Changing Risk of Perioperative Myocardial Infarction

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Abstract

Introduction: Years ago, patients with recent myocardial infarction (MI) were reported to be at high risk of reinfarction (27%) and death after surgery. Therapy has changed in the 3 decades since those reports, so we reexamined that risk as well as other cardiac comorbidities and surgical work values in predicting adverse outcome.

Methods: We used the National Surgical Quality Improvement Program Participant Use Files for 2005 to 2009. We included all patients of all included specialties, for outpatient and inpatient surgery. Cardiac comorbidities included history of congestive heart failure (30 days) or MI (6 months), percutaneous coronary intervention, previous cardiac surgery, and history of angina (30 days). Other predictors included a frailty index and American Society of Anesthesiologists (ASA) class. Adverse cardiac events included cardiac arrest requiring cardiopulmonary resuscitation, MI, and death. Cases were stratified according to surgical work units. Univariate χ^2 analysis and multivariate logistic regression established simple relationships and interactions, with $p < 0.05$ significant.

Results: Of patients who had recent MI, 2.1% had reinfarction perioperatively and 26% of those died. The odds ratio for infarction with vs without recent MI in inpatients age 40 years of age and older was 4.6. Frailty and ASA class were stronger predictors of perioperative MI and cardiac arrest than was history of MI, and risk increased as surgical work increased.

Discussion: The risk because of preoperative MI has improved by an order of magnitude in the last 30 years. The ASA class and especially frailty are better predictors of adverse cardiac events.

Introduction

Half of perioperative mortality is said to be because of major adverse cardiac events.[1] Numerous efforts have been made to identify who is at risk and to what degree. For example, Goldman et al[2] prospectively studied 1001 patients older than age 40 years who were undergoing noncardiac surgery. Of those who had a myocardial infarction (MI) in the 6 months preceding surgery, 27.3% had a perioperative MI or cardiac death. Of those patients who had an MI more than 6 months before surgery or had no previous MI (there was no difference in outcome for the 2 groups), 2.8% had a perioperative MI or cardiac death.

Numerous studies from the 1960s through the 1980s found similar risk of preexisting cardiac disease, with mortality because of perioperative MI at about 50%, as reviewed by Mangano.[3] On the basis of this risk, anesthesiologists recommended against all but urgent surgery until 6 months elapsed after an MI. Some studies in the 1980s, however, found less risk of previous MI. For example, Rao et al[4] found that of 195 patients with previous infarct, 10 (5.1%) had perioperative MI. However, they monitored most of their patients (except minor surgery lasting less than 30 minutes) with an arterial line and pulmonary artery catheter and aggressively treated them in the intensive care unit for several days postoperatively, an expensive therapy that is not a standard of care and has not been duplicated in subsequent research.

During the last 30 years, medical therapy has changed, with statins, β-blockers, and aspirin becoming more standard; interventional therapy has advanced with coronary artery stents and coronary artery bypass using the internal mammary artery; anesthetic practice has changed; and surgeons have adopted less invasive approaches. Perioperative MI remains a contributor to perioperative morbidity and mortality, yet we found only one study in recent years examining the risk of previous MI on postoperative mortality.[5]

As the demographics of the surgical population change, age or single risk factors such as MI alone as acuity adjustors are inadequate. Clinicians are assessing risk in increasingly standardized ways.[6-9] For example, a 50-year-old patient with congestive heart failure (CHF) and diabetes with renal failure is more worrisome than an octogenarian still working and living independently. A frailty index is a single score based on a standardized assessment of multiple measures, but the American Society of Anesthesiologists (ASA) class incorporates similar information except in a subjective way. The ASA class is useful because it is simple and widely known, but it suffers from interuser variability.[10] Frailty is proving to be a powerful predictor of surgical morbidity and mortality.[11]

Data from the National Surgical Quality Improvement Program (NSQIP) have been used extensively to evaluate surgical risk and improve outcomes.[12,13] NSQIP collects data in a uniform way from more than 250 hospitals around the US and Canada. Trained nurse reviewers submit all of the data, and sites are reviewed to ensure interrater reliability. A validated sampling method is used to collect data on a broad variety of cases, and outcomes are tracked for 30 days. It represents a highly reliable dataset that allows us to reexamine the risk of previous MI on postoperative outcome, to determine whether that risk has changed, and to measure the role of other cardiac comorbidities.

