Risks of noncardiac surgery early after percutaneous coronary intervention

Nathaniel R. Smilowitz, MD,[a,b] Jeffrey Lorin, MD,[a,b] and Jeffrey S. Berger, MD, MS[a,c] *New York, NY*

Abstract Background Prior registry data suggest that 4%-20% of patients require noncardiac surgery (NCS) within 2 years of percutaneous coronary intervention (PCI). Contemporary data on NCS after PCI in the United States among women and men are limited. We determined the rate of early hospital readmission for NCS and associated outcomes in a large cohort of patients who underwent PCI in the United States.

Methods Adults undergoing PCI between January 1 and June 30, 2014, were identified from the Nationwide Readmission Database. Patients readmitted for NCS within 6 months of PCI were identified. Outcomes of interest were in-hospital death, myocardial infarction (MI), and bleeding defined by *International Classification of Diseases, Ninth Revision,* codes.

Results Among 221,379 patients who underwent PCI and survived to hospital discharge, 3.5% (n = 7,696) were readmitted for NCS within 6 months post-PCI, and 41% of these hospitalizations were elective. Early NCS was complicated by MI in 4.7% of cases, and 21% of perioperative MIs were fatal. Bleeding was recorded in 32.0% of patients. All-cause mortality occurred in 4.4% of patients (n = 339) readmitted for surgery. The risk of death or MI was greatest when NCS was performed within the first month after PCI.

Conclusions Despite clear guidelines to avoid surgery early after PCI, NCS was performed in 1 of every 29 patients with recent PCI, corresponding to as many as ~30,000 patients each year nationwide. Surgical mortality and perioperative MI were high in this setting. Strategies to minimize perioperative thrombotic and bleeding risks during readmission for NCS after PCI are necessary. (Am Heart J 2019;217:64-71.)

Percutaneous coronary intervention (PCI) is routinely performed for stable ischemic heart disease and acute coronary syndromes in the United States. Older registry data suggest that up to 7.5% of patients require surgery in the first 6 months following PCI and up to 20% undergo surgery within 2 years.[1-6] Patients who require noncardiac surgery (NCS) early after PCI are at increased risk of perioperative events compared with those without coronary stents.[6-11] This increased risk is likely due to differences in baseline cardiovascular comorbidities and burden of coronary artery disease, early discontinuation of antiplatelet therapy during the perioperative period, and the prothrombotic risks of recent stents and NCS.[12]

As a consequence, clinical practice guidelines recommend avoiding surgery in the first 6 to 12 months after PCI with drug-eluting stents (DESs) and the first 4-6 weeks after PCI with bare metal stents (BMSs) unless the benefits of early surgery outweigh the associated perioperative cardiovascular risks.[13-15] However, contemporary studies reporting the frequency and outcomes of surgery after PCI are largely based on European cohorts; studies from the United States have been single center,[6] have included mostly men,[11] or were conducted in the era of first-generation DESs and largely prior to a major revision in perioperative care guidelines.[11,13] In the present study, we sought to investigate the frequency

From the [a]Leon H. Charney Division of Cardiology, Department of Medicine, New York University School of Medicine, New York, NY, [b]Division of Cardiology, Department of Medicine, Veterans Affairs New York Harbor Health Care System, New York, NY, and [c]Department of Surgery, New York University School of Medicine, New York, NY.

Conflict of interest disclosures: none.

Sponsor/funding: This research is supported in part by an NYU CTSA grant, UL1 TR001445 and KL2 TR001446, from the National Center for Advancing Translational Sciences, National Institutes of Health.

Submitted January 25, 2019; accepted July 13, 2019.

Reprint requests: Nathaniel Smilowitz, MD, Assistant Professor of Medicine, The Leon H. Charney Division of Cardiology, NYU Langone Health, NYU School of Medicine, 423 E 23rd St, Room 12020-W, New York, NY 10010.

E-mail:

0002-8703

Published by Elsevier Inc.

https://doi.org/10.1016/j.ahj.2019.07.010

and timing of in-hospital NCS within 6 months after PCI in a broadly representative nationwide cohort of patients in the United States in the contemporary era of second-generation DESs. In the same cohort, we also determined the incidence of in-hospital complications associated with surgery early after PCI.

