LESS IS MORE

Outcomes and Processes of Care Related to Preoperative Medical Consultation

Duminda N. Wijeysundera, MD; Peter C. Austin, PhD; W. Scott Beattie, MD, PhD; Janet E. Hux, MD, MSc; Andreas Laupacis, MD, MSc

Background: Preoperative consultations by internal medicine physicians facilitate documentation of comorbid disease, optimization of medical conditions, risk stratification, and initiation of interventions intended to reduce risk. Nonetheless, the impact of these consultations, which may be performed by general internists or specialists, on outcomes is unclear.

Methods: We used population-based administrative databases to conduct a cohort study of patients 40 years or older who underwent major elective noncardiac surgery in Ontario, Canada, between 1994 and 2004. Propensity scores were used to assemble a matched-pairs cohort that reduced differences between patients who did and did not undergo preoperative consultation by general internists or specialists. The association of consultation with mortality and hospital stay was determined within this matched cohort. As a sensitivity analysis, we evaluated the association of consultation with an outcome for which no difference would be expected: postoperative wound infection.

Results: Of 269 866 patients in the cohort, 38.8% (n = 104 695) underwent consultation. Within the matched cohort (n = 191 852), consultation was associated with increased 30-day mortality (relative risk [RR], 1.16; 95% confidence interval [CI], 1.07-1.25; number needed to harm, 516), 1-year mortality (1.08; 1.04-1.12; number needed to harm, 227), mean hospital stay (difference, 0.67 days; 0.59-0.76), preoperative testing, and preoperative pharmacologic interventions. Notably, consultation was not associated with any difference in postoperative wound infections (RR, 0.98; 95% CI, 0.95-1.02). These findings were stable across subgroups as well as sensitivity analyses that tested for unmeasured confounding.

Conclusions: Medical consultation before major elective noncardiac surgery is associated with increased mortality and hospital stay, as well as increases in preoperative pharmacologic interventions and testing. These findings highlight the need to better understand mechanisms by which consultation influences outcomes and to identify efficacious interventions to decrease perioperative risk.

Arch Intern Med. 2010;170(15):1365-1374

MANY OF THE 234 MILLION people worldwide who undergo major surgery each year have medical comorbidities.[1] For example, approximately 20% have diabetes mellitus,[2] whereas 14% have chronic obstructive pulmonary disease.[3] For such patients, preoperative consultations by internal medicine physicians (hereinafter referred to as *preoperative medical consultations*) present opportunities to better document comorbid disease, undertake risk stratification, optimize preexisting medical conditions, initiate interventions intended to decrease perioperative risk, and defer or cancel surgery, if necessary.

However, the impact of these consultations, which may be performed by either general internists or specialists (eg, cardiologists or endocrinologists), on outcomes is unclear. In a single-center cohort study of 1282 participants, perioperative medical consultation was associated with increased hospital stay and costs, but there was no significant difference in related processes of care, such as β-blockade.[4] Conversely, a single-center randomized trial of 355 participants found that routine preoperative outpatient medical consultation reduced last-minute delays of surgery but had no significant effect on hospital stay or postoperative complications.[5] Notably, 60% of patients in the control arm of this study underwent inpatient preoperative medical consultation after admission to the hospital. Given this paucity of information, we undertook a population-based cohort study in Ontario, Canada, to determine whether preoperative medical consultation was associated with reduced mortality and hospital stay after major elective noncardiac surgery.

Author Affiliations are listed at the end of this article.

METHODS

After research ethics approval was received from Sunnybrook Health Sciences Centre, we used the following linked population-based administrative health care databases to undertake a retrospective cohort study in Ontario: the Canadian Institute for Health Information (CIHI) Discharge Abstract Database (hospital admissions), the Ontario Health Insurance Plan (OHIP) database (physician service claims), the Registered Persons Database (vital statistics), the Institute of Clinical Evaluative Sciences Physician Database (physicians' specialties), the Ontario Drug Benefit database (prescription medications for individuals older than 65 years), and the 2001 Canadian census. Although these databases lack physiologic and laboratory measures (eg, blood pressure and hemoglobin), they have been validated for many outcomes, exposures, and comorbidities.[6-9] During the study period, Ontario was Canada's most populous province, with more than 12 million residents who have universal access to physician and hospital services through a publicly funded health care program.

