CLINICAL RESEARCH STUDY

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Reevaluating the Cardiac Risk of Noncardiac Surgery Using the National Surgical Quality Improvement Program

Brandon R. Peterson, MD,[a] Antoinette Cotton,[b] Andrew J. Foy, MD[a]

[a]Penn State Heart and Vascular Institute, Penn State College of Medicine, Penn State Milton S. Hershey Medical Center, Hershey; [b]Eberly College of Science, Penn State University, State College, Penn.

ABSTRACT

BACKGROUND: As surgical techniques evolve and patient outcomes improve over time, a renewed analysis of the cardiac risk of noncardiac surgeries is needed. The goal of this study was to investigate and categorize the cardiac risk of elective noncardiac surgeries.

METHODS: This was a cohort study of surgical data and outcomes from the 2018 National Surgical Quality Improvement Program Participant Use Data File; 807,413 cases were analyzed after excluding non-elective, emergent, and cardiac surgeries. Postoperative major adverse cardiac events (MACE) were defined as 30-day all-cause mortality, myocardial infarction, or cardiac arrest. According to their 95% confidence intervals (CI) for postoperative MACE, surgeries were categorized as low risk (95% CI <1%), intermediate risk (95% CI above and below 1%), or elevated risk (95% CI ≥1%). Multivariable logistic regression analyses were performed to determine differences in the odds for postoperative MACE for the intermediate- and elevated-risk categories relative to the low-risk category while controlling for several risk factors of prognostic importance.

RESULTS: Postoperative MACE occurred in 4047/807,413 cases (0.50%), including in 1708/667,735 (0.26%) of the low-risk category, in 516/53,499 (0.96%) of the intermediate-risk category, and in 1823/86,179 (2.12%) of the elevated-risk category. The elevated-risk category accounted for 10.7% of total procedures and 45.1% of total postoperative MACE. Compared with the low-risk category, the multivariable adjusted risk of postoperative MACE was increased in the intermediate-risk category (adjusted odds ratio 2.35; 95% CI, 2.12-2.62) and the elevated-risk category (adjusted odds ratio 3.15; 95% CI, 2.92-3.39).

CONCLUSION: : Categorization of noncardiac surgeries according to cardiac risk may help to identify populations who are most likely to benefit from preoperative cardiac evaluation when indicated.

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KEYWORDS: Cardiac arrest; Myocardial infarction; Noncardiac surgery; Perioperative risk

INTRODUCTION

Recommendations from the appropriate use criteria for the evaluation of stable ischemic heart disease suggest that preoperative cardiac stress testing is rarely appropriate when used in the context of low-risk noncardiac surgery.[1] Guidelines for the preoperative evaluation of patients prior to noncardiac surgery recommend against routine preoperative cardiac testing in patients at low cardiac risk, as indicated by a 30-day postoperative incidence of death or myocardial infarction <1%.[2] Previous guidelines from the American College of Cardiology and American Heart Association, as well as current guidelines from the European Society of Cardiology (ESC) and European Society of Anaesthesiology (ESA), have described low-, intermediate-, and high-risk

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Requests for reprints should be addressed to Brandon R. Peterson, Penn State Heart and Vascular Institute, Penn State College of Medicine, 500 University Drive, Mail Code H047, Hershey, PA 17033.

E-mail addresses: bpeterson2@pennstatehealth.psu.edu MD

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categories of noncardiac surgery based on the expected incidence of postoperative myocardial infarction and cardiac arrest.[3,4] As surgical techniques have evolved and patient outcomes improve over time, however, it is unclear whether the categorizations of cardiac risk described in these guidelines remain accurate. The goal of our study was to reevaluate and newly categorize the cardiac risk of elective, nonemergent, noncardiac surgeries using patient data and outcomes from the American College of Surgeons National Surgical Quality Improvement Program (ACS NSQIP) database.

CLINICAL SIGNIFICANCE

- The cardiac risk of noncardiac surgeries has improved over time.
- Noncardiac surgeries may be risk stratified into low, intermediate, and elevated cardiac risk.
- Many noncardiac surgeries, previously categorized as elevated cardiac risk, were found to be low cardiac risk.
- Models assessing the cardiac risk of noncardiac surgery require periodic update as outcomes improve.

