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CLINICAL RESEARCH STUDY

Perioperative cardiovascular mortality in noncardiac surgery: Validation of the Lee cardiac risk index

Eric Boersma,[a] Miklos D. Kertai, MD,[b] Olaf Schouten, MD,[c] Jeroen J. Bax, MD,[f] Peter Noordzij, MD,[b] Ewout W. Steyerberg,[d] Arend F.L. Schinkel, MD,[a] Marian van Santen,[e] Maarten L. Simoons, MD,[a] Ian R. Thomson, MD,[g] Jan Klein, MD,[b] Hero van Urk, MD,[c] Don Poldermans, MD[c]

[a]Departments of Cardiology, [b]Anesthesiology, [c]Vascular Surgery, [d]Clinical Decision Sciences, and [e]Medical Registration, Erasmus Medical Center, Rotterdam; [f]Department of Cardiology, University Hospital Leiden, Leiden, The Netherlands; and [g]Department of Anesthesiology, University of Manitoba, Winnipeg, Canada.

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ABSTRACT

PURPOSE: The Lee risk index was developed to predict major cardiac complications in noncardiac surgery. We retrospectively evaluated its ability to predict cardiovascular death in the large cohort of patients who recently underwent noncardiac surgery in our institution.

METHODS: The administrative database of the Erasmus MC, Rotterdam, The Netherlands, contains information on 108 593 noncardiac surgical procedures performed from 1991 to 2000. The Lee index assigns 1 point to each of the following characteristics: high-risk surgery, ischemic heart disease, heart failure, cerebrovascular disease, renal insufficiency, and diabetes mellitus. We retrospectively used available information in our database to adapt the Lee index calculated the adapted index for each procedure, and analyzed its relation to cardiovascular death.

RESULTS: A total of 1877 patients (1.7%) died perioperatively, including 543 (0.5%) classified as cardiovascular death. The cardiovascular death rates were 0.3% (255/75 352) for Lee Class 1, 0.7% (196/28 892) for Class 2, 1.7% (57/3380) for Class 3, and 3.6% (35/969) for Class 4. The corresponding odds ratios were 1 (reference), 2.0, 5.1, and 11.0, with no overlap for the 95% confidence interval of each class. The C statistic for the prediction of cardiovascular mortality using the Lee index was 0.63. If age and more detailed information regarding the type of surgery was retrospectively added, the C statistic in this exploratory analysis improved to 0.85.

CONCLUSION: The adapted Lee index was predictive of cardiovascular mortality in our administrative database, but its simple classification of surgical procedures as high-risk versus not high-risk seems suboptimal. Nevertheless, if the goal is to compare outcomes across hospitals or regions using administrative data, the use of the adapted Lee index, as augmented by age and more detailed classification of type of surgery, is a promising option worthy of prospective testing.

Requests for reprints should be addressed to Eric Boersma, Clinical Epidemiology Unit, Department of Cardiology, Room H543, Erasmus MC, Dr Molewaterplein 40, 3015 GD Rotterdam, The Netherlands.

E-mail address: h.boersma@erasmusmc.nl.

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Patients undergoing major noncardiac surgery are at high risk of cardiovascular morbidity and mortality. Evidence suggests that perioperative myocardial infarction is commonly caused by rupture of a coronary plaque, leading to thrombus formation and subsequent vessel occlusion, similar to what occurs in nonsurgical settings.[1,2] The clinical importance of perioperative cardiovascular complications is well recognized, and numerous investigations have described the relation between patient's characteristics and the risk of adverse cardiovascular outcome.[3-11]

In the 1990s, Lee and colleagues systematically analyzed the risk of major cardiac complications (which included myocardial infarction, cardiogenic pulmonary edema, cardiac arrest, and cardiac death) in 4315 patients undergoing noncardiac surgery, the largest cohort ever described.[8] The resulting Lee index, which is a modification of the original Goldman index, is now considered by many clinicians and researchers to be the most relevant index to predict cardiac risk. However, the patients studied by Lee and colleagues cannot be considered as an average, unselected surgical cohort because their study included only patients with a several-day expected length of hospital stay and excluded neurologic surgery; as a result, it was relatively dominated by patients undergoing thoracic (12%), vascular (21%), and orthopedic surgery (35%).