DESIGN

We retrospectively identified all Ontario residents older than 40 years who underwent the following elective surgical procedures between April 1, 1994, and March 31, 2004: abdominal aortic aneurysm repair, carotid endarterectomy, peripheral vascular bypass, total hip replacement, total knee replacement, large-bowel surgery, liver resection, Whipple procedure, pneumonectomy, pulmonary lobectomy, gastrectomy, esophagectomy, nephrectomy, or cystectomy. These procedures were selected because they are intermediate to high risk,[10] applicable to either sex, and previously described in the CIHI database.[11,12] Procedure codes in the CIHI database are very accurate.[7,9]

The principal exposure was preoperative medical consultation. Because no specific OHIP fee code identifies medical consultations for preoperative evaluation (as opposed to nonoperative indications), we used a validated claims-based definition: an OHIP claim for a consultation by a cardiologist, general internist, endocrinologist, geriatrician, or nephrologist within 4 months before surgery. In a multicenter cross-sectional study, this algorithm had a sensitivity of 90%, specificity of 92%, positive predictive value of 93%, and negative predictive value of 90% compared with re-abstraction of medical records.[13]

The outcomes of interest were postoperative mortality (30-day and 1-year), hospital stay, and in-hospital acute stroke. Mortality was determined by means of the CIHI database and Registered Persons Database, whereas the CIHI database was used to measure hospital stay. Although administrative data do not generally capture postoperative complications well,[14] the CIHI database describes postadmission strokes with moderate accuracy (sensitivity, 73%; positive predictive value, 77%).[7]

Demographic information was obtained from the Registered Persons Database. We used validated algorithms to identify diabetes mellitus[6] and hypertension.[8] The OHIP database was used to identify patients who had previously required dialysis. Using the CIHI database, we identified other comorbidities on the basis of codes from the *International Classification of Diseases* (9th or 10th Revision) from hospitalizations within 2 years preceding surgery: ischemic heart disease, congestive heart failure, cerebrovascular disease, atrial fibrillation, aortic stenosis, mitral stenosis, peripheral vascular disease, pulmonary disease, chronic renal insufficiency, malignant disease, liver disease, rheumatologic disease, previous venous thromboembolism, and dementia.[15-17] The CIHI database was also used to identify previous mechanical aortic or mitral valve replacement procedures performed within 10 years preceding surgery. We used the OHIP database to identify outpatient anesthesia consultations[18] and intraoperative invasive monitoring. Patients' socioeconomic status was estimated from their neighborhood median income in the 2001 Canadian census.

To understand how preoperative medical consultation might influence outcomes, we used the OHIP database to identify related processes of care: preoperative outpatient testing, preoperative cardiac interventions, postoperative admission to monitored beds, and postoperative mechanical ventilation. In addition, the Ontario Drug Benefit database was used to identify outpatient prescriptions (β-blockers, statins, warfarin sodium, and low-molecular-weight heparins) in patients older than 65 years.

ANALYSES

Bivariate tests were initially used to compare patients who did and did not undergo preoperative medical consultation (*t* test, *U* test, χ^2 test, Fisher exact test). A nonparsimonious multivariable logistic regression model was then developed to estimate a propensity score for consultation.[19] Clinical significance guided the initial choice of covariates: age, sex, year, surgery, income quintile, hospital type (teaching, low-volume nonteaching, mid-volume nonteaching, high-volume nonteaching), comorbid disease, anesthesia consultation, and invasive monitoring. The following comorbid diseases were included in the model: ischemic heart disease, congestive heart failure, cerebrovascular disease, atrial fibrillation, aortic stenosis, valvular heart disease necessitating anticoagulation (mitral stenosis or mechanical aortic or mitral valve replacement), peripheral vascular disease, hypertension, diabetes mellitus, pulmonary disease, renal disease, rheumatologic disease, malignant disease, previous venous thromboembolism, and dementia. Previously described methods were used to categorize nonteaching hospitals into tertiles[20] based on the annual volume of included procedures. A structured iterative approach was used to refine this model to achieve covariate balance within the matched pairs.[21] Covariate balance was measured by means of the standardized difference, in which an absolute standardized difference greater than 10% represents meaningful imbalance.[21] We matched consultation patients to no-consultation patients (without replacement) by means of a greedy-matching algorithm with a caliper width of 0.2 SD of the log odds of the propensity score. Continuous and dichotomous outcomes were then compared by statistical methods appropriate for paired data.[21]