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Methods

We developed a dataset using five years of NSQIP Participant Use Data (2005 to 2009). Variables from the comorbidites that were most consistent with a cardiac history were identified and are listed in Table 1. Adverse events related to the heart were similarly identified (Table 1). Univariate analysis using a χ^2 test was performed with all comorbidities predicting each adverse event. Multivariate logistic regression analysis was performed to account for preoperative conditions that may have affected outcomes, as well as to look for interactions between the cardiac risk variables. Variables known from the NSQIP semiannual reports to be highly predictive of cardiac risk were included in the model. These variables were preoperative albumin level, emergency status of the operation, ASA classification, and wound class.

We also used a simplified frailty index, which was recently developed and described elsewhere,[14] and was modified from the Canadian Study of Health and Aging Frailty Index[15] to use NSQIP data. This index included the following: 1) nonindependent functional status; 2) history of diabetes mellitus; 3) history of either chronic obstructive pulmonary disease or pneumonia; 4) history of CHF; 5) history of MI; 6) history of percutaneous coronary intervention, cardiac surgery, or angina; 7) hypertension requiring the use of medications; 8) peripheral vascular disease or "rest pain"; 9) impaired sensorium; 10) transient ischemic attack or cerebrovascular accident without residual deficit; and 11) cerebrovascular accident with deficit.

Finally, we stratified patients according to surgical work (in relative value units, [RVUs]),[16] divided into groups of fewer than 10, 10 to 20, and more than 20 RVUs, and we examined the incidence of perioperative MI and death.

All statistical analysis was performed using SPSS version 20 (IBM SPSS, Armonk, NY). A p value of <0.05 was considered statistically significant. The study was done with the approval

Table 1. Comorbidities and adverse events

Comorbidities and adverse events	Definition
Comorbidity	
CHF in 30 days before surgery	"YES" is entered for patients with CHF, which is the inability of the heart to pump a sufficient quantity of blood to meet the metabolic needs of the body or the ability to do so only at increased ventricular filling pressure. Only newly diagnosed CHF within the previous 30 days or a diagnosis of chronic CHF with new signs or symptoms in the 30 days before surgery fulfills this definition. Common manifestations are abnormal limitation in exercise tolerance because of dyspnea or fatigue; orthopnea (dyspnea on lying supine); paroxysmal nocturnal dyspnea (awakening from sleep with dyspnea); increased jugular venous pressure; pulmonary rales on physical examination; cardiomegaly; and pulmonary vascular engorgement.
History of MI 6 months before surgery	"YES" is entered for patients with a history of a non-Q-wave or a Q-wave infarct in the 6 months before surgery as diagnosed in the patient's medical record.
Previous PCI	"YES" is entered for patients who have undergone PCI at any time (including any attempted PCI). This includes either balloon dilation or stent placement. This does not include valvuloplasty procedures.
Previous cardiac surgery	"YES" is entered if the patient has had any major cardiac surgical procedures (performed either as an "off-pump" repair or using cardiopulmonary bypass). This includes coronary artery bypass graft surgery, valve replacement or repair, repair of atrial or ventricular septal defects, great thoracic vessel repair, cardiac transplant, left ventricular aneurysmectomy, insertion of left ventricular assist devices, etc. Not included are pacemaker insertions or AICD insertions.
History of angina in one month before surgery	"YES" is entered if patient reports pain or discomfort between the diaphragm and the mandible resulting from myocardial ischemia. Typically, angina is a dull, diffuse (fist-sized or larger) substernal chest discomfort precipitated by exertion or emotion and relieved by rest or nitroglycerine. Radiation to the arms and shoulders often occurs, and occasionally to the neck, jaw (mandible, not maxilla), or interscapular region. For patients receiving antianginal medications, "YES" is entered only if the patient has had angina at any time within one month before surgery.
Adverse event	
MI	A new transmural acute MI occurring during surgery or within 30 days as manifested by new Q waves on ECG
Cardiac arrest requiring CPR	The absence of cardiac rhythm or presence of chaotic cardiac rhythm that results in loss of consciousness requiring the initiation of any component of basic and/or advanced cardiac life support within 30 days of the operation. Any patient with an AICD that fires but the patient has no loss of consciousness should be excluded.
Death	Death within 30 days of index operation

AICD = automatic implantable cardioverter defibrillator; CHF = congestive heart failure; CPR = cardiopulmonary resuscitation; ECG = electrocardiogram; MI = myocardial infarction; PCI = percutaneous coronary intervention.