The current study evaluates the Lee index in 108 593 patients who underwent noncardiac surgery in the Erasmus Medical Center from 1991 to 2000. Because we relied on medical records and administrative data gathered as part of routine medical care, rather than duplicating the prospective methods of the Lee study, we used cardiovascular mortality, instead of the broader range of clinical cardiac complications that were considered in the original Lee study, as our primary endpoint.

Methods

Hospital setting, procedures and patients

The Erasmus Medical Center, a metropolitan university hospital that serves a population of approximately 3 million people in the southwestern area of The Netherlands, acts as a tertiary referral center for approximately 30 affiliated hospitals. Between January 1, 1991, and December 31, 2000, 122 860 noncardiac surgical procedures were performed in patients above the age of 15 years in the Erasmus Medical Center. We excluded 14 267 planned and unplanned procedures that were conducted within 30 days after an initial operation, and analyzed the perioperative course of the remaining 108 593 procedures, which were performed in 75 581 different patients. Over the 10-year observation period, 20 885 patients had multiple surgeries in the Erasmus Medical Center. They were included as many times as they had surgeries that were more than 30 days apart. The median span between 2 successive procedures was 297 days (interquartile range, 123 to 677 days). The operation (not the patient) was the unit of analysis because this approach is consistent with clinical practice, wherein the risk of perioperative complications is assessed in relation to a specific procedure.

Sources of data

For each patient undergoing surgery, a number of data items are routinely entered into the computerized hospital information system at the time the patient is hospitalized. First, surgical techniques are classified by the treating physician according to a standardized national coding system, which was developed in cooperation with the National Health Service and medical insurance companies. This system is used for reimbursement and to record and monitor the experience of surgeons and surgical residents. Using this classification, we grouped surgical procedures into 14 categories, with a total of 11 969 procedures (11.0%) classified into multiple categories.

Second, from written information that is provided by the patient's general practitioner, referring physician, or hospital physicians involved in perioperative care, each patient's medical history is classified according to the *International Classification of Diseases, Ninth Revision (ICD-9).*[12] The classification and the entry of the data in the electronic database are performed by dedicated administrative personnel who have completed in-depth training on medical data registration. We recorded the following medical conditions: history of diabetes mellitus (ICD-9250), myocardial infarction (ICD-9410, 411, and 412), angina pectoris (ICD-9413 and 414), prior heart failure (ICD-9428), cerebrovascular accident (ICD-9430), and renal disease (ICD-9580). These recorded diagnoses served as surrogates for 5 more detailed criteria used in the Lee index[8] in which ischemic heart disease was defined as a history of myocardial infarction or positive exercise test, current complaint of ischemic chest pain, or use of nitrate therapy, or Q waves on the electrocardiogram, but patients with a history of coronary bypass surgery or angioplasty were included only if they had current complaints of chest pain presumed to be due to ischemia; heart failure was defined as a history of heart failure, pulmonary edema, or paroxysmal nocturnal dyspnea, a physical examination showing an S_3 gallop or bilateral rales, or a chest radiograph showing pulmonary vascular redistribution; renal failure was a creatine level >2.0 mg/dL; diabetes was insulin requiring; and cerebrovascular disease was defined as a history of a stroke or transient ischemic attack. For the score criterion, high-risk surgery, we categorized procedures in the same way as the Lee index: retroperitoneal, intrathoracic, or suprainguinal vascular procedures were defined as high risk.