Subgroup analyses were performed on the basis of sex, ischemic heart disease, diabetes mellitus, pulmonary disease, surgery, hospital type, concurrent anesthesia consultation, time, and perioperative cardiac risk as measured by the Revised Cardiac Risk Index.[22] For these subgroup analyses, we repeated the same propensity-score matching process while simultaneously forcing an exact match on the subgroup characteristics. Conditional logistic regression was then used to assess for interactions between the exposure and specific subgroups. Because data on outpatient prescriptions in Ontario are available only for individuals older than 65 years and a 1-year look-back period was used to ascertain prior medication use, we performed an additional subgroup analysis among patients older than 66 years.

Several sensitivity analyses were also performed. First, we repeated the analyses after redefining the exposure with regard to the location where the consultation occurred (outpatient consultation only), type of physician who performed the consultation (general internist or specialist), and time between consultation and surgery (1-7 days, 8-60 days, or 61-120 days). In each case, comparisons were made against individuals who had not undergone preoperative medical consultation. Second, we assessed whether patients who underwent consultation had systematically different adherence to non–surgery-related preventive health measures (mammography, colonoscopy, and fecal occult blood testing). These analyses tested for unmeasured residual confounding. If patients who underwent consultation had systematically higher adherence, they may have been at lower risk for adverse outcomes (ie, healthy user bias); conversely, if they had lower adherence, they may have been at higher risk. Third, we measured the association of medical consultation with events that may be indicative of increased risk but are unlikely to be influenced by medical consultation, namely, epidural anesthesia (OHIP database)[2] and in-hospital wound infection (CIHI database).[23] These "tracer" analyses also tested for residual confounding. Specifically, we hypothesized that consultation would not be associated with increased rates of these events. Fourth, we tested the sensitivity of our findings to alternative matching methods, namely, exact matching on patient characteristics, exact matching on hospital characteristics, and matching on a modified propensity score. In the third matching scheme, the original propensity score was modified to include an estimate of unmeasured disease burden, namely, the number of hospital admissions within 2 years before surgery. Finally, we assessed the influence of an unmeasured binary confounder on the association between consultation and 30-day mortality.[24]

Analyses were performed with SAS, version 9.1 (SAS Institute Inc, Cary, North Carolina), and the R statistical programming language.[25] A 2-tailed *P* value less than .05 was used to define statistical significance.

RESULTS

The study cohort consisted of 269 866 patients, of whom 38.8% (n=104 695) underwent preoperative medical consultation (**Table 1**). Of these consultations, 94.2% (n=98 583) were performed in outpatient settings. The median duration between consultation and surgery was 15 days (interquartile range, 8-31 days). Individuals who did and did not undergo consultation differed for all measured characteristics (Table 1).

Of patients who underwent consultation, 91.6% (n=95 926) were matched to similar patients who did not. The covariate balance in the matched cohort was considerably improved (**Table 2**). Within this matched cohort, preoperative consultation was associated with higher rates of preoperative testing, preoperative use of β-blockers or statins (especially new use), and preoperative cardiac interventions (**Table 3**). Consultation was also associated with increased 30-day (relative risk [RR], 1.16; 95% confidence interval [CI], 1.07-1.25; $P<.001$) and 1-year (1.08; 1.04-1.12; $P<.001$) mortality (Table 3). These differences corresponded to numbers needed to harm of 516 (95% CI, 338-1089) at 30 days and 227 (155-426) at 1 year. Mean hospital stay was also longer in the consultation arm (9.07 days vs 8.39 days; difference, 0.67 days; 95% CI, 0.59-0.76; $P<.001$). The association of consultation with mortality was not influenced by any prespecified subgroup (**Table 4**).