METHODS

We reviewed data from the 2018 ACS NSQIP Participant Use Data File (PUF). This database includes patient-level surgery data and 30-day surgical outcomes collected prospectively from 722 participating sites throughout the United States. We reviewed the most recently available ACS NSQIP PUF, which includes data for surgeries performed at participating sites from January through December 31, 2018.

We excluded data from cardiac surgeries and from surgeries that were designated in the PUF as either emergent or nonelective. Surgeries were then sorted into broad categories including: abdominal, endocrine, gynecologic, head/neck, orthopedic, spinal, superficial, thoracic, urologic, vascular, and other, similar to the approach described by Glance et al[5] in developing their surgical mortality risk model. Within each category, we grouped Current Procedural Terminology (CPT) codes based on anatomical position, procedure type, and surgical approach, consistent with CPT surgical groupings defined by the American Academy of Professional Coders.[6]

We extracted patient clinical risk factors for coronary artery disease including hypertension, diabetes mellitus, and smoking status. We also extracted data about preoperative creatinine, patient functional status (independent vs dependent), and American Society of Anesthesiologists physical status classification, which variables were previously identified as factors associated with postoperative myocardial infarction and cardiac arrest.[7] We also recorded patient age and sex, as well as preoperative white blood cell count and hematocrit. For patients in which age was recorded only as "90+" in the NSQIP PUF, an age of 90 years was assigned for analysis purposes.

We reviewed the PUF for incidence of postoperative major adverse cardiac events (MACE). We defined postoperative MACE as all-cause mortality, myocardial infarction, or cardiac arrest occurring within 30 days of surgery to reflect definitions of MACE and cardiac risk used in the American College of Cardiology/American Heart Association and the ESC/ESA perioperative guidelines.[2,3] For each surgical grouping, we used the Clopper-Pearson method to determine 95% confidence intervals (CI) for MACE. According to the 95% CI for postoperative MACE, surgical groups were categorized as low risk (95% CI <1%), intermediate risk (95% CI above and below 1%), or elevated risk (95% CI ≥1%).

Multivariable adjusted logistic regression analyses were performed for the purpose of determining the odds of postoperative MACE, and the odds of the individual components thereof, for the intermediate and elevated-risk categories relative to the low-risk category, while simultaneously controlling for various potentially confounding demographic and clinical risk factors. Surgical cases with missing variable data were excluded. Age, preoperative creatinine, preoperative hematocrit, and preoperative white blood cell count were evaluated as continuous variables in the logistic regression model. Reference values for the remaining categorical variables in the logistic regression analyses were assigned as follows: sex (female), hypertension (none), diabetes mellitus (none), smoking (none), functional class (independent), American Society of Anesthesiologists physical status class (≤2). SPSS was used for the data analysis (IBM SPSS Statistics for Windows, Version 27.0, IBM Corp, Armonk, NY).

This study was submitted to the Institutional Review Board at the Penn State College of Medicine and determined to be exempt from review.

RESULTS

The 2018 PUF data file included a total of 1,020,511 surgical cases, of which 807,413 cases were included in the analysis after excluding nonelective surgeries, emergent surgeries, and cardiac surgeries. Postoperative MACE were reported in 4047 of 807,413 patients (0.50%) undergoing elective, nonemergent noncardiac surgery. Patients with postoperative MACE were more likely to be male, to be older, and to have higher creatinine, higher white blood cell count, and lower hematocrit compared with those without postoperative MACE. Patients with postoperative MACE were also more likely to smoke and to have diagnoses of hypertension and diabetes mellitus compared with patients without postoperative MACE. A detailed comparison of patient characteristics among those who did and did not experience postoperative MACE is shown in Table 1.

