patients planned for NCS.
- Large RCTs are needed to evaluate both the risk and benefits of omission, continuation, or initiation of CCBs in the perioperative patient.
- Perioperative continuation of chronic alpha-2 receptor agonists therapy has not been addressed in RCTs.
- There are no established data for the use of glycoprotein IIB/IIIA inhibitors as a bridging strategy in patients undergoing NCS.
- The optimal approach to beta-blocker initiation in the perioperative period remains unknown, including the identification of patient subgroups who may derive the greatest benefit, medication selection, the timing of beta-blocker initiation with respect to surgery, and the safety of preoperative dose titration.
- Challenges in the perioperative care of patients with diabetes mellitus include assessing markers of glucose control that predict postoperative outcomes, selection of methods to control perioperative glucose, and the perioperative management of old and new diabetic agents as few studies address optimal perioperative blood glucose levels or timing of reinitiation of SGLT2i after surgery.
- Further research is needed, but advisories suggest GLP-1 agonists should be held for 1 dose before elective NCS to reduce the risk of pulmonary aspiration of gastric contents at the time of surgery.

Intraoperative Management

- Data supporting the effectiveness of routine use of intraoperative TEE during noncardiac procedures is limited.
- Currently, there is no high-quality evidence to support the routine use of MCS in patients at risk for cardiogenic shock undergoing NCS.

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- There are no large RCTs demonstrating that PA catheters improve patient outcomes or are cost effective.

Perioperative Surveillance

- MINS is an underrecognized clinical dilemma requiring further investigation to understand its underlying pathophysiological mechanisms. There are limited data regarding optimal therapy for risk mitigation after the diagnosis of MINS, including the use of antiplatelet agents and statins.

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ARTICLE INFORMATION

This document was approved by the American College of Cardiology Clinical Policy Approval Committee and the American Heart Association Science Advisory and Coordinating Committee in May 2024, the American College of Cardiology Science and Quality Committee in July 2024, and the American Heart Association Executive Committee in August 2024. It was reviewed by the Surveillance Committee in February 2026 and subsequently reaffirmed by the Joint Committee on Clinical Practice Guidelines in March 2026.

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This 2026 guideline replaces the 2024 perioperative guideline. The Surveillance Committee evaluated the evidence published through March 2026 and determined that the 2024 guideline remains valid and current. No new evidence was identified that changed the existing recommendations; the recommendations, supportive text, figures, tables, and references are identical to those in the 2024 publication. Details of the process are described in the 2026 ACC/AHA Methodology and Policies Manual.

*Writing committee members are required to recuse themselves from voting on sections to which their specific relationships with industry may apply; see Appendix 1 for detailed information.

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1.5. Definitions of Surgical Timing and Risk

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Appendix 1. Author Relationships With Industry and Other Entities—2024 AHA/ACC/ACS/ASNC/HRS/SCA/SCCT/SCMR/SVM Guideline for Perioperative Cardiovascular Management for Noncardiac Surgery

Committee Member	Employment	Consultant	Speakers Bureau	Ownership/ Partnership/ Principal	Personal Research	Institutional, Organizational, or Other Financial Benefit	Expert Witness
Annemarie Thompson, Chair	Duke University Hospital–Professor of Anesthesiology, Medicine, and Population Health Sciences; Director, Anesthesiology Residency Program, ASA Perioperative Medicine Education Track Chair, Division of Cardiothoracic Anesthesiology and Critical Care	None	None	None	None	None	None
Kirsten E. Fleischmann, Vice Chair	UCSF School of Medicine–Professor of Clinical Medicine; Assistant Chair of Medicine for Faculty Experience; Associate Chief of Cardiology for Faculty Experience; Medical Director, Adult Cardiac Stress & ECG Laboratories, UCSF Health	None	None	None	NOT RELEVANT • ADA grant, PI*	NOT RELEVANT • Massachusetts Medical Society • NIH, Co-I† • PCORI • UCSF Health, Medical Director ECG/Stress Lab†	None
Nathaniel R. Smilowitz, Vice Chair	NYU Langone Health, NYU School of Medicine–Assistant Professor of Medicine, Interventional Cardiology, The Leon H. Charney Division of Cardiology	RELEVANT • Abbott†	None	None	None	NOT RELEVANT • Abiomed‡ • AHA/Sarah Ross Soter Center for Women's Cardiovascular Research at NYU Grossman School of Medicine‡ • BioCardia‡ • DOD/University of Florida‡ • NHLBI/NIH‡	None
Niti R. Aggarwal	Mayo Clinic–Assistant Professor of Medicine, Consultant, Department of Cardiovascular Disease	None	None	None	None	None	None
Faraz S. Ahmad	Northwestern University Feinberg School of Medicine–Assistant Professor of Medicine (Cardiology)	NOT RELEVANT • Teladoc Livongo† RELEVANT • Pfizer	None	NOT RELEVANT • Healthority*	NOT RELEVANT • AHA† • Atman Health† • CDC† • Duke University School of Medicine† • NIH† • PCORI† RELEVANT • Pfizer	None	None