Methods

Study population

Adults ≥18 years old admitted for PCI between January 1 and June 30, 2014, were identified from the United States (US) Agency for Healthcare Research and Quality (AHRQ) Healthcare Cost and Utilization Project's (HCUP's) Nationwide Readmission Database (NRD), a national administrative database of hospital discharge-level data. The most recent year of data from the NRD includes 22 states and represents 51.2% of the US population and 49.3% of all US hospitalizations.[16] Percutaneous coronary interventions were identified based on primary or nonprimary *International Classification of Diseases, Ninth Revision, Clinical Modification* (ICD-9-CM) procedure codes (ICD-9 procedure codes 36.01, 36.02, 36.05, 36.06, 36.07, 36.09, 17.55, and 00.66). Patients with acute myocardial infarction (AMI) were identified using ICD-9 diagnosis codes for acute ST-segment elevation myocardial infarction (MI) (ICD-9 diagnosis codes 410.01 to 410.61, 410.81, and 410.91) and non–ST-segment elevation MI (ICD-9 diagnosis code 410.71).[17] Coronary stent type was determined by ICD-9 procedure codes. Among patients with >1 admission for PCI during the calendar year, the most recent PCI admission prior to hospitalization for NCS was included in the analysis. Among patients with multiple PCIs who did not undergo NCS during the study period, only the first hospitalization for PCI during the calendar year was included in the analysis. Demographics and clinical comorbidities were defined by relevant ICD-9 diagnosis codes and AHRQ Elixhauser comorbidities for all patients.

Study outcome

The primary study outcome was hospital readmission for NCS within 6 months, determined based on methodology described by HCUP.[18] Hospitalizations for NCS were identified by the presence of any ICD-9 procedure code for a major therapeutic operating room procedure (HCUP Procedure Class 4) during the admission, as previously described.[17] Clinical Classifications Software procedure codes, AHRQ-defined groups of related ICD-9 procedure codes, were used to cluster hospitalizations by surgical subtype. Hospital admissions for general abdominal surgery, genitourinary surgery, neurosurgery, orthopedic surgery, otolaryngology, skin and breast surgery, thoracic surgery, vascular surgery, and other NCS not classified elsewhere were included in the readmission analysis.[19] Hospital admissions with a principal Clinical Classifications Software procedure code for cardiac procedures or surgery were excluded from the readmission analysis. Among patients with multiple readmissions for surgery within 6 months of the index hospital discharge after PCI, only the first readmission was included for analysis. Patients who underwent PCI in July through December were not included in the analysis due to incomplete 6-month follow-up data on readmissions.[18] Outcomes of interest during hospital readmission for NCS were all-cause mortality, AMI, and bleeding. Patients with documented bleeding and bleeding requiring intervention were identified by the relevant ICD-9 diagnosis and procedure codes, as previously described (Supplementary Appendix).[20,21] Red blood cell transfusions were identified from the ICD-9 procedure codes (ICD-9 procedure codes 99.01-99.04).

Statistical analysis

Categorical variables were reported as percentages and were compared by χ^2 tests. Continuous variables were reported as means with the standard error of measurement and were compared using linear regression. Multivariable logistic regression models were generated to estimate odds ratios (ORs) adjusted for patient demographics, cardiovascular risk factors, and comorbidities. Models included age, sex, obesity, hypertension, hyperlipidemia, diabetes mellitus, chronic kidney disease, end-stage renal disease, prior revascularization with either PCI or coronary artery bypass grafting, peripheral vascular disease, congestive heart failure, valvular heart disease, prior venous thromboembolism, atrial fibrillation, malignancy, and anemia as covariates for adjustment. We performed subgroup analyses of patients by sex, coronary stent type (ie, DESs and BMSs), clinical presentation during admission for PCI, and elective versus urgent hospitalization for surgery. Sensitivity analyses were performed for patients undergoing major vascular and orthopedic surgery.

In all analyses, sampling weights were applied to determine national incidence estimates, including prespecified clustering and strata, unless otherwise noted.[22] Statistical analyses were performed using SPSS 25 (IBM SPSS Statistics, Armonk, NY). Statistical tests are 2-sided, and P values <.05 were considered to be statistically significant. The NRD is a publicly available, deidentified data set, and the study was exempt from institutional board review. This research is supported in part by an NYU CTSA grant, UL1 TR001445 and KL2 TR001446, from the National Center for Advancing Translational Sciences, National Institutes of Health. The authors are solely responsible for the design and conduct of this study, all study analyses, the drafting and editing of the paper, and its final contents.

Table I. Characteristics of patients with and without hospitalization for NCS within 6 months of percutaneous coronary intervention