Eighty-seven groups of surgery were defined based on surgical category, anatomical location, and surgical approach. Of these, 40 were low risk (comprising 667,735 procedures), 29 were intermediate risk (comprising 53,499 procedures), and 18 were elevated risk (comprising 86,179

Table 1 Demographics and Clinical Risk Factors in Patients with and without MACE following Noncardiac Surgery

Patient Characteristics	MACE n = 4047	No MACE n = 803,366
Female, n (%)	1682 (41.6%)	467,868 (58.2%)
Age, years, mean ± SD	70.5 ± 11.5	56.7 ± 16.0
Hypertension, n (%)	2998 (74.1%)	353,079 (43.9%)
Diabetes mellitus, n (%)	1273 (31.5%)	118,947 (14.8%)
Smoking, n (%)	804 (19.9%)	121,368 (15.1%)
Functional status: Independent, n (%)	3632 (89.8%)	789,235 (98.2%)
ASA Physical Status Class ≥3, n (%)	3479 (86.0%)	352,425 (43.9%)
Creatinine, mg/dL, mean ± SD	1.35 ± 1.32	0.97 ± 0.75
White blood cell count, mean ± SD	8.24 ± 3.57	7.31 ± 2.52
Hematocrit, mean ± SD	37.8 ± 6.01	40.3 ± 4.73

ASA = American Society of Anesthesiologists; MACE = major adverse cardiac event.

procedures). Postoperative MACE were reported in 1708/667,735 (0.26%) of the low-risk category, in 516/53,499 (0.96%) of the intermediate-risk category, and in 1823/86,179 (2.12%) of the elevated-risk category. The elevated-risk category accounted for 10.7% of total procedures, and 45.1% of total postoperative MACE. Table 2, Table 3, and Table 4 show the incidence of postoperative MACE for the low-risk, intermediate-risk, and elevated-cardiac-risk categories, respectively.

When compared with the low-risk category, the intermediate-risk category had increased multivariable adjusted risk for postoperative MACE (adjusted odds ratio [aOR] 2.35; 95% CI, 2.12-2.62), myocardial infarction (aOR 1.76; 95% CI, 1.48-2.09), cardiac arrest (aOR 2.42; 95% CI, 1.97-2.98), and all-cause mortality (aOR 2.98; 95% CI, 2.59-3.43). The elevated-risk category, when compared with the low-risk category, had increased multivariable adjusted risk for postoperative MACE (aOR 3.15; 95% CI, 2.92-3.39), myocardial infarction (aOR 2.71; 95% CI, 2.42-3.02), cardiac arrest (aOR 3.64; 95% CI, 3.15-4.21), and all-cause mortality (aOR 3.59; 95% CI, 3.23-3.98).

DISCUSSION

An accurate understanding of the cardiac risk associated with noncardiac surgery is essential to inform individual and institutional protocols about the appropriate use of preoperative cardiac evaluation and testing. Using the NSQIP database, we stratified noncardiac surgeries into low-, intermediate-, and elevated-risk categories based on their incidence and 95% CI for postoperative MACE, which categories may be useful in identifying populations most likely to benefit from preoperative cardiac testing.

The need to reevaluate the cardiac risk of noncardiac surgeries is essential as patient outcomes continue to improve over time. Using the Nationwide Inpatient Sample, Semel et al[8] found a significant decrease in 30-day postoperative mortality following cardiac and noncardiac surgeries over time (1.68% in 1996 to 1.32% in 2006). Smilowitz et al[9] analyzed 10,581,621 noncardiac surgeries over a 10-year period from 2004 to 2013 and similarly found improved outcomes, including a 0.5% reduction (3.1% to 2.6%) in major adverse cardiovascular and cerebrovascular events. Campos et al[10] found that, as bariatric surgery evolved from an entirely open approach in 1993 to a primarily laparascopic approach in 2016, patient mortality (0.6% to 0.04%) and adverse cardiovascular and thromboembolic events (0.9% to 0.3%) significantly improved over that time period. Gupta et al,[7] in their study developing the NSQIP Myocardial Infarction and Cardiac Arrest risk calculator, found postoperative myocardial infarction and cardiac arrest to occur in 0.65% of patients in the NSQIP PUF from 2007, as compared with a 0.33% incidence of postoperative myocardial infarction and cardiac arrest in this study of the NSQIP PUF from 2018. With improving outcomes over time, cardiac risk models likely require periodic re-calibration and validation with newer datasets to ensure continued accurate discrimination of perioperative cardiac outcomes.