Consultation was also associated with increased postoperative mechanical ventilation and admission to monitored beds, but no significant difference in acute stroke (Table 3). Nonetheless, in post hoc subgroup analyses, consultation was associated with a significantly increased risk of stroke after intra-abdominal or intrathoracic surgery (RR, 1.47; 95% CI, 1.14-1.89) but not after orthopedic or vascular surgery (interaction, $P=.02$) (eTable 1; http://www.archinternmed.com). These differences were mirrored by qualitatively similar variation (interaction, $P<.001$) in new β-blocker use (eTable 1). Specifically, in the setting of intra-abdominal or intrathoracic surgery, consultation was associated with relatively higher rates of both new β-blocker use and postoperative stroke (eTable 1). Within the first 30 days after hospital discharge, preoperative consultation was associated with reduced rates of prescriptions for warfarin and low-molecular-weight heparins (Table 3).

The sensitivity analyses generally suggested that any residual confounding within the matched cohort was not large. Consultation was not associated with differences in postoperative wound infections or adherence to screening mammography (Table 3). Notably, it was associated with increased adherence to colon cancer screening (which may be suggestive of healthier patients) and reduced rates of epidural anesthesia (which may be suggestive of lower perceived perioperative risk). The association of consultation with mortality was qualitatively unchanged when we redefined the exposure as outpatient consultations alone or used alternative matching processes (eTable 2). However, the association was increased in magnitude when the exposure was defined as consultations performed by specialists (cardiologist, endocrinologist, geriatrician, or nephrologist) or consultations performed within 1 to 7 days before surgery (eTable 2). An unmeasured confounder could render the association between consultation and 30-day mortality statistically nonsignificant but only if it at least doubled the odds of mortality and was present in 20% of patients who underwent consultation as compared with 10% of those who did not (**Table 5**).

COMMENT

In this population-based cohort study, preoperative medical consultation was associated with significant, albeit small, increases in mortality and hospital stay after major elective noncardiac surgery. These findings persisted despite extensive adjustments for confounders and were stable across a range of subgroups and sensitivity analyses. It was also evident that internists were actively guiding care as opposed to passively "clearing" patients for surgery. Specifically, consultation was associated with increases in related processes of care, such as specialized cardiac testing and β-blockade. However, the appropriateness of these interventions is debatable. For example, the Perioperative Ischemic Evaluation Study suggested that β-blockade, although previously recommended,[10] may actually increase perioperative death and acute stroke.[26] In addition, several commonly ordered tests, such as echocardiography and pulmonary function tests, are not generally recommended by consensus-based guidelines[10,27] because they add little prognostic information.[28,29]

Given that the present study was observational in design, it is important to establish that the observed association between consultation and mortality was not entirely due to confounding by indication. Specifically, patients referred for consultation have more comorbid illness and are therefore at increased risk for adverse outcomes. Despite using statistical methods to adjust for these differences, our data sources might have lacked sufficient detail for adequate risk adjustment.

Table 1. Characteristics of Individuals Who Did or Did Not Undergo Preoperative Medical Consultation in the Entire Cohort