Endpoint definition

The hospital information system also contains the patient's vital status at hospital discharge and clinical postoperative diagnoses. For example, diagnosed perioperative myocardial infarctions are reported, but the patients do not routinely have serial postoperative electrocardiograms or blood sampling for determination of cardiac biomarkers. Consequently, clinically unsuspected or painless perioperative myocardial infarctions may well be missed. Similarly, clinically apparent strokes were reported, but systematic neurologic evaluations were not performed. In view of these limitations, we chose cardiovascular death as the primary endpoint of our analyses. Cardiovascular death, which was defined as any death with a cardiovascular complication as the primary or secondary cause (according to the definitions of the World Health Organization), included deaths following myocardial infarction, cardiac arrhythmia, resuscitation, heart failure, or stroke. Noncardiovascular death was defined as any death with a principal noncardiovascular cause, including surgery-related bleeding complications, cancer, trauma, and infection. Sudden death in a previously stable patient was considered as cardiovascular.

To obtain the cause of death, 2 investigators (MDK, DP) independently reviewed all available perioperative data but were blind to preoperative characteristics and aimed to reach consensus. If consensus could not be reached, the opinion of a third, independent investigator (PN) was final. Events were counted until hospital discharge or 30 days after surgery, whichever day came first.

Data quality and ethical considerations

We should emphasize that the data that we used were collected for administrative purposes and not for the purposes of this study by clinicians using standardized data collection forms. We designed and undertook this study several years after the last patient was enrolled, and we were not able to verify the completeness or the correctness of the data. By necessity, we had to rely on the information that was provided by the clinicians who took care of the patients during everyday clinical practice.

This study was approved by the Medical Ethics Committee of the Erasmus Medical Center. However, given the retrospective nature of our study, informed consent could not be obtained from each patient.

Statistical analysis

Continuous data are described as median values and corresponding 25th and 75th percentiles, and dichotomous data are described as numbers and percentages. With the limitations noted previously, we estimated the Lee index for each patient in our dataset. Univariable logistic regression analyses were used to evaluate the relation among the adapted Lee index (with individual dummy variables for each score category) as calculated with information in our administrative database, the clinical characteristics that are part of this index, and our primary endpoint, which was cardiovascular death including stroke, rather than the endpoint of Lee and colleagues, who considered the composite endpoint of myocardial infarction, cardiogenic pulmonary edema, cardiac arrest, or cardiovascular death. Crude, unadjusted odds ratios and corresponding 95% confidence intervals are reported.

Subsequently, multivariable logistic regression analyses were performed to evaluate if the predictive power of the adapted Lee index could be improved retrospectively in our dataset by adding age or more detailed information on the type of surgery, according to the classification recommended by the American Heart Association/American College of Cardiology.[13] The 4 categories were low risk (breast, carotid, dental, endocrine, eye, gynecology, reconstructive), low-intermediate risk (orthopedic, urologic), intermediate-high risk (abdominal; ear, nose, throat; neurologic; pulmonary; renal transplant; vascular, excluding aortic and carotid), and high risk (aortic). Adjusted odds ratios and corresponding 95% confidence intervals were calculated. The performance of risk models was determined by the C statistic, which indicates how well a model rank orders patients with respect to their outcomes, where 0.5 indicates no predictive value and 1.0 indicates perfect performance.[14]

Because our dataset involved patients with multiple operations, independence of observations could not be excluded beforehand. Therefore, to examine this phenomenon, all regression analyses were first performed using conventional techniques and repeated using generalized estimation equations,[15] with "patient" as the classification factor. No relevant differences were observed between the parameter estimates as determined according to both methodologies. Therefore, we concluded that interobservation correlation was not a major issue in our dataset, and we present only the results based on classical methods.

Results

A total of 52 387 surgical procedures were performed in men, including 12 378 orthopedic surgeries (24%); 9273 ear, nose, and throat surgeries (18%); and 8637 abdominal surgeries (16%). Among the 56 206 procedures in women, gynecological surgery was most common with 15 312 procedures (27%), followed by orthopedic surgery with 9840 (18%), and abdominal surgery with 7816 (14%). Because of reallocation of patients among regional hospitals, the annual volumes of ophthalmic and gynecological procedures decreased in the early 1990s. During the study period, the volume of orthopedic surgery gradually increased, whereas the volume of abdominal surgery decreased slightly.