We found similarities as well as important distinctions in our data, compared with existing models for categorizing the cardiac risk of noncardiac surgeries. For example, the Revised Cardiac Risk Index (RCRI) defines high-cardiac-risk surgery as intraperitoneal, intrathoracic, and suprainguinal vascular surgery.[11] We similarly found elevated-risk surgeries to be associated with the abdominal, thoracic, and vascular categories, in agreement with the RCRI. However, multiple abdominal/intraperitoneal procedures were also associated with a low risk of postoperative MACE, particularly in the setting of a laparoscopic approach, which otherwise would be inappropriately assigned as high risk using the RCRI model. Whether an adjustment to the assignment of high-risk surgery in the RCRI based on this recent data could improve discrimination of cardiac outcomes by the RCRI is worth further investigation.

The current ESC/ESA perioperative guidelines indicate that major orthopedic surgeries such as hip surgery and spine surgery, as well as major urological and gynecological procedures, are associated with postoperative MACE in the range of 1%-5%.[3] In contrast to this, with exceptions such as kidney and bladder surgery, as well as hip surgery excluding total hip arthroplasty, we found that procedures in the categories of orthopedic, spinal, urologic, and gynecologic surgery were most commonly associated with low risk (<1%) of postoperative MACE. Even surgeries with elevated postoperative MACE in our study, such as open esophageal surgery (3.6%; 95% CI, 2.7%-4.7%) and pneumonectomy (2.9%; 95% CI, 2.1%-3.8%) had lower adverse cardiac events than suggested in the ESC/ESA guidelines, which predict a postoperative MACE >5% for both of these procedures.[3] These discrepancies may result from improvement in surgical outcomes over time, as previously discussed. Additionally, data for the cardiac-risk categories in

Table 2 Sample Size and MACE Incidence for Low Risk Category of Noncardiac Surgeries