	PCI without NCS at 6 m	PCI with NCS at 6 m	*P* value
	(n = 213,683)	(n = 7696)	
Demographics and clinical characteristics			
Age, y (SE)	64.5 (0.10)	67.5 (0.23)	<.001
Female sex (%)	68,434 (32.0%)	2847 (37.0%)	<.001
Obesity	37,374 (17.5%)	1375 (17.9%)	.612
Hypertension	165,334 (77.4%)	6291 (81.7%)	<.001
Dyslipidemia	152,763 (71.5%)	5220 (67.8%)	<.001
Diabetes mellitus	79,899 (37.4%)	3776 (49.1%)	<.001
Chronic kidney disease	33,451 (15.7%)	2335 (30.3%)	<.001
End-stage renal disease	5695 (2.7%)	846 (11.0%)	<.001
Prior CABG	15,432 (7.2%)	749 (9.7%)	<.001
Prior PCI *	45,640 (21.4%)	1784 (23.2%)	.026
Peripheral vascular disease	23,532 (11.0%)	2181 (28.3%)	<.001
Congestive heart failure	3301 (1.5%)	320 (4.2%)	<.001
Valvular heart disease	1106 (0.5%)	127 (1.7%)	<.001
Atrial fibrillation	27,368 (12.8%)	1430 (18.6%)	<.001
Anemia	24,849 (11.6%)	1829 (23.8%)	<.001
Malignancy	4091 (1.9%)	391 (5.1%)	<.001
Chronic pulmonary disease	38,417 (18%)	1781 (23.1%)	<.001
Hospital presentation			
AMI	140,803 (65.9%)	4462 (58%)	<.001
PCI with BMS	36,143 (16.9%)	2161 (28.1%)	<.001
PCI with DES	165,300 (77.4%)	4815 (62.6%)	<.001

CABG, coronary artery bypass grafting.
* Any PCI performed prior to the index hospitalization for PCI in 2014.

Results

Patients undergoing PCI

A total of 227,349 patients underwent PCI in the first 6 months of 2014. A majority of PCI (66.2%, n = 150,519) were performed for AMI. Overall, 5,970 patients (2.6%) died in-hospital after PCI. Among the patients who survived, the mean age was 64.5 years and 67.8% of patients were men. Demographics and baseline characteristics of the remaining 221,379 individuals who underwent PCI and survived to hospital discharge are shown in Table I.

Readmission for NCS

Among 221,379 adults who underwent PCI and survived to hospital discharge, 7,696 (3.5%) were readmitted for NCS within the first 6 months after PCI (see Figure 1); of these, 21.8%, 39.6%, and 38.6% of patients were rehospitalized for surgery within 1 month, 1-3 months, and 3-6 months, respectively. Most surgical hospitalizations (n = 4516, 58.7%) were urgent, whereas 41.3% (n = 3,180) were electively planned. The proportion of elective admissions for NCS increased from 24.7% within 30 days of PCI to 45.6% after 1 to 6 months ($P < .001$). Patients who were readmitted for surgery within 6 months were older; more likely to be women; and more likely to have cardiovascular comorbidities, including diabetes, kidney disease, and heart failure, and medical illnesses including anemia and malignancy. Patients who underwent surgery were less likely to have presented with AMI (58.0% vs 65.9%, $P < .001$) and undergone PCI with a DES (62.6% vs 77.4%, $P < .001$). Full clinical characteristics associated with hospital readmission for NCS are shown in Table I. In a multivariable model adjusted for demographics and clinical covariates, MI during index hospital admission (OR 0.75, 95% CI 0.69-0.82) and DES placement (OR 0.53, 95% CI 0.48-0.58) were associated with a lower likelihood of readmission for surgery (Supplemental Table I).

Among those readmitted for NCS, perioperative MI occurred in 365 (4.7%) cases, of which 78 were fatal (21.4%). A total of 339 (4.4%) patients died during readmission for NCS after PCI. Death or MI occurred in 626 cases (8.1%). Documented bleeding occurred in 2,460 of patients undergoing surgery early after PCI (32.0%), and transfusion of red blood cells was required in 1,609 cases (20.9%). Among patients with bleeding, perioperative mortality was significantly higher than those patients without bleeding (7.9% [195 patients] vs 2.7% [143 patients], $P < .001$).

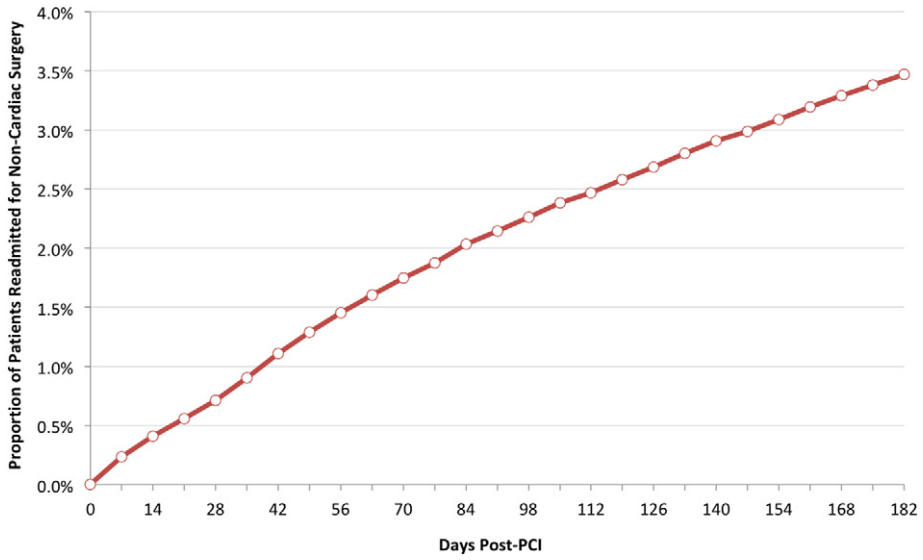
Perioperative risks varied based on the time interval between PCI and NCS, as shown in Figure 2. Patients with surgery within ≤1 month of PCI had the greatest risk of death or MI (11.4%). Risks of death or MI during hospitalization for NCS 1-3 months after PCI (adjusted OR 0.64, 95% CI 0.46-0.88) and 3-6 months after PCI (adjusted OR 0.72, 95% CI 0.53-0.99) were significantly lower than risks of NCS within 1 month of PCI after adjusting for age, sex, and urgent/emergent indication for hospital readmission. Bleeding risks were also greatest when surgery was performed within 1 month of PCI (Supplemental Figure 1).