With a median age of 51 years (25th to 75th percentile: 34-65 years), men were 7 years older than were women (median 44 years; 25th to 75th percentile: 32-62 years). The majority of patients had a score of 0 points on the adapted Lee index (Figure 1). During the study period, no systematic change in scores on the adapted Lee index was observed in men. By comparison, scores in women worsened slightly in

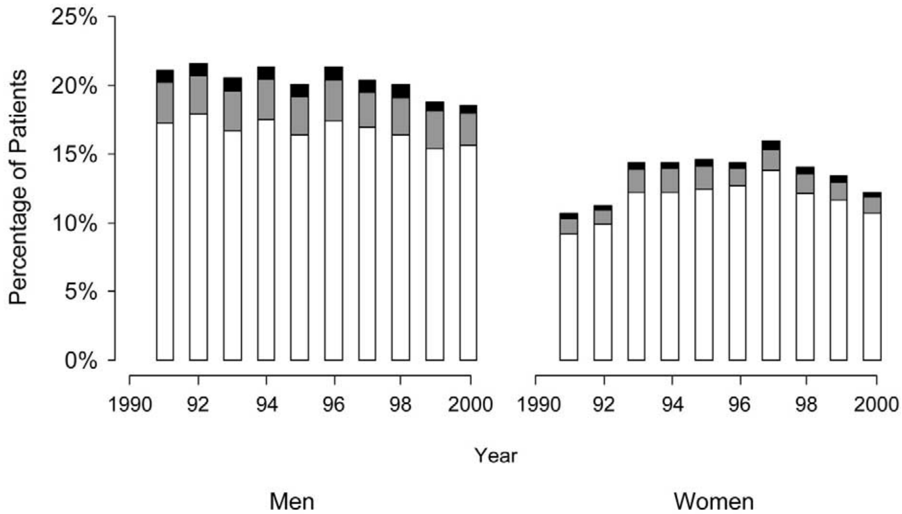

Figure 1 Time trends in the cardiovascular risk profile. Data indicate the percentage of patients with a score of 1 point (white portion of the bar), 2 points (grey portion), and ≥3 points according to the cardiovascular risk index as developed by Lee and colleagues.[8]

1993 and remained constant thereafter, a shift that was strongly related to the decline in the number of gynecological procedures.

A total of 1877 patients (1.7%) died perioperatively. A cardiovascular complication was the principal (405 patients) or the secondary (138 patients) cause of death in 543 patients (0.5% of the sample; 29% of deaths). Patients in whom an autopsy report was available (326 patients; 17% of deaths) were more often labeled as having cardiovascular death than patients in whom no such report was available (37% [122/326] vs 27% [421/1551] patients; $P < 0.001$). Infection, the most common noncardiovascular cause of death, was the primary cause in 231 patients and the secondary cause in 308 patients, representing 29% of deaths.

All-cause mortality and cardiovascular mortality were higher in men than in women: 2.2% (1167/52 387) versus 1.3% (710/56 206) ($P < 0.001$), and 0.7% (350/52 387) versus 0.3% (193/56 206) ($P < 0.001$). During the study period, no systematic change in all-cause mortality was observed in men (Figure 2). In contrast, all-cause mortality in women increased significantly from 0.9% (55/6280) in 1991 to 1.3% (69/5151) in 1993 and 1.5% (79/5315) in 2000 (71% increase; $P < 0.001$). There were no significant changes in cardiovascular mortality over time in either men or women.