Operation	CPT Codes	Sample Size, n	MACE, n	MACE, %	95% CI, %
Abdominal					
Stomach, bariatric, laparoscopic	43644, 43645, 43770-43775	20,230	30	0.15%	0.10-0.21%
Intestine (except rectum), laparoscopic	44180-44238	32,766	278	0.85%	0.75-0.95%
Appendix, laparoscopic	44970-44979	3995	4	0.10%	0.03-0.26%
Gallbladder/biliary tract, laparoscopic	47562-47579	33,220	64	0.19%	0.15-0.25%
Hernia, open	49491-49611	56,349	114	0.20%	0.17-0.24%
Hernia, laparoscopic	49650-49659	31,288	78	0.25%	0.20-0.31%
Endocrine					
Thyroid	60000, 60100-60281, 60300	18,094	16	0.09%	0.05-0.14%
Parathyroid	60500-60512	5597	11	0.20%	0.10-0.35%
Adrenal, adrenalectomy, laparoscopic	60650	902	3	0.33%	0.07-0.97%
Gynecology					
Vulva, perineum, and introitus	56405-56821	1420	1	0.07%	0-0.39%
Vagina	57000-57426	10,514	9	0.09%	0.04-0.16%
Uterus (except hysterectomy), open	58100-58146, 58300-58356, 58400-58540	2921	1	0.03%	0-0.19%
Uterus, hysterectomy, open	58150-58294	19,786	49	0.25%	0.18-0.33%
Uterus, laparoscopic/hysteroscopic	58541-58674	42,224	36	0.09%	0.06-0.12%
Ovary/oviduct, laparoscopic	58660-58679	13,538	6	0.04%	0.02-0.10%
Ovary/oviduct, open	58600-58615, 58700-58960	4254	28	0.66%	0.44-0.95%
Head/Neck					
Lips, mouth, tongue, palate, and uvula	40490-42299	1988	7	0.35%	0.14-0.72%
Salivary glands and ducts	42300-42699	2480	7	0.28%	0.11-0.58%
Pharynx, adenoids, and tonsils	42700-42999	6036	3	0.05%	0.01-0.15%
Ear, auditory system	69000-69979	1901	0	0.00%	0-0.19%*
Orthopedic					
Musculoskeletal, head	21010-21499	1331	4	0.30%	0.08-0.77%
Shoulder, upper arm, and elbow	23000-24802, 24999	14,740	36	0.24%	0.17-0.34%
Forearm, wrist, hand, and fingers	25000-25695, 26115-26785, 26989	12,182	10	0.08%	0.04-0.15%
Hip, total hip arthroplasty	27130, 27132	39,519	152	0.38%	0.33-0.45%
Thigh, knee (except total knee replacement), leg, ankle, foot, and toes	27301-27446, 27448-27580, 27599-27848, 27892-28446	19,224	48	0.25%	0.18-0.33%
Knee, total knee arthroplasty	27447	64,425	194	0.30%	0.26-0.35%
Musculoskeletal, arthroscopy/endoscopy	29800-29999	36,999	18	0.05%	0.03-0.08%
Spine					
Spine (except arthrodesis or laminectomy)	22010-22328, 22840-22899, 63300-63308, 63700-63710	2736	11	0.40%	0.20-0.72%
Spine, arthrodesis (fusion)	22532-22634, 22800-22819, 22830	25,611	126	0.49%	0.41-0.59%
Spine, laminectomy	62380, 63001-63295	25,688	80	0.31%	0.25-0.39%
Superficial					
Skin and integumentary system	11000-11047, 11960, 14000-15999	10,461	68	0.65%	0.51-0.82%
Breast	19000-19126, 19281-19396, 19499	61,901	40	0.06%	0.05-0.09%
Lymph nodes and lymphatic channels	38300-38999	2971	17	0.57%	0.33-0.91%
Urology					
Kidney, laparoscopic	50541-50549	8872	53	0.60%	0.45-0.78%
Urethra	53000-53899	1376	2	0.15%	0.02 — 0.52%
Prostate, transurethral resection	52601, 52648	9720	39	0.40%	0.29-0.55%
Prostate (except transurethral resection)	55700-55866, 55873	12,487	46	0.37%	0.27-0.49%
Male genital (except prostate)	54000-55680, 55899	4372	9	0.21%	0.09-0.39%
Vascular					
Artery/vein, ligation	37565-37785	2686	8	0.30%	0.13-0.59%
Other					
Nerves	64553-64913	931	2	0.21%	0.03-0.77%

CI = confidence interval; CPT = Current Procedural Terminology; MACE = major adverse cardiac event.
*One-sided 97.5% confidence interval.

the ESC/ESA guidelines were derived from a study of postoperative mortality[5] and not of postoperative cardiac events, which may have resulted in an inaccurate categorization of cardiac risk as described in the guidelines.

Table 3 Sample Size and MACE Incidence for Intermediate Risk Category of Noncardiac Surgeries