Subgroups

Demographics. Women were more likely to be readmitted for surgery within 6 months after PCI than men (4.0% vs 3.2%, $P < .001$). Among patients readmitted for NCS after PCI, there no difference in perioperative death or MI during surgical readmission by sex (9.0% for women vs 7.6% for men, $P = .15$) (Supplemental Figure 2).

Elective NCS after PCI. Among 3,180 patients who were electively admitted for surgery within 6 months after PCI, perioperative MI occurred in 94 (3.0%) cases, of which 32 were fatal (34.0%). A total of 96 (3.0%) patients

Figure 1

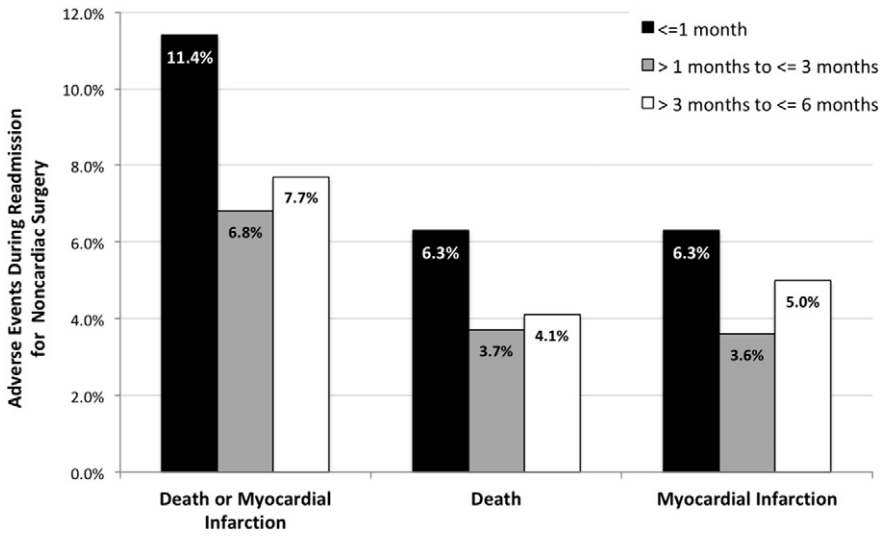


Time to readmission for NCS after PCI.

died during elective readmission for NCS after PCI, and death or MI occurred in 159 cases (5.0%). Bleeding occurred in 698 of patients undergoing elective NCS after PCI (22.0%), and transfusion of packed red blood cells was administered in 447 cases (14.0%). Among patients electively hospitalized for surgery, 2,748 (86.4%) were admitted ≥1 month after PCI, and 1,287 (40.5%) were performed ≥3 months after PCI. Vascular (36.0%), orthopedic (17.5%), and general (15.9%) surgical procedures were the most commonly performed primary procedures during elective hospitalizations for NCS. Risks of death or MI declined over time, from 6.9% when surgery was performed within 1 month to 4.3% when surgery was performed between 3 and 6 months post-PCI (Figure 3). In contrast, patients who were urgently or emergently admitted for NCS within 6 months after PCI had a greater frequency of death or MI than patients electively hospitalized, overall (10.3% vs 5.0%, $P < .001$) and at all time intervals between PCI and surgery.