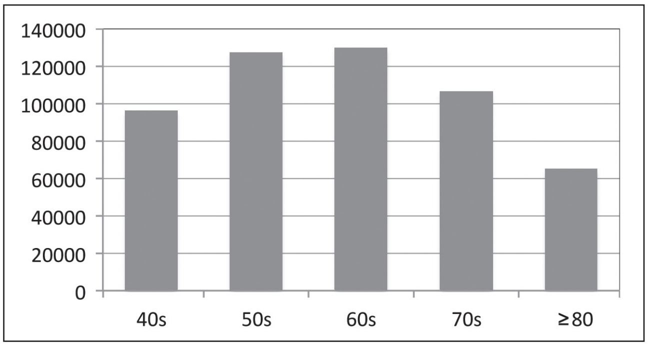

Figure 1. Age Distribution of inpatients age 40 years and older.

of Henry Ford Hospital's internal review board as well as under the Data Use Agreement of the American College of Surgeons.

Results

The NSQIP study population collected between 2005 and 2009 includes 971,455 patients. The frequencies of comorbidities were as follows: 1% CHF in the previous 30 days, 0.7% recent MI (in the 6 months before surgery), 5.4% previous percutaneous coronary intervention, 5.9% previous major cardiac surgery, and 1% angina in previous 30 days. Adverse events within 30 days after surgery were 0.3% MI, 0.4% cardiac arrest requiring cardiopulmonary resuscitation, and 1.7% death.

To analyze postoperative morbidity, we selected 2 subpopulations: 1) patients aged 40 years and older and (2) inpatients aged 40 years and older. The age distribution of the inpatients aged 40 years and older is illustrated in Figure 1, with patients aged 80 years and older in one of the categories. The ASA class of these inpatients was as follows: 3.0% ASA Class 1, 35.6% ASA 2, 49.7% ASA 3, 11.0% ASA 4, and 0.5% ASA 5.

Of 782,240 patients aged 40 years and older, 775,165 had no MI within 6 months before surgery, and 2540 (approximately 0.3%) of those had an MI perioperatively (Table 2). Of the 7075 patients who had recent MI, 148 (2.1%) had perioperative MI. The odds ratio (OR) for perioperative MI given a recent preoperative MI was 6.5 (confidence interval [CI], 5.5 to 7.7).

For 525,469 inpatients aged 40 years and older 2462 of 518,819 (0.5%) with no recent MI had perioperative MI, whereas 142 of 6650 (2.1%) with recent MI had perioperative MI (Table 2). The OR of perioperative MI given recent preoperative MI was 4.6 (CI, 3.9-5.4).

In the group of inpatients aged 40 years and older, 2604 had an MI and 674 (25.9%) of them died within 30 days of surgery vs 14,995 (2.9%) who died within 30 days but did not have an MI.

Table 2. Perioperative myocardial infarction with or without history of recent myocardial infarction

Patient population	History of MI[a]	No history of MI[b]	Total	OR (95% CI)
Total NSQIP population	149/7198 (2.0)	2665/964,257 (0.3)	2814/971,455 (0.3)	8.2 (6.9-9.7)
Age ≥40 years	148/7075 (2.1)	2540/775,165 (0.3)	2688/782,240 (0.3)	6.5 (5.5-7.7)
Inpatients aged ≥40 years	142/6650 (2.1)	2462/518,819 (0.5)	2604/525,469 (0.5)	4.6 (3.9-5.4)

[a] Patients with MI within six months preceding surgery. Values are the number of perioperative MIs/number in grouop (percentage).
[b] Patients with no MI within six months preceding surgery. Values are the number of perioperative MIs/number in group (percentage).
CI = confidence interval; MI = myocardial infarction; NSQIP = National Surgical Quality Improvement Program; OR = odds ratio.