Operation	CPT Codes	Sample Size, n	MACE, n	MACE, %	95% CI, %
Abdominal					
Spleen, splenectomy, open	38100-38115	170	4	2.35%	0.64-5.91%
Spleen, splenectomy, laparoscopic	38120-38129	381	3	0.79%	0.16-2.27%
Esophagus, laparoscopic	43279-43289	8057	67	0.83%	0.65-1.05%
Stomach (except bariatric), laparoscopic	43651, 43659	811	5	0.62%	0.20-1.43%
Stomach, bariatric, open	43842-43848	354	1	0.28%	0.01-1.56%
Intestine (except rectum or colectomy), open	44005-44139, 44300-44799	9321	111	1.19%	0.98-1.43%
Meckel's diverticulum and mesentery	44800 — 44899	54	2	3.70%	0.44-12.30%
Appendix, open	44900, 44950-44960	203	0	0.00%	0-1.80%*
Liver (except hepatectomy), open	47000-47015, 47300-47362, 47380-47399	129	0	0.00%	0-2.82%*
Liver, laparoscopic	47370-47379	772	5	0.65%	0.21-1.50%
Pancreas (except pancreatectomy)	48500-48548, 48999	430	4	0.93%	0.25-2.34%
Abdomen, peritoneum, and omentum, laparoscopic	49320-49329	3697	36	0.97%	0.68-1.35%
Endocrine					
Thymus, carotid body, and endocrine other	60520-60522, 60600, 60605, 60659, 60699	186	0	0.00%	0-1.96%*
Adrenal, adrenalectomy, open	60540, 60545	162	0	0.00%	0-2.25%*
Gynecology					
Cervix	57452-57800	64	0	0.00%	0-5.60%*
Ectopic pregnancy, abdominal hysterotomy, postpartum curettage	59100-59160	181	0	0.00%	0-2.02%*
Head/Neck					
Larynx	31300-31599	497	7	1.41%	0.57-2.88%
Orthopedic					
Musculoskeletal, other	20005-20999	947	4	0.42%	0.12-1.08%
Neck (soft tissues) and thorax	21501-21899	493	1	0.20%	0.01-1.12%
Thoracic					
Chest wall	19260-19272	112	1	0.89%	0.02-4.87%
Trachea and bronchi	31600-31899	96	0	0.00%	0-3.77%*
Lungs and pleura, thoracoscopy	32601-32674	7146	75	1.05%	0.83-1.31%
Mediastinum and diaphragm	39000-39599	196	1	0.51%	0.01-2.81%
Urology					
Ureter	50600-50980	445	4	0.90%	0.25-2.29%
Vascular					
Artery/vein, embolectomy/thrombectomy	34001-34490	201	5	2.49%	0.81-5.71%
Artery/vein, other	34501-34530, 35180-35286, 35691-37218, 37500-37501, 37788-37799	3637	28	0.77%	0.51-1.11%
Other					
Colon, rectum, and anus	45000-45999, 46020-46999	7717	77	1.00%	0.79-1.25%
Intersex	55970-55980	86	0	0.00%	0-4.20%*
Skull, meninges, and brain	61304-62148	6954	75	1.08%	0.85-1.35%

CI = confidence interval; CPT = Current Procedural Terminology; MACE = major adverse cardiac event.
*One-sided 97.5% confidence interval.

Updated estimation of surgical risk categories will help clinicians to appropriately apply preoperative societal recommendations and appropriate use criteria in the setting of patients undergoing low-risk noncardiac surgery. For example, the Multimodality Appropriate Use Criteria for the Detection and Risk Assessment of Stable Ischemic Heart Disease provide specific criteria for the use of preoperative cardiac testing in patients undergoing low-risk or intermediate-risk noncardiac surgery, without specifying what surgeries are associated with low cardiac risk or intermediate cardiac risk.[1] Additionally, societal guidelines in the Choosing Wisely campaign describe multiple scenarios in which preoperative cardiac testing is inappropriate prior to low-cardiac-risk procedures,[12] without specifying which procedures should be considered low cardiac risk. Categorizations described in this study may help to clarify which noncardiac surgeries are associated with low risk of postoperative MACE to avoid overuse of preoperative cardiac testing.

Table 4 Sample Size and MACE Incidence for Elevated-Risk Category of Noncardiac Surgeries