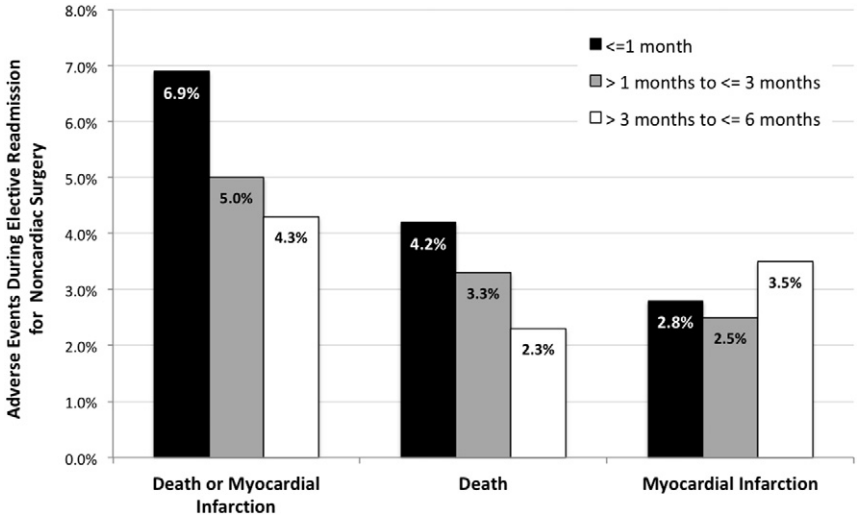
PCI presentation and stent type. Patients who underwent PCI for AMI were less likely to be readmitted

Figure 2



In-hospital adverse cardiovascular events during hospital readmission for NCS by time interval between PCI and surgery.

Figure 3



In-hospital adverse cardiovascular events among patients who were electively readmitted for NCS by time interval between PCI and surgery.

for NCS within 6 months than patients who underwent PCI for stable coronary artery disease (3.1% vs 4.2%, $P < .001$), with no difference in the composite of perioperative death or MI between the 2 groups (8.2% vs 8.0%, $P = .84$) (Table II). Patients who underwent PCI with DES were less likely to be readmitted for NCS within 6 months than patients who underwent PCI with BMS (3.0% vs 4.1%, $P < .001$), with no difference in perioperative death or MI among those undergoing NCS (7.4% vs 7.3%, $P = .89$). The frequency of perioperative adverse cardiovascular events stratified by the time interval between PCI and readmission for NCS is shown for patients grouped by the clinical indication for PCI (Supplemental Figure 3) and by coronary stent type (Supplemental Figure 4).

NCS subtype. Among the 7,696 patients who were readmitted for NCS within 6 months of PCI, 72.1% had procedure codes for 1 surgical subtype and 27.9% had codes for ≥2 surgical subtypes during hospitalization. The primary surgical procedure during the hospitalization was vascular surgery in 25.6%, orthopedic surgery in 22.1%, and general surgery in 19.5% patients (Table III). Most hospitalizations for primary vascular surgery within 6 months of PCI were elective; only 42% of procedures occurred during urgent admissions. In contrast, most readmissions for the remaining surgical subtypes, including general and orthopedic surgery, were urgent or emergent (Table III). The frequencies of perioperative adverse cardiovascular events complicating orthopedic, general, and vascular surgical procedures stratified by the time interval between PCI and NCS are shown in Supplemental Figure 5. All surgical procedures performed during hospital readmission are reported in Supplemental Table II.

Table II. Perioperative outcomes by clinical indication for PCI and by stent type

PCI clinical indication	MI	No MI	*P* value	
	(n = 145,266)	(n = 76,113)		
Readmission for NCS	4452 (3.1%)	3233 (4.2%)	<.001	
Perioperative MI	211/4452 (4.7%)	154/3233 (4.8%)	.98	
Perioperative mortality	206/4452 (4.6%)	133/3233 (4.1%)	.50	
Perioperative MACE	367/4452 (8.2%)	259/3233 (8.0%)	.84	
Stent type	DES	BMS	Angioplasty only	*P* value
	(n = 170,115)	(n = 36,113)	(n = 15,151)	
Readmission for NCS	4815 (2.8%)	2058 (5.7%)	824 (5.4%)	<.001
Perioperative MI	202/4815 (4.2%)	79/2058 (3.8%)	84/824 (10.3%)	<.001
Perioperative mortality	213/4815 (4.4%)	82/2058 (4.0%)	44/824 (5.3%)	.60
Perioperative MACE	370/4815 (7.7%)	135/2058 (6.6%)	121/824 (14.7%)	<.001

Discussion

In this analysis of a large contemporary cohort of patients in the United States undergoing PCI, 3.5% were readmitted for NCS within 6 months of PCI, corresponding to up to ~30,000 patients each year nationwide. Early surgery was complicated by MI in 4.7% of cases, 21% of perioperative MI were fatal, and bleeding was documented in nearly one third of cases. All-cause mortality occurred in 4.4% of patients readmitted for NCS. Among the 75% of patients who underwent DES placement during the index PCI, 2.8% were readmitted for NCS within 6 months despite clinical practice guideline recommendations to delay surgery for at least 6 to 12 months after DES PCI.[13-15] Among patients who required NCS within 6 months of PCI, 41% of patients were electively admitted for NCS. Outcomes during elective hospitalization for surgery after PCI were more favorable than those for urgent or emergent readmission. Still, 3% of patients died during an elective hospitalization for surgery after PCI.