Important differences in the incidence of perioperative cardiovascular death were observed in relation to type of surgery (Table 1). Patients undergoing vascular surgery, especially those undergoing aortic surgery, had the highest cardiovascular mortality (1.8%), followed by patients undergoing neurologic surgery (1.7%), renal transplant (about 1.1%), and pulmonary surgery (1.1%). Breast, dental, eye, and gynecology surgery were associated with cardiovascular mortality rates below 0.1%. The 15 318 patients (14%) who had laparoscopic procedure had a lower incidence of cardiovascular death than did patients who had open surgery (0.2% vs 0.6%; $P < 0.001$) (Table 2). The 774 patients (0.7%) who underwent emergency surgery had a significantly higher rate of cardiovascular death than did patients who underwent nonemergency surgery (6.1% vs 0.5%; $P < 0.001$).

In univariable analyses, the adapted Lee index and its individual components were associated with an increased risk of cardiovascular death (Table 2). The prospective C statistic for the prediction of cardiovascular mortality in this validation analysis was 0.63. The C statistic for this exploratory analysis was substantially higher in the subset of 66 530 low- to intermediate-risk surgical procedures (including breast, carotid, dental, endocrine, eye, gynecology, orthopedic, reconstructive, and urologic surgery) than in the remaining 42 063 intermediate- to high-risk procedures (0.68 vs 0.56). When more detailed information, including the type of surgery (defined as low, low-intermediate, intermediate-high, and high), whether it was laparoscopic or open, and whether it was emergent, was added to the Lee index, the retrospective C statistic was 0.79 (Table 3). If age were included, the C statistic rose further, to 0.85.

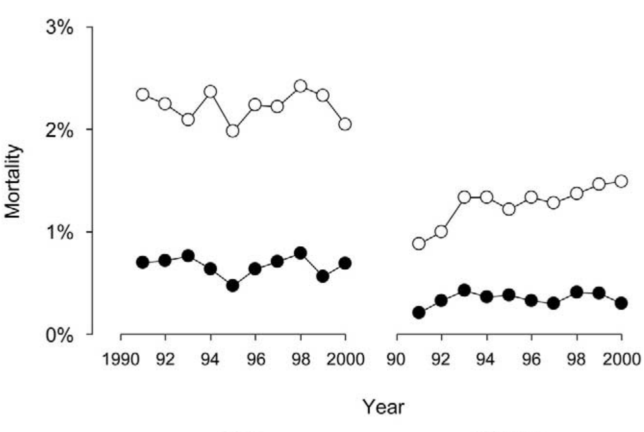

Figure 2 Time trends in the incidence of perioperative all-cause mortality (open circles) and cardiovascular death (closed circles).

Table 1 Perioperative cardiovascular and all-cause death in patients undergoing noncardiac surgery for various indications

Type of surgery	Number of procedures	Cardiovascular death: Primary cause	Cardiovascular death: Secondary cause	Cardiovascular death: Total	All-cause death
		Number (%)			
Abdominal	16 453	63 (0.4)	50 (0.3)	113 (0.7)	606 (3.7)
Hepatico, pancreatico, billiary	2752	10 (0.4)	4 (0.1)	14 (0.5)	129 (4.7)
Esophagogastric	11 982	53 (0.4)	44 (0.4)	97 (0.8)	488 (4.1)
Other abdominal	3714	12 (0.3)	7 (0.2)	19 (0.5)	122 (3.3)
Breast	2411	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)
Dental	1225	1 (0.1)	0 (0.0)	1 (0.1)	2 (0.2)
Ear, nose, throat	15 291	114 (0.7)	22 (0.1)	136 (0.9)	411 (2.7)
Endocrine	1029	1 (0.1)	2 (0.2)	3 (0.3)	6 (0.6)
Eye	9163	1 (0.0)	0 (0.0)	1 (0.0)	11 (0.1)
Gynecology	15 343	2 (0.0)	1 (0.0)	3 (0.0)	20 (0.1)
Neurologic	5797	87 (1.5)	14 (0.2)	101 (1.7)	381 (6.6)
Orthopedic	22 218	34 (0.2)	9 (0.0)	43 (0.2)	116 (0.5)
Reconstructive	4157	5 (0.1)	2 (0.0)	7 (0.2)	12 (0.3)
Pulmonary	1965	14 (0.7)	7 (0.4)	21 (1.1)	86 (4.4)
Renal transplant	711	8 (1.1)	0 (0.0)	8 (1.1)	14 (2.0)
Urologic	11 116	28 (0.3)	10 (0.1)	38 (0.3)	159 (1.4)
Vascular	6234	90 (1.4)	25 (0.4)	115 (1.8)	277 (4.4)
Aortic-acute	196	21 (10.7)	7 (3.6)	28 (14.3)	57 (29.1)
Aortic-elective	890	29 (3.3)	7 (0.8)	36 (4.0)	72 (8.1)
Carotid endarterectomy	891	4 (0.4)	2 (0.2)	6 (0.7)	18 (2.0)
Peripheral bypass	927	14 (1.5)	2 (0.2)	16 (1.7)	28 (3.0)
Other vascular	3854	36 (0.9)	13 (0.3)	49 (1.3)	142 (3.7)
Other	9423	18 (0.2)	13 (0.1)	31 (0.3)	92 (1.0)
Any type	108 593	405 (0.4)	138 (0.1)	543 (0.5)	1877 (1.7)