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Committee Member	Employment	Consultant	Speakers Bureau	Ownership/ Partnership/ Principal	Personal Research	Institutional, Organizational, or Other Financial Benefit	Expert Witness
Robert B. Allen	Juris Doctor heart surgery patient (septal myectomy); AHA volunteer-SW Region Board; Prior Chair, Corporate Operations Coordinating Committee	None	None	None	None	None	None
S. Elissa Altin	Yale School of Medicine–Assistant Professor	None	None	None	RELEVANT • Boston Scientific	NOT RELEVANT • Bard‡ • Cardiovascular Systems, Inc.‡ • MicroPort‡	None
Andrew Auerbach	UCSF, Division of Hospital Medicine–Professor of Medicine	None	None	NOT RELEVANT • ADviCE* • Kuretic*	None	NOT RELEVANT • AHRQ† • FDA† • NHLBI† • UpToDate†	None
Jeffrey S. Berger	NYU School of Medicine–Associate Professor of Medicine and Surgery; Director, Center for the Prevention of Cardiovascular Disease	RELEVANT • Amgen • Janssen Pharmaceuticals†	None	None	RELEVANT • Amgen	None	None
Benjamin Chow	University of Ottawa Heart Institute–Professor of Medicine (Cardiology and Nuclear Medicine) and Radiology	None	None	None	NOT RELEVANT • TD Bank† RELEVANT • Artrya† • Siemens*	None	None
Habib A. Dakik	American University of Beirut Medical Center–Professor of Medicine, Chief of Cardiology	None	NOT RELEVANT • GE Healthcare	None	None	None	None
Lisa de las Fuentes	Washington University School of Medicine in St. Louis–Professor of Medicine and Biostatistics	NOT RELEVANT • Acceleron • Aerovate • Altavant • Bayer • CVR Consulting† • Express Scripts • Gossamer • Impact PH† • Johnson & Johnson† • Liquidia • Merck • Sommetrics* • Vaderis • V-Wave • WebMD, LLC†	NOT RELEVANT • Ferrer • Simply Speaking†	None	NOT RELEVANT • Acceleron† • Altavant† • Bayer† • Gossamer† • Johnson & Johnson† • Medtronic† • PhaseBio† • Respira† • Trio Analytics† • United Therapeutics† • University of Kentucky (DSMB)* • University of Toronto (DSMB)* • Vaderis†	NOT RELEVANT • ACC* • AHA† • NIH† • PHA†	NOT RELEVANT • Plaintiff, patent infringement (Johnson & Johnson), 2022†

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Committee Member	Employment	Consultant	Speakers Bureau	Ownership/ Partnership/ Principal	Personal Research	Institutional, Organizational, or Other Financial Benefit	Expert Witness
Eric L. Eisenstein	Duke University–Associate Professor Emeritus in Medicine; University of Victoria, Canada–Adjunct Associate Professor, School of Health Information Science	None	None	None	NOT RELEVANT • Burroughs Wellcome Fund–Innovation in Regulatory Science† • Eunice Kennedy Shriver National Institute of Child Health and Human Development* • NCATS* • NHLBI* • NIH*	NOT RELEVANT • EHR2EDC (Sanofi)†	None
Marie Gerhard-Hermann	Harvard Medical School–Associate Professor	None	None	None	NOT RELEVANT • Progeria Research Foundation†	NOT RELEVANT • ABIM, Cardiovascular Exam Committee • NIH, NCATS	None
Kamrouz Ghadimi	Duke University School of Medicine–Associate Professor, Anesthesiology & Critical Care; Director, Clinical Research Unit, Department of Anesthesiology	None	None	None	NOT RELEVANT • IARS† • Octapharma* • PCORI	None	None
Bessie Kachulis	Columbia University Medical Center–Professor of Anesthesiology; Director of Evidence Based Medicine, Cardiothoracic Anesthesiology	None	None	None	None	None	None
Jacinthe Leclerc	Université Laval–Scientist; Quebec Heart & Lung Institute–Adjunct Professor of Pharmacy	None	None	None	None	NOT RELEVANT • JSS Medical Research (DSMB)	None
Christopher S. Lee	Boston College, William F. Connell School of Nursing–Barry Family/ Goldman Sachs Endowed Professor	None	None	None	NOT RELEVANT • NIH†	None	None
Tracy E. Macaulay	University of Kentucky College of Pharmacy–Clinical Professor of Pharmacy & Medicine	None	None	None	None	None	None
Gail Mates	AHA National Spokesperson, Go Red for Women; You're the Cure Committee Member; Health for Good Chair; Mission Board Member	None	None	None	None	None	None