The present study is the first to provide a contemporary perspective on the incidence of NCS early after PCI in a representative sample of hospitals in the United States among women and men and in the era of second-generation DESs and after changes to guidelines discouraging NCS after PCI. In prior studies, 5.1% to 7.5% of patients required NCS within 6 months of PCI.[2,6] An analysis of 126,773 patients undergoing PCI at the VA from 2000 to 2010 reported that the frequency of surgery declined over time, with 6.6% requiring surgery within 1 year of DES PCI in the final year of the analysis.[3] The lower frequency of NCS after PCI in the present analysis likely reflects a continuation of this trend. The present study expands upon the prior observational studies from the United States that were restricted to US veterans, included 98% men, reflected practice patterns with first-generation DES, and included data collected largely before major changes in perioperative guidelines were published recommending delays in surgery post-PCI.[3,11,13]

The prevalence of coronary artery disease in patients undergoing NCS has increased over time, and it is estimated that 120,000 adults have an MI after NCS in the United States every year.[23-25] Recent PCI confers a substantial risk of perioperative MI, and MI after NCS is associated with adverse events and significant morbidity and mortality.[1,6,19] In the present analysis, the incidence of perioperative MI early after PCI was significantly greater than the ~0.7% incidence of perioperative MI previously reported in all US patients undergoing NCS in 2014, and MI was associated with a high case fatality rate.[17,24] These data are consistent with older studies reporting frequent adverse cardiovascular events (ranging from 3% to 11%) when NCS is performed within 6-12 months after PCI.[1,3,5,8,10,11] However, the risks depend on the characteristics of the surgical population, the interval between PCI and surgery, and definitions of cardiovascular events.

To avoid cardiovascular complications, patients who are planned for PCI should be queried about any anticipated need for NCS, as this information may guide the strategy for coronary revascularization. Guideline-directed medical therapy may be preferred to PCI in patients with stable ischemic heart disease and planned NCS because a large randomized controlled trial did not demonstrate a reduction in death or MI with revascularization compared with medical therapy.[26] Unfortunately, most hospitalizations for NCS in the present analysis were classified as urgent or emergent, and it is often difficult to predict which patients planned for PCI will need NCS. Among the 41% of patients who were electively hospitalized for NCS within 6 months of PCI, substantial risks of death or MI in the perioperative period were observed. Longer delays to surgery were associated with lower risks of adverse cardiovascular events. In patients in whom PCI is deemed essential, the need for NCS may affect the choice of stent and duration of dual antiplatelet therapy (DAPT). Historically, BMSs have been selected in patients at risk for early NCS or bleeding post-PCI. However, contemporary second-generation DESs currently require a minimum of only 3-6 months of DAPT in stable patients, and even shorter DAPT durations of 1-3 months may be acceptable for biodegradable polymer and polymer-free DESs.[27] Stents with the lowest risk of thrombosis and the shortest requirements for DAPT should be preferred in patients who require NCS early after PCI. Although guidelines initially recommended delaying NCS for 1 month after BMS implantation and 12 months after DES,[14] recent evidence suggests that surgery at 6 months after DES PCI, or even earlier, may be safe.[1,2,11,28] Based on the current study findings, a delay of at least 3-6 months to elective NCS is advisable.

Study limitations

Data are derived from diagnosis and procedure codes and are subject to reporting bias and/or errors in coding. First, the diagnosis of perioperative AMI during readmission for surgery may be underreported or missed entirely because up to two thirds of perioperative MIs are clinically silent and may not be recognized without routine biomarker screening.[29-31] Myocardial injury after noncardiac surgery (MINS) occurs in 17%-24% of cases in large observational registries, depending on the sensitivity of the cardiac troponin assay, and is associated with increased postoperative 30-day and long-term mortality.[29-32] MINS has been formally recognized as an important entity in the "Fourth Universal Definition of Myocardial Infarction."[29] Unfortunately, approaches to postoperative surveillance with troponin measurement and the frequency of MINS without coded MI were not available in the NRD. Second, discrete clinical data, including the

Table III. Primary surgery types during hospital readmission, overall and within subgroups of urgent and elective hospitalization for NCS

Surgery type	All readmissions for NCS	Urgent readmission for NCS	Elective readmission for NCS	% Urgent surgical readmission
Vascular surgery	1974 (25.6%)	830 (18.4%)	1144 (36%)	42.0%
Orthopedic surgery	1704 (22.1%)	1147 (25.4%)	557 (17.5%)	67.3%
General surgery	1498 (19.5%)	992 (22.0%)	506 (15.9%)	66.2%
Skin/breast surgery	968 (12.6%)	651 (14.4%)	317 (10.0%)	67.3%
Thoracic surgery	667 (8.7%)	352 (7.8%)	315 (9.9%)	52.8%
Genitourinary surgery	494 (6.4%)	320 (7.1%)	174 (5.5%)	64.8%
Neurosurgery	243 (3.2%)	141 (3.1%)	102 (3.2%)	57.6%
Other surgery	148 (1.9%)	83 (1.8%)	65 (2.0%)	56.1%