Discussion

Cardiovascular mortality still is a major burden in patients undergoing noncardiac surgery. In the investigated cohort, about 7 of every 1000 procedures in men and 3 of every 1000 procedures in women resulted in fatal in-hospital cardiovascular complications. In contrast, anesthesia-related mortality occurs only in approximately 1 of 250 000 procedures.[16] Interestingly, patients who underwent postmortem examination were considerably more often classified as cardiovascular death than were patients in whom no such examination was performed, suggesting that the incidence and effect of cardiovascular complications after noncardiac surgery may be underestimated in clinical practice.

The Lee index (or revised Goldman index) is considered the best currently available cardiac risk prediction index in noncardiac surgery because it was developed on contemporary, prospectively gathered clinical data from unselected patients who underwent a wide spectrum of procedures and were followed systematically postoperatively, including standardized visits and cardiac biomarkers, for a range of clinically relevant cardiac outcomes.[17,18] In our study, the Lee index was adapted for an administrative database and its use extended to a different goal––the use of administrative data specifically to predict perioperative cardiovascular mortality. However, in agreement with another investigation,[19] our data also suggest that the Lee index is probably suboptimal for identifying patients with greater cardiac risk, perhaps because it excluded emergency operations and perhaps because the type of surgery, which is one of the main determinants of adverse cardiovascular outcome,[13] was considered in only 2 subtypes: high risk, including intraperitoneal, intrathoracic and suprainguinal vascular procedures; and all remaining nonlaparascopic procedures, mainly including orthopedic, abdominal, and other vascular procedures. We found that a more subtle classification, as suggested by the American Heart Association/American College of Cardiology guideline committee,[13] resulted, at least retrospectively, in a substantially better risk discrimination. We realize that the Lee index was developed for the prediction of prospectively detected "major cardiac complications" (which included myocardial infarction, cardiogenic pulmonary edema, cardiac arrest, and cardiac death) and not for the prediction of cardiovascular death only. It is unknown whether the C statistics would have been more favorable if we had used the same endpoint as Lee and colleagues, but some believe it may be easier to predict the incidence of death than to predict a broader range of clinical outcomes.[20] In addition, from the perspective of assessing quality of care

Table 2 Univariable relation among the Lee index, demographic and clinical characteristics, and perioperative cardiovascular death