Operation	CPT Codes	Sample Size, n	MACE, n	MACE, %	95% CI, %
Abdominal					
Abdomen, peritoneum, and omentum, open	22999, 49000-49255, 49400-49465, 49900-49999	3292	52	1.58%	1.18-2.07%
Esophagus, open	43020-43135, 43300-43425	1508	54	3.58%	2.70-4.65%
Stomach (except bariatric) open	43500-43641, 43800-43840, 43850-43999	1783	33	1.85%	1.28-2.59%
Intestine, colectomy, open	44140-44160	11866	189	1.59%	1.38%-1.83%
Liver, hepatectomy	47100-47130	5576	120	2.15%	1.79-2.57%
Gallbladder/biliary tract, open	47400-47556, 47600-47999	1407	32	2.27%	1.56-3.20%
Pancreas, pancreatectomy	48100-48160	8010	202	2.52%	2.14-2.82%
Orthopedic					
Hip (except total hip arthroplasty)	26990-27125, 27134-27286, 27299	4977	85	1.71%	1.37-2.11%
Thoracic					
Lungs and pleura (except thoracoscopy and pneumonectomy)	32035 — 32408, 32550-32562, 32701-32999	294	15	5.10%	2.89-8.28%
Lungs and pleura, pneumonectomy	32440-32540	1782	51	2.86%	2.14-3.75%
Urology					
Kidney, open	50010-50540	2836	50	1.76%	1.31-2.32%
Bladder	51020-52500, 52630-52647, 52649-52700	13947	169	1.21%	1.04-1.41%
Vascular					
Amputation (upper and lower extremity)	24900-24940, 25900-25931, 26910-26952, 27290-27295, 27590-27598, 27880-27889, 28800-28805	2228	78	3.50%	2.78-4.35%
Aorta/artery, endovascular repair	34701-34834	3626	88	2.43%	1.95-2.98%
Aorta/artery, aneurysm repair/graft insertion	35001-35152	1158	64	5.53%	4.28 — 7.00%
Artery, thromboendarterectomy	35301-35390	9953	179	1.80%	1.55-2.08%
Artery, bypass graft	35501-35683	5288	231	4.37%	3.83-4.95%
Artery, endovascular revascularization	37220-37239	6648	131	1.97%	1.65-2.33%

CI = confidence interval; CPT = Current Procedural Terminology; MACE = major adverse cardiac event.

STRENGTHS AND LIMITATIONS

This study has a number of strengths, including incorporation of patient data and 30-day surgical outcomes collected from hundreds of institutions participating in the NSQIP database. Our study provides an important update in reporting categories of cardiac surgical risk compared wiith prior categorizations in major guidelines, which relied on either expert opinion or older surgical data. The surgical categories described in this manuscript include a broad range of procedures across multiple surgical specialties, and include distinctions in outcomes between open and laparoscopic surgical approaches.

Our study has a number of important limitations. For example, while many surgical procedures had thousands of data points in the NSQIP PUF, other less common procedures had significantly fewer data points, affecting the precision to which we could estimate cardiac risk in these procedures. Our study focused on elective, nonemergent procedures, and our results cannot be extrapolated to nonelective or emergent surgeries, which are likely to have relatively increased complications, including higher incidence of postoperative MACE. Postoperative troponin values are not systematically reported or collected in NSQIP, and therefore it is possible that postoperative myocardial infarction may be underestimated. Our study focused on postoperative myocardial infarction and cardiac arrest, while additional cardiovascular outcomes such as postoperative atrial fibrillation or congestive heart failure are not tracked in the NSQIP database and therefore were not included.

Beyond the surgical categories described here, factors such as patient age and comorbidities are associated with cardiac risk, and should be accounted for when determining individual patient risk. We demonstrated this in our study by showing significant differences in patient demographics and comorbidities between patients with and without MACE following noncardiac surgery, with many of these factors associated with increased risk of MACE on logistic regression analyses. NSQIP-based risk calculators such as the NSQIP Myocardial Infarction and Cardiac Arrest risk calculator and the Universal ACS Surgical Risk Calculator help to account for these differences by incorporating both patient and surgical risk factors to discriminate cardiac outcomes;[7,13] however, as previously discussed, both models may be subject to overestimation of cardiac risk as patient outcomes have improved over time.

CONCLUSION

Periodic re-evaluation of patient outcomes using current surgical data is essential to provide an accurate

understanding of the cardiac risk of elective, nonemergent noncardiac surgeries. In this study, we determined categories of low, intermediate, and elevated cardiac risk from the NSQIP database, which will help clinicians to guide preoperative cardiac testing and evaluation to patient populations who are most at risk for postoperative adverse cardiac events.