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Committee Member	Employment	Consultant	Speakers Bureau	Ownership/ Partnership/ Principal	Personal Research	Institutional, Organizational, or Other Financial Benefit	Expert Witness
Geno J. Merli	Thomas Jefferson University Sidney Kimmel Medical College–Professor, Co-Director, Jefferson Vascular Center; Thomas Jefferson University Hospital–Senior VP, Associate CMO	NOT RELEVANT • LoweRisk, LLC*	None	None	RELEVANT • Bristol Myers Squibb/Pfizer*	None	None
Debabrata Mukherjee	Texas Tech University Health Science Center El Paso–Chief, Cardiovascular Medicine; Chairman, Department of Internal Medicine	NOT RELEVANT • ACC†	None	None	None	None	None
Purvi Parwani	Loma Linda University Health–Associate Professor of Medicine; Director, Echocardiography Laboratory	RELEVANT • Medtronic	RELEVANT • AstraZeneca	None	None	NOT RELEVANT • SCMR	None
Jeanne E. Poole	University of Washington–Professor of Medicine, Division of Cardiology	None	None	None	NOT RELEVANT • Boston Scientific (institutional research grant) RELEVANT • AtriCure • Biotronik† • Kestra, Inc.† • Medtronic	NOT RELEVANT • HRS†	None
Michael W. Rich	Washington University School of Medicine–Professor of Medicine	None	None	None	None	None	None
Kurt Ruetzler	Cleveland Clinic–Assistant Professor of Anesthesiology, Department of Anesthesiology	None	None	None	None	None	None
Steven C. Stain	Lahey Hospital and Medical Center–Chair, Department of Surgery	None	None	None	None	None	None

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Committee Member	Employment	Consultant	Speakers Bureau	Ownership/ Partnership/ Principal	Personal Research	Institutional, Organizational, or Other Financial Benefit	Expert Witness
BobbieJean Sweitzer	University of VA INOVA Health–Professor, Medical Education	NOT RELEVANT • UpToDate	None	None	None	NOT RELEVANT • IARS†	NOT RELEVANT • Defendant, elderly man died of aspergillosis, 2022† • Defendant, elderly man developed bradycardia during GA, 2022 • Plaintiff, hypoxic encephalopathy after NPPE after airway obstruction, 2022 • Plaintiff, patient with extreme obesity and OSA had to be intubated urgently in ED, 2021 • Plaintiff, patient died after massive intraoperative hemorrhage during back surgery, 2021 • Plaintiff, elderly woman having elective spine surgery bled to death, 2021 • Plaintiff, ischemic optic neuritis with visual loss, 2021 • Plaintiff, patient had arm injury during transport from procedure room to the recovery room, 2021 • Plaintiff, cardiac arrest after general anesthesia for shoulder surgery, 2021
Amy W. Talbot§	AHA/ACC Science and Health Advisor, Guidelines	None	None	None	None	None	None
Saraschandra Vallabhajosyula	Warren Alpert Medical School of Brown University and Lifespan Cardiovascular Institute–Assistant Professor of Medicine, Division of Cardiology, Department of Medicine; Medical Director, Cardiac Intensive Care Unit and Inpatient Services	None	None	None	None	NOT RELEVANT • Abiomed‡ • Tufts University‡	None

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Committee Member	Employment	Consultant	Speakers Bureau	Ownership/ Partnership/ Principal	Personal Research	Institutional, Organizational, or Other Financial Benefit	Expert Witness
John Whittle	University College London Hospitals–Clinical Lead, Perioperative Medicine (Critical Care) and Prehabilitation; Honorary Associate Professor & Lead for Perioperative Translational Medicine	NOT RELEVANT • EBPOM • Predicate HPG • SplendoHealth	None	None	None	NOT RELEVANT • Baxter • InBody • PhysioFlow • UCLH Charity • UK NIH	None
Kim Allan Williams, Sr.	University of Louisville School of Medicine–Chair, Department of Internal Medicine	None	None	None	None	None	None

This table represents all relationships of committee members with industry and other entities that were reported by authors, including those not deemed to be relevant to this document, at the time this document was under development. The table does not necessarily reflect relationships with industry at the time of publication. A person is deemed to have a significant interest in a business if the interest represents ownership of ≥5% of the voting stock or share of the business entity, or ownership of ≥$5000 of the fair market value of the business entity; or if funds received by the person from the business entity exceed 5% of the person's gross income for the previous year. Relationships that exist with no financial benefit are also included for the purpose of transparency. Relationships in this table are modest unless otherwise noted. Please refer to https://www.acc.org/guidelines/about-guidelines-and-clinical-documents/relationships-with-industry-policy for definitions of disclosure categories or additional information about the ACC/AHA Disclosure Policy for Writing Committees.

*No financial benefit.