Characteristic		Number of procedures	Number (%) cardiovascular death	Crude, unadjusted odds ratio (95% confidence interval)
		Number (%)		
Adaptation of the Lee index score and its components (see Methods)				
Adapted Lee index	≥3	969	35 (3.6)	11.0 (7.7-15.8)
	2	3380	57 (1.7)	5.1 (3.8-6.7)
	1	28 892	196 (0.7)	2.0 (1.7-2.4)
	0	75 352	255 (0.3)	1
Type of surgery*	High risk	29 426	224 (0.8)	1.9 (1.6-2.3)
	Not high risk	79 167	319 (0.4)	1
History of ischemic heart disease	Yes	3588	77 (2.1)	4.9 (3.9-6.3)
	No	105 005	466 (0.4)	1
History of heart failure	Yes	1377	50 (3.6)	8.2 (6.1-11.0)
	No	107 216	493 (0.5)	1
History of CVA	Yes	500	11 (2.2)	4.6 (2.5-8.3)
	No	108 093	532 (0.5)	1
Renal insufficiency	Yes	1894	31 (1.6)	3.5 (2.4-5.0)
	No	106 699	512 (0.5)	1
Diabetes mellitus	Yes	2001	36 (1.8)	3.8 (2.7-5.4)
	No	106 592	507 (0.5)	1
Detailed data on type of surgery				
Type of surgery†	High risk	1078	63 (5.8)	73.6 (46.9-115)
	Intermediate-high risk	40 985	371 (0.9)	10.8 (7.4-15.9)
	Low-intermediate risk	33 275	81 (0.2)	2.9 (1.9-4.4)
	Low risk	33 255	28 (0.1)	1
Laparascopic procedure	Yes	15 318	24 (0.2)	0.3 (0.2-0.4)
	No	93 275	519 (0.6)	1
Emergency surgery	Yes	774	47 (6.1)	14.0 (10.2-19.0)
	No	107 819	496 (0.5)	1
Other potential risk determinants				
Age (years)	≥80	5314	77 (1.5)	23.0 (14.8-35.7)
	70-80	12 619	165 (1.3)	20.7 (13.7-31.1)
	60-70	15 742	146 (0.9)	14.6 (9.7-22.1)
	50-60	15 675	91 (0.6)	9.1 (5.9-14.0)
	40-50	16 987	37 (0.2)	3.4 (2.1-5.6)
	<40	42 256	27 (0.1)	1

CVA = cerebrovascular accident.

*According to the Lee index: high risk = intraperitoneal, intrathoracic, and suprainguinal vascular procedures; not high risk = other procedures.

†According to the American Heart Association/American College of Cardiology classification: high risk = aortic; intermediate risk = abdominal; ear, nose, throat; neurologic; orthopedic; pulmonary; renal transplant; urologic; vascular, excluding aortic and carotid; low risk = breast; carotid; dental; endocrine; eye; gynecology; reconstructive. Within the intermediate risk group, patients undergoing orthopedic or urologic surgery had significantly lower risk than patients undergoing other types of surgery. Therefore, we labeled orthopedic and urologic procedures as low-intermediate risk, and the remaining procedures as intermediate-high risk.

using administrative databases, cardiovascular mortality is certainly a relevant endpoint.

The American Heart Association/American College of Cardiology guidelines identify advanced age as a minor predictor of cardiovascular risk.[13] In our study, as in essentially every study of perioperative risk, cardiovascular mortality increased progressively with age.[3-11] Indeed, elderly patients might often have asymptomatic coronary disease, which places them at increased risk of perioperative cardiovascular complications. The key question has been whether age itself is an independent predictor or whether its importance is subsumed by its strong relation with other measurable evidence of the severity of disease or of comorbid conditions. Our finding of the major importance of age per se might be because our approach to assessing risk factors was by means of the medical history as coded according to the *ICD-9* system and subsequently entered in an electronic database by administrative personnel based on written information provided by health-care professionals. These employees are specifically instructed to avoid inappropriate over-diagnosis; as a result, key medical conditions might have been overlooked, and, consequently, the relative contribution of these factors to cardiovascular death might have been underestimated, thereby also increasing the apparent

Table 3 Multivariable relation among the Lee index, type of surgery, age, and perioperative cardiovascular death, based on analyses of 108 593 subjects undergoing noncardiac surgery