References

1. Wolk MJ, Bailey SR, Doherty JU, et al. ACCF/AHA/ASE/ASNC/HFSA/HRS/SCAI/SCCT/SCMR/STS 2013 multimodality appropriate use criteria for the detection and risk assessment of stable ischemic heart disease: a report of the American College of Cardiology Foundation Appropriate Use Criteria Task Force, American Heart Association, American Society of Echocardiography, American Society of Nuclear Cardiology, Heart Failure Society of America, Heart Rhythm Society, Society for Cardiovascular Angiography and Interventions, Society of Cardiovascular Computed Tomography, Society for Cardiovascular Magnetic Resonance, and Society of Thoracic Surgeons. *J Am Coll Cardiol* 2014;63(4):380–406.
2. Fleisher LA, Fleischmann KE, Auerbach AD, et al. 2014 ACC/AHA guideline on perioperative cardiovascular evaluation and management of patients undergoing noncardiac surgery: a report of the American College of Cardiology/American Heart Association Task Force on Practice Guidelines. *J Am Coll Cardiol* 2014;64(22):e77–e137.
3. Kristensen SD, Knuuti J, Saraste A, et al. 2014 ESC/ESA guidelines on non-cardiac surgery: cardiovascular assessment and management: the Joint Task Force on non-cardiac surgery: cardiovascular assessment and management of the European Society of Cardiology (ESC) and the European Society of Anaesthesiology (ESA). *Eur Heart J* 2014;35(35):2383–431.
4. Fleisher LA, Beckman JA, Brown KA, et al. ACC/AHA 2007 Guidelines on Perioperative Cardiovascular Evaluation and Care for Noncardiac Surgery A Report of the American College of Cardiology/American Heart Association Task Force on Practice Guidelines (Writing Committee to Revise the 2002 Guidelines on Perioperative Cardiovascular Evaluation for Noncardiac Surgery): developed in collaboration with the American Society of Echocardiography, American Society of Nuclear Cardiology, Heart Rhythm Society, Society of Cardiovascular Anesthesiologists, Society for Cardiovascular Angiography and Interventions, Society for Vascular Medicine and Biology, and Society for Vascular Surgery. *Circulation* 2007;116(17):e418–500.
5. Glance L, Lustik S, Hannan E, et al. The Surgical Mortality Probability Model: derivation and validation of a simple risk prediction rule for noncardiac surgery. *Ann Surg* 2012;255(4):696–702.
6. Codify by AAPC. CPT® Codes Lookup. Available at: https://www.aapc.com/codes/cpt-codes-range/. Accessed April 6, 2021.
7. Gupta PK, Gupta H, Sundaram A, et al. Development and validation of a risk calculator for prediction of cardiac risk after surgery. *Circulation* 2011;124(4):381–7.
8. Semel ME, Lipsitz SR, Funk LM, Bader AM, Weiser TG, Gawande AA. Rates and patterns of death after surgery in the United States, 1996 and 2006. *Surgery* 2012;151(2):171–82.
9. Smilowitz NR, Gupta N, Ramakrishna H, Guo Y, Berger JS, Bangalore S. Perioperative major adverse cardiovascular and cerebrovascular events associated with noncardiac surgery. *JAMA Cardiol* 2017;2(2):181–7.
10. Campos GM, Khoraki J, Browning MG, Pessoa BM, Mazzini GS, Wolfe L. Changes in utilization of bariatric surgery in the United States from 1993 to 2016. *Ann Surg* 2020;271(2):201.
11. Lee TH, Marcantonio ER, Mangione CM, et al. Derivation and prospective validation of a simple index for prediction of cardiac risk of major noncardiac surgery. *Circulation* 1999;100(10):1043–9.
12. Reed SJ, Pearson S. Choosing Wisely® recommendation analysis: prioritizing opportunities for reducing inappropriate care. Available at: https://www.choosingwisely.org/wp-content/uploads/2015/05/ICE-R_Preoperative-Stress-Testing.pdf. Accessed August 22, 2021.
13. Bilimoria KY, Liu Y, Paruch JL, et al. Development and evaluation of the universal ACS NSQIP surgical risk calculator: a decision aide and informed consent tool for patients and surgeons. *J Am Coll Surg* 2013;217(5) [833-842.e1-3.