Table 3. Logistic regression of risk factors for cardiac arrest

Risk factor	B	SE	Wald χ^{2a}	df	p value[b]	Exp(B)	Lower CI for Exp(B)	Upper CI for Exp(B)
CHF	0.191	0.060	10.045	1	0.002	1.211	1.076	1.363
Recent MI	0.036	0.073	0.244	1	0.621	1.037	0.899	1.195
PCI	–0.067	0.047	2.079	1	0.149	0.935	0.853	1.024
PCS	–0.025	0.044	0.337	1	0.561	0.975	0.894	1.062
History of angina	0.189	0.076	6.145	1	0.013	1.208	1.040	1.402
ASA Class								
1	–3.127	0.501	38.893	1	0.001	0.044	0.016	0.117
2	–1.484	0.414	12.856	1	0.001	0.227	0.101	0.510
3	0.205	0.410	0.249	1	0.618	1.227	0.549	2.742
4	1.253	0.411	9.289	1	0.002	3.499	1.564	7.831
5	2.013	0.416	23.388	1	0.001	7.486	3.311	16.926
Emergency surgery	–0.703	0.038	346.691	1	0.001	0.495	0.460	0.533
Frailty[c]	3.275	0.138	563.978	1	0.001	26.443	20.180	34.650

[a] Wald χ^2 test of the null hypothesis that the coefficient equals zero.
[b] Statistical significance is $p < 0.05$.
[c] See Methods for description of frailty index.
ASA = American Society of Anesthesiologists; B = coefficient for the logistic regression equation for predicting the dependent variable from the independent variable: $\log (p/1 - p) = B_0 + B_1 \times X_1 + B_2 \times X_2 + B_3 \times X_3 + \ldots B_n \times X_n$ where p is the probability of cardiac arrest; CHF = congestive heart failure; CI = confidence interval; df = degrees of freedom for the Wald χ^2 test; Exp(B) exponentiation of the B coefficient, an odds ratio; MI = myocardial infarction; PCI = percutaneous coronary intervention; PCS = previous cardiac surgery; SE = standard error around the coefficient.

Table 4. Logistic regression of risk factors for perioperative myocardial infarction

Risk factor	B	SE	Wald χ^{2a}	df	p value[b]	Exp(B)	Lower CI for Exp(B)	Upper CI for Exp(B)
CHF	–0.588	0.103	32.531	1	0.002	0.555	0.454	0.680
Recent MI	0.002	0.098	.000	1	0.984	1.002	0.828	1.213
PCI	0.345	0.052	44.058	1	0.001	1.412	1.275	1.564
PCS	0.217	0.052	17.139	1	0.001	1.242	1.121	1.376
History of angina	0.345	0.093	13.834	1	0.001	1.411	1.177	1.693
ASA Class								
1	–1.476	1.070	1.904	1	0.001	0.228	0.028	1.860
2	0.429	1.003	0.183	1	0.168	1.536	0.215	10.963
3	1.942	1.001	3.765	1	0.052	6.974	0.981	49.594
4	2.514	1.002	6.299	1	0.012	12.353	1.735	87.980
5	2.702	1.009	7.166	1	0.007	14.906	2.062	107.747
Emergency surgery	–0.653	0.050	169.492	1	0.001	0.520	0.472	0.574
Frailty[c]	3.732	0.177	444.617	1	0.001	41.757	29.518	59.072

[a] Wald χ^2 test of the null hypothesis that the coefficient equals zero.
[b] Statistical significance is $p < 0.05$.
[c] See Methods for description of frailty index.
ASA = American Society of Anesthesiologists; B = coefficient for the logistic regression equation for predicting the dependent variable from the independent variable: $\log (p/1 - p) = B_0 + B_1 \times X_1 + B_2 \times X_2 + B_3 \times X_3 + \ldots B_n \times X_n$ where p is the probability of cardiac arrest; CHF = congestive heart failure; CI = confidence interval; df = degrees of freedom for the Wald χ^2 test; Exp(B) exponentiation of the B coefficient, an odds ratio; MI = myocardial infarction; PCI = percutaneous coronary intervention; PCS = previous cardiac surgery; SE = standard error around the coefficient.

The OR of a patient dying whether or not s/he had a perioperative MI was 11.8.

We also did logistic regression analysis of possible risk factors for perioperative cardiac arrest (Table 3) and perioperative MI (Table 4), including recent CHF, recent MI, history of percutaneous coronary intervention, history of previous major cardiac surgery, recent angina, ASA class, emergency surgery, and frailty index. Frailty and ASA class were the strongest predictors of cardiac arrest; the OR—Exp(B)—for frailty was 26.4, and the ORs for ASA Classes 3, 4, and 5 were 1.2, 3.5, and 7.5, respectively. For perioperative MI, frailty and ASA class also were the most powerful predictors, with the OR for frailty being 41.8, and the ORs for ASA Classes 3, 4, and 5 being 6.9, 12.3, and 14.9, respectively.