results of diagnostic coronary angiography, were not captured in this administrative data set. Thus, we were unable to account for the extent and severity of coronary artery disease or the completeness of revascularization with PCI. In an analysis of 12,486 noncardiac surgical procedures performed at the VA in patients with prior PCI, incomplete revascularization was associated with a 19% increase in 30-day postoperative major adverse cardiovascular events (MACE) and a 37% increased risk of perioperative MI.[33] Documentation of stent type was based on ICD-9 procedure codes, and errors in coding may have led to lower-than-expected frequency of DES use in this analysis. Still, these data are consistent with prior reports that suggest that BMSs are still routinely used in roughly 25% of PCIs in clinical practice.[34] Third, perioperative medications, specifically use of antiplatelet and antithrombotic regimens, were not available. Interruption of DAPT within 30 days of PCI is strongly associated with stent thrombosis even in second-generation cobalt chromium everolimus-eluting DES.[35] Perioperative discontinuation of antiplatelet therapy has been associated with perioperative MACE.[36] In patients with prior stents, perioperative aspirin continuation is associated with a lower incidence of death or MI (hazard ratio 0.5, 95% CI 0.26-0.95) with no association between aspirin and bleeding.[37] Current perioperative guidelines recommend continuation of aspirin throughout the perioperative period and continuation of DAPT only when surgical bleeding risks are low. When a P2Y12 inhibitor is interrupted for surgery, it should be resumed postoperatively as soon as possible.[14,15,38] Fourth, the sequence of NCS preceding AMI could not be determined in this database, but NCS is contraindicated early after AMI. Fifth, only in-hospital outcomes were available from the NRD, which may lead to underestimation of post-operative event rates.

Conclusions

In the present analysis, 3.5% of patients were readmitted for NCS within 6 months post-PCI, corresponding to up to ~30,000 patients each year nationwide. Early surgery was complicated by MI in 4.7% of cases, 21% of perioperative MIs were fatal, and bleeding rates were high. All-cause mortality occurred in 4.4% of patients readmitted for surgery. The greatest risks for death or MI were observed when NCS was performed within the first month after PCI. Substantial risks were also observed in patients who were electively admitted for NCS at all time points in the first 6 months after PCI. Strategies to minimize perioperative thrombotic and bleeding risks during readmission for NCS after PCI are necessary.

Appendix. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.ahj.2019.07.010.

References

1. Egholm G, Kristensen SD, Thim T, et al. Risk associated with surgery within 12 months after coronary drug-eluting stent implantation. J Am Coll Cardiol 2016;68:2622-32.
2. Saia F, Belotti LM, Guastaroba P, et al. Risk of adverse cardiac and bleeding events following cardiac and noncardiac surgery in patients with coronary stent: how important is the interplay between stent type and time from stenting to surgery? Circ Cardiovasc Qual Outcomes 2016;9:39-47.
3. Hawn MT, Graham LA, Richman JR, et al. The incidence and timing of noncardiac surgery after cardiac stent implantation. J Am Coll Surg 2012;214:658-66. discussion 666-657.
4. Berger PB, Kleiman NS, Pencina MJ, et al. Frequency of major noncardiac surgery and subsequent adverse events in the year after drug-eluting stent placement results from the event (evaluation of drug-eluting stents and ischemic events) registry. JACC Cardiovasc Interv 2010;3:920-7.
5. Hollis RH, Graham LA, Richman JS, et al. Adverse cardiac events in patients with coronary stents undergoing noncardiac surgery: a systematic review. Am J Surg 2012;204:494-501.
6. Mahmoud KD, Sanon S, Habermann EB, et al. Perioperative cardiovascular risk of prior coronary stent implantation among patients undergoing noncardiac surgery. J Am Coll Cardiol 2016;67:1038-49.
7. Kaluza GL, Joseph J, Lee JR, et al. Catastrophic outcomes of noncardiac surgery soon after coronary stenting. J Am Coll Cardiol 2000;35:1288-94.
8. Anwaruddin S, Askari AT, Saudye H, et al. Characterization of post-operative risk associated with prior drug-eluting stent use. JACC Cardiovasc Interv 2009;2:542-9.
9. Wijeysundera DN, Wijeysundera HC, Yun L, et al. Risk of elective major noncardiac surgery after coronary stent insertion: a population-based study. Circulation 2012;126:1355-62.
10. Cruden NL, Harding SA, Flapan AD, et al. Previous coronary stent implantation and cardiac events in patients undergoing noncardiac surgery. Circ Cardiovasc Interv 2010;3:236-42.
11. Hawn MT, Graham LA, Richman JS, et al. Risk of major adverse cardiac events following noncardiac surgery in patients with coronary stents. JAMA 2013;310:1462-72.