†Significant relationship.

‡This disclosure was entered under the Clinical Trial Enroller category in the ACC's disclosure system. To appear in this category, the author acknowledges that there is no direct or institutional relationship with the trial sponsor as defined in the (ACCF or AHA/ACC) Disclosure Policy for Writing Committees.

§Amy Talbot is an ACC/AHA joint staff member and acts as the Science and Health Advisor. No relevant relationships to report. Nonvoting author on measures and not included/counted in the RWI balance for this committee.

ABIM indicates American Board of Internal Medicine; ACC, American College of Cardiology; ADA, Americans with Disabilities; AHA, American Heart Association; AHRQ, Agency for Healthcare Research and Quality; ASA, American Society of Anesthesiologists; CDC, Centers for Disease Control and Prevention; CMO, chief medical officer; Co-I, co-investigator; DOD, US Department of Defense; DSMB, data and safety monitoring board; ECG, electrocardiogram; ED, emergency department; EBPOM, Evidence Based Perioperative Medicine; EHR2EDC, Electronic Health Records to Electronic Data Capture systems; FDA, US Food and Drug Administration; GA, general anesthesia; HRS, Heart Rhythm Society; IARS, International Anesthesia Research Society; NCATS, National Center for Advancing Translational Sciences; NHLBI, National Heart, Lung, and Blood Institute; NIH, National Institutes of Health; NPPE, negative pressure pulmonary edema; NYU, New York University; OSA, obstructive sleep apnea; PCORI, Patient-Centered Outcomes Research Institute; PHA, Pulmonary Hypertension Association; PI, Principal Investigator; SCMR, Society for Cardiovascular Magnetic Resonance; SW, Southwest; UCLH, University College London Hospitals; UCSF, University of California, San Francisco; UK, United Kingdom; VA, Virginia; and VP, vice president.

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Appendix 2. Peer Review Committee Relationships With Industry and Other Entities—2024 AHA/ACC/ACS/ASNC/HRS/SCA/SCCT/SCMR/SVM Guideline for Perioperative Cardiovascular Management for Noncardiac Surgery

Reviewer	Employment	Consultant	Speakers Bureau	Ownership/ Partnership/ Principal	Personal Research	Institutional, Organizational, or Other Financial Benefit	Expert Witness
Jacqueline E. Tamis-Holland, Chair	Cleveland Clinic	None	• EBIX	None	• Concepts Medical* • CORSIRA II trial, Investigator	• AHA* • NYS*	None
Marietta Ambrose	University of Pennsylvania	None	None	None	None	None	None
Danielle Blais	Ohio State University Wexner Medical Center	None	None	None	None	None	None
Jeanna Blitz	Noridian Healthcare Solutions	• Guidepoint • Providence Anesthesia Associates • Society for Advancement of Patient Blood Management	None	None	None	• Caption Health* • Society for Perioperative Assessment and Quality Improvement*	None
Renee Bullock-Palmer	Deborah Heart and Lung Center	None	None	None	None	• Abbott • AHA* • Amgen • ASNC* • IAC, Board of Directors*	None
Shea E. Hogan	Denver Health	None	None	None	None	• ACC • CPC Clinical Research†	• Plaintiff (State of Colorado), review of standard of care, 2023 • Plaintiff (Rieback Legal, Inc.), 2023 • Plaintiff (Round Table), case review 2023
Michelle M. Kittleson	Cedars-Sinai Smidt Heart Institute	None	• Encore Medical Education*	None	None	• Actelion‡ • Eidos Therapeutics‡ • Gilead/One Legacy/Baylor‡ • *Journal of Heart and Lung Transplantation** • NIH‡ • Sanofi (Genzyme Corporation)‡ • United Therapeutics‡	None
Clauden Louis	BayCare Medical System; Winter Haven Hospital; Bostick Heart Center	None	None	None	None	None	None

(*Continued*)

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Appendix 2. Continued

Reviewer	Employment	Consultant	Speakers Bureau	Ownership/ Partnership/ Principal	Personal Research	Institutional, Organizational, or Other Financial Benefit	Expert Witness
Elizabeth Magnuson	Saint Luke's Mid America Heart Institute	None	None	None	None	• Abbott† • ACC • AHA* • Ancora Heart† • Corvia† • Edwards Lifesciences† • NHLBI† • V-Wave†	None
Kanae Mukai (representing SCMR)	Salinas Valley Health	• Canon Medical Systems • Circle Cardiovascular Imaging	None	None	None	None	None
Grant Reed	Cleveland Clinic Foundation	• Boston Scientific† • Philips Healthcare	None	None	None	None	None
Jennifer Rymer (representing SVM)	Duke University	• Chiesi† • Medscape	None	None	• AHA† • Idorsia† • Novo Nordisk, Inc.† • Vascular Cures†	• Idorsia‡	None

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