Finally, we examined outcomes (perioperative MI and death) in inpatients aged 40 years or older stratified by surgical complexity (RVUs). As surgical RVUs increased, the incidence of perioperative MI increased in patients with and without a history of recent MI, but the incidence was greater in those with a recent MI (Table 5). Also, as surgical RVUs increased, the incidence of death increased (Table 5). The incidence of death was greater in those with a history of recent MI; however, many deaths were noncardiac. For example, in the highest RVU group there were 73 perioperative MIs and 408 deaths (Table 5) in the patients with recent MI. In the mid- and high-RVU categories, 14% to 16% of patients with recent MI died even though only 1.9% to 2.5% of them had another MI after surgery. In all RVU categories except the lowest RVUs with no history of recent MI, the incidence of death was several-fold greater than the incidence of perioperative MI.

Discussion

In the decades since the study by Goldman et al,[2] our data show the absolute and relative risk of perioperative MI and death has decreased. The absolute risk of perioperative MI for patients with recent MI has decreased by an order of magnitude from 27.3% to 2.1%.

The risk of perioperative MI for patients with recent MI has improved, but so has the risk for patients without recent MI by an order of magnitude from 2.8% to 0.3%. Our data do not allow us to analyze what accounts for this improvement, but the reason is likely multifactorial.

Goldman et al[2] did not report an OR, but we calculated this ratio from their data. Of 22 patients with recent preoperative MI, 6 had a perioperative MI or cardiac death, and of 973 without recent preoperative MI, 26 had perioperative MI or cardiac death. The OR, therefore, was 9.7 for risk of perioperative MI or cardiac death given preoperative MI.

The OR of perioperative MI for patients with vs without recent MI has decreased from the 9.7 calculated from the data by Goldman et al. Which population one chooses to compare could be either all patients aged 40 years and older or inpatients aged 40 years and older. Surgical practice has changed so that some patients who would have been inpatients in the 1970s would now be outpatients. Nonetheless, an OR between 4.7 (inpatients only) and 6.5 (inpatients and outpatients) in our data seems an appropriate comparison and is substantially less than 9.7. Not only is the absolute risk improved but also the relative risk for patients with preexisting cardiac disease is reduced by at least one third, if not one half. The risk of perioperative MI for a patient who had a recent preoperative MI has fallen from 9.7 times greater than that of a patient who had no recent MI to 4.7 to 6.5 times greater.

The inhospital mortality for perioperative MI was approximately 50% in the earlier studies.[3] In our data, 30-day mortality after perioperative MI was 25.9%. Although this number is an improvement, it is still high and remains a serious concern. Also, delayed morbidity for this population remains high. Patients surviving an inhospital MI had a 28-fold increase in cardiac complications within 6 months of surgery.[17]

Recent studies of patients undergoing vascular surgery have also reported mortality from perioperative MI as below 50%, finding 16% to 21% mortality.[18,19] Previous coronary artery bypass grafting, even more than a year before vascular surgery, has been reported to reduce the risk of cardiac mortality,[19] but McFall et al[20] found that bypass grafting did not decrease reinfarction or mortality in major vascular surgery.

We focused on recent MI as a predictor of outcome for historical comparison and found that 2% of patients with recent MI will experience a reinfarction, but others have used known coronary artery disease (CAD) or CAD risk factors as predictors of outcome. Mangano et al[21] showed that those with risk factors who were treated with atenolol had a 6-month mortality of 0% whereas those not treated had 8% mortality. At-risk patients of Wallace et al[22] had 2% 30-day mortality when treated with atenolol. Badner et al[23] found at-risk patients had 5.6% perioperative MI (17% fatal). Lee et al[6] reported 2% of at-risk patients had major cardiac events perioperatively. Most impressively, Wallace et al[22] illustrated a reduction in 30-day all-cause mortality after surgery from 1% in 1996 to 0.4% in 2008 (vs 1.7% in our total population), whereas 1-year mortality fell from 16% to 4% in their study population, which included at-risk and low-risk patients.