12. Smilowitz NR, Berger JS. Perioperative management to reduce cardiovascular events. Circulation 2016;133:1125-30.
13. 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:e418-99.
14. 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:e77-e137.
15. 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;35:2383-431.
16. Steiner C, Elixhauser A, Schnaier J. The healthcare cost and utilization project: an overview. Eff Clin Pract 2002;5:143-51.
17. Smilowitz NR, Gupta N, Guo Y, et al. Perioperative acute myocardial infarction associated with non-cardiac surgery. Eur Heart J 2017;38:2409-17.
18. Barrett M, Steiner C, Andrews R, et al. HCUP Methods Series Report # 2011:2011-*01*.
19. Smilowitz NR, Beckman JA, Sherman SE, et al. Hospital readmission after perioperative acute myocardial infarction associated with noncardiac surgery. Circulation 2018;137:2332-9.
20. Selak V, Kerr A, Poppe K, et al. Annual risk of major bleeding among persons without cardiovascular disease not receiving antiplatelet therapy. JAMA 2018;319:2507-20.
21. Redfors B, Watson BM, McAndrew T, et al. Mortality, length of stay, and cost implications of procedural bleeding after percutaneous interventions using large-bore catheters. JAMA Cardiol 2017;2:798-802.
22. Yoon F, Sheng M, Jiang HJ, et al. HCUP Methods Series Report # 2017:2017-*01*.
23. Devereaux PJ. Suboptimal outcome of myocardial infarction after noncardiac surgery: physicians can and should do more. Circulation 2018;137:2340-3.
24. Smilowitz NR, Gupta N, Ramakrishna H, et al. Perioperative major adverse cardiovascular and cerebrovascular events associated with noncardiac surgery. JAMA Cardiol 2017;2:181-7.
25. Smilowitz NR, Gupta N, Guo Y, et al. Trends in cardiovascular risk factor and disease prevalence in patients undergoing non-cardiac surgery. Heart 2018;104:1180-6.
26. McFalls EO, Ward HB, Moritz TE, et al. Coronary-artery revascularization before elective major vascular surgery. N Engl J Med 2004;351:2795-804.
27. Urban P, Meredith IT, Abizaid A, et al. Polymer-free drug-coated coronary stents in patients at high bleeding risk. N Engl J Med 2015;373:2038-47.
28. Bangalore S, Silbaugh TS, Normand SL, et al. Drug-eluting stents versus bare metal stents prior to noncardiac surgery. Catheter Cardiovasc Interv 2015;85:533-41.
29. Thygesen K, Alpert JS, Jaffe AS, et al. Executive Group on behalf of the Joint European Society of Cardiology /American College of Cardiology /American Heart Association /World Heart Federation Task Force for the Universal Definition of Myocardial I. Fourth universal definition of myocardial infarction (2018). Circulation 2018;138:e618-51.
30. Landesberg G, Shatz V, Akopnik I, et al. Association of cardiac troponin, CK-MB, and postoperative myocardial ischemia with long-term survival after major vascular surgery. J Am Coll Cardiol 2003;42:1547-54.
31. Writing Committee for the VSI, Devereaux PJ, Biccard BM, et al. Association of postoperative high-sensitivity troponin levels with myocardial injury and 30-day mortality among patients undergoing noncardiac surgery. JAMA 2017;317:1642-51.
32. Vascular Events In Noncardiac Surgery Patients Cohort Evaluation Study I, Devereaux PJ, Chan MT, et al. Association between postoperative troponin levels and 30-day mortality among patients undergoing noncardiac surgery. JAMA 2012;307:2295-304.
33. Armstrong EJ, Graham LA, Waldo SW, et al. Incomplete revascularization is associated with an increased risk for major adverse cardiovascular events among patients undergoing noncardiac surgery. JACC Cardiovasc Interv 2017;10:329-38.
34. Bangalore S, Gupta N, Guo Y, et al. Int J Cardiol 2014;175:108-19.
35. Genereux P, Rutledge DR, Palmerini T, et al. Stent thrombosis and dual antiplatelet therapy interruption with everolimus-eluting stents: Insights from the xience v coronary stent system trials. Circ Cardiovasc Interv 2015;8.
36. Rossini R, Musumeci G, Capodanno D, et al. Perioperative management of oral antiplatelet therapy and clinical outcomes in coronary stent patients undergoing surgery. Results of a multicentre registry. Thromb Haemost 2015;113:272-82.
37. Graham MM, Sessler DI, Parlow JL, et al. Aspirin in patients with previous percutaneous coronary intervention undergoing noncardiac surgery. Ann Intern Med 2018;168:237-44.
38. Rossini R, Musumeci G, Visconti LO, et al. Perioperative management of antiplatelet therapy in patients with coronary stents undergoing cardiac and non-cardiac surgery: a consensus document from Italian cardiological, surgical and anaesthesiological societies. EuroIntervention 2014;10:38-46.