Characteristic		Odds ratio (95% confidence interval)		
		Adapted Lee index only	Adapted Lee index and type of surgery	Adapted Lee index, type of surgery and age
Model C statistic		0.63	0.79	0.85
Adapted Lee index	≥3	11.0 (7.7-15.8)		
	2	5.1 (3.8-6.7)		
	1	2.0 (1.7-2.4)		
	0	1		
Adapted Lee index, excluding type of surgery*	≥3		9.2 (5.5-15.4)	6.4 (3.8-10.8)
	2		5.6 (4.0-7.9)	4.0 (2.9-5.6)
	1		2.3 (1.8-3.0)	1.7 (1.3-2.2)
	0		1	1
Type of surgery†	High risk		35.7 (22.1-57.6)	20.0 (12.3-32.5)
	Intermediate-high risk		10.3 (7.0-15.2)	10.3 (7.0-15.1)
	Low-intermediate risk		2.8 (1.8-4.3)	2.7 (1.7-4.1)
	Low risk		1	1
Laparascopic procedure	Yes		0.3 (0.2-0.4)	0.3 (0.2-0.4)
	No		1	1
Emergency surgery	Yes		4.6 (3.2-6.5)	4.4 (3.1-6.4)
	No		1	1
Age (years)	≥80			19.9 (12.8-31.1)
	70-80			12.6 (8.3-19.0)
	60-70			8.5 (5.6-12.9)
	50-60			5.6 (3.6-8.7)
	40-50			2.5 (1.5-4.1)
	<40			1

*Index that assigns one point to each of the following characteristics: ischemic heart disease, history of heart failure, history of cerebrovascular disease, renal insufficiency, and diabetes mellitus.

†According to the Amercian Heart Association/American College of Cardiology classification: high risk = aortic; intermediate risk = abdominal; ear, nose, throat; neurologic; orthopedic; pulmonary; renal transplant; urologic; vascular, excluding aortic and carotid; low risk = breast; carotid; dental; endocrine; eye; gynecology; reconstructive. Within the intermediate risk group, patients undergoing orthopedic or urologic surgery had significantly lower risk than patients undergoing other types of surgery. Therefore, we labeled orthopedic and urologic procedures as low-intermediate risk, and the remaining procedures as intermediate-high risk.

independent contribution of age itself.[21] In addition, we restricted our analyses to patients who underwent surgery. No information was included from patients who were screened but who did not undergo surgery because the risk was perceived as prohibitive. Obviously, exclusion of patients at risk of adverse cardiovascular outcome might have diluted estimates of relative risk.

The identification of patients at risk of perioperative cardiovascular complications has improved considerably in recent years. Beta-blockers reduce complication rates for some categories of patients, such as those undergoing major vascular surgery,[22-24] and statins may be useful as well.[25] By comparison, routine coronary revascularization is not beneficial.[26] The development and implementation of such strategies for the entire spectrum of surgical patients remains an important challenge for contemporary medicine.[27] In that regard, it is noteworthy that the incidence of fatal perioperative cardiovascular complications at our center did not decline during the 10-year study period.

Conclusion

This single center study, which involved over 100 000 subjects, demonstrated that perioperative cardiovascular mortality is a major burden in patients undergoing noncardiac surgery. Little progress has been achieved in reducing cardiovascular mortality during the years of the study. The adapted Lee index had an admirable performance to predict cardiovascular mortality, but its simple classification of procedures as high risk versus not high risk seems suboptimal. Our analysis is limited by the fact that our data are derived from an administrative database, the retrospective nature of the data, the *ICD-9* coding of clinical characteristics, and our evaluation of cardiovascular death rather than a broader range of clinical complications. Our approach seems most applicable to situations in which administrative data are to be used to assess outcomes and to compare outcomes in different hospitals or regions. Furthermore, prospective studies are warranted to confirm our findings.

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