All measures of perioperative morbidity and mortality for patients with a history of MI (preexisting CAD) have improved in the above cited studies compared with those from the 1970s. In addition, cardiac events seem no longer to account for half of perioperative morbidity since our inpatients 40 years of age and older had 2604 perioperative MIs and 15,669 deaths. Nonetheless, recent preoperative MI still must be viewed as a serious risk factor.[1,3] An OR greater than 1 signifies elevated risk, and the much-improved risk we report is still considerable and requires continuing diligent care.

The improvement in outcomes we measured is not matched by that observed by Livhits et al,[5] who collected data in California between 1999 and 2004. When MI occurred in the 1 month before surgery, they found 33% reinfarction, with nearly half of those patients dying (14% mortality), similar to 1970s outcomes. Our data recorded MI in the 6 months before surgery, but not in 30-day increments so we cannot compare with that finding. At 3 to 6 months after MI, Livhits et al found 6% reinfarction, showing a decrease in risk with time from preoperative MI, although still higher than what we observed.[5] Even when we analyzed outcomes by surgical RVU, patients in the highest RVU category with a history of recent MI had a reinfarction rate of only 2.5%. The selected study population of Livhits et al, composed of patients having 5 major operations, seems not the same as ours because 2.9% of their patients had an MI in the year before surgery whereas 1.2% of our inpatients age 40 years and older had an MI in the preceding 6 months, and their patients' mean age was 69 years whereas that of our group of inpatients aged 40 and older was 63 years. For the purpose of evaluating a change in outcomes compared with older studies, we believe our population of inpatients aged 40 years and older is more suitable. Livhits et al appropriately recommend delaying elective surgery after MI by at least 8 weeks, using temporizing measures if necessary.

Frailty, other indexes, and screening procedures have been proposed as ways to stratify perioperative risk.[6-9,14] We found that risk increased as surgical RVUs increased, but patient factors account for operative mortality in all but the most complex cases.[24] In our data the multifactorial measures of frailty and ASA class were better predictors of adverse outcome than single factors such as history of MI.

In summary, we examined the risk of previous MI and other risk factors on perioperative cardiac morbidity using the NSQIP database. The risk of perioperative major cardiac events has improved by an order of magnitude during the last 30 years. Cardiac events remain a major contributor to morbidity and mortality, but now are closer to one fifth rather than the previously reported one half of perioperative mortality. Frailty and ASA class are the more powerful predictors of adverse outcome. ❖

Table 5. Perioperative myocardial infarction and death by relative value units category and history of recent myocardial infarction

Surgical RVU	Recent history	No Periop MI no. (%)	Periop MI no. (%)	χ^2	OR (95% CI)	No Death no. (%)	Death no. (%)	χ^2	OR (95% CI)
<10	No MI	63,265 (99.8)	149 (0.2)	59.9	7.4	62,384 (98.4)	103 (1.6)	248.4	6.3
(n = 64,119)	MI	693 (98.3)	12 (1.7)		(4.1-13.3)	639 (90.6)	66 (9.4)		(4.8-8.1)
10-20	No MI	235,321 (99.6)	871 (0.4)	176.0	5.2	230,187 (97.5)	6005 (2.5)	1957.0	7.1
(n = 239,234)	MI	2985 (98.1)	57 (1.9)		(3.9-6.8)	2566 (84.4)	476 (15.6)		(6.4-7.9)
>20	No MI	217,771 (99.3)	1442 (0.7)	145.8	3.9	211,529 (96.5)	7684 (3.5)	908.3	4.5
(n = 222,116)	MI	2830 (97.5)	73 (2.5)		(3.1-4.9)	2495 (85.9)	408 (14.1)		(4.0-5.0)
Total	No MI	516,357 (99.5)	2462 (0.5)	367.3	4.6	504,100 (97.2)	14,719 (2.8)	2974.8	5.7
(N = 525,469)	MI	6508 (97.9)	142 (2.1)		(3.9-5.4)	5700 (85.7)	950 (14.3)		(5.3-6.1)

[a] Perioperative indicates during or within 30 days after surgery, death was for that occurring within 30 days after surgery, and recent indicates within 6 months before surgery.
CI = confidence interval; MI = myocardial infarction; OR = odds ratio; Periop = perioperative; RVU = relative value units.

Disclosure Statement

The author(s) have no conflicts of interest to disclose.

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