Characteristic	No. (%)[a] Consultation (n=104 695)	No Consultation (n=165 171)	Absolute Standardized Difference, %	*P* Value
Demographics				
Age, mean (SD), y	70.1 (9.6)	67.3 (10.6)	27.3	<.001
Female sex	54 085 (51.7)	84 559 (51.2)	1.0	<.001
Neighborhood income, $				
Quintile 1 (highest)	22 166 (21.2)	33 412 (20.2)	2.5	<.001
Quintile 2	22 163 (21.2)	33 537 (20.3)	2.2	
Quintile 3	20 660 (19.7)	32 038 (19.4)	0.8	
Quintile 4	18 995 (18.1)	31 880 (19.3)	3.1	
Quintile 5 (lowest)	20 185 (19.3)	33 248 (20.1)	2.0	
Missing	526 (0.5)	1056 (0.6)	1.4	
Hospital type				
Teaching	37 320 (35.6)	54 804 (33.2)	5.1	<.001
High-volume nonteaching	24 206 (23.1)	33 327 (20.2)	7.2	
Mid-volume nonteaching	21 503 (20.5)	37 859 (22.9)	5.8	
Low-volume nonteaching	21 666 (20.7)	39 181 (23.7)	7.2	
Procedure				
AAA repair	4051 (3.9)	3869 (2.3)	9.2	<.001
Carotid endarterectomy	4709 (4.5)	7314 (4.4)	0.5	
Peripheral vascular bypass	6439 (6.2)	9588 (5.8)	1.7	
Total hip replacement	27 715 (26.5)	36 613 (22.2)	10.0	
Total knee replacement	37 681 (36.0)	48 228 (29.2)	14.5	
Large-bowel resection	14 896 (14.2)	38 801 (23.5)	23.9	
Gastrectomy or esophagectomy	1881 (1.8)	3738 (2.3)	3.5	
Liver resection	449 (0.4)	1478 (0.9)	6.2	
Whipple procedure	375 (0.4)	728 (0.4)	1.3	
Nephrectomy	2828 (2.7)	5990 (3.6)	5.2	
Cystectomy	817 (0.8)	1426 (0.9)	1.1	
Pneumonectomy or lobectomy	2854 (2.7)	7398 (4.5)	9.7	
Comorbid disease				
Coronary artery disease	14 796 (14.1)	11 465 (6.9)	23.7	<.001
Congestive heart failure	4177 (4.0)	2812 (1.7)	13.9	<.001
Cerebrovascular disease	5852 (5.6)	6003 (3.6)	9.6	<.001
Peripheral vascular disease	8985 (8.6)	9123 (5.5)	12.1	<.001
Atrial fibrillation	5049 (4.8)	3486 (2.1)	14.9	<.001
Cardiac valvular condition				
Aortic stenosis	302 (0.3)	265 (0.2)	2.7	<.001
Need for anticoagulation[b]	650 (0.6)	424 (0.3)	5.5	<.001
Hypertension	62 928 (60.1)	82 235 (49.8)	20.8	<.001
Diabetes mellitus	23 452 (22.4)	25 666 (15.5)	17.7	<.001
Pulmonary disease	6776 (6.5)	7174 (4.3)	9.7	<.001
Dialysis or renal disease	1840 (1.8)	1532 (0.9)	7.8	<.001
Rheumatologic disease	3110 (3.0)	4271 (2.6)	2.4	<.001
Liver disease	512 (0.5)	705 (0.4)	0.9	.02
Thromboembolic disease	1451 (1.4)	1510 (0.9)	4.4	<.001
Dementia	559 (0.5)	476 (0.3)	3.8	<.001
Malignant disease				
Primary	14 364 (13.7)	29 386 (17.8)	11.3	<.001
Metastatic	4952 (4.7)	11 160 (6.8)	9.0	
Other consultations				
Anesthesia[c]	41 294 (39.4)	63 378 (38.4)	2.1	<.001
Intraoperative monitoring				
Arterial line	30 878 (29.5)	44 053 (26.7)	6.2	<.001
Central venous line	7724 (7.4)	11 495 (7.0)	1.5	<.001
Pulmonary artery catheter	4020 (3.8)	3606 (2.2)	9.4	<.001

Abbreviation: AAA, abdominal aortic aneurysm.
[a] Because of rounding, percentages may not total 100.
[b] History of mitral stenosis, mechanical aortic valve replacement, or mechanical mitral valve replacement.
[c] Outpatient anesthesia consultation within 60 days before surgery.

However, we conducted many sensitivity analyses that suggested that any residual confounding was not large. In tracer analyses, other indicators of higher risk (eg, wound infections and poor adherence to preventive health measures) were not increased in the consultation arm. Epidural anesthesia, which tends to be preferentially used in

Table 2. Characteristics of the Propensity-Score Matched Pairs

Characteristic	Consultation (n=95 926), No. (%)[a]	No Consultation (n=95 926), No. (%)[a]	Absolute Standardized Difference, %
Demographics			
Age, mean (SD), y	69.8 (9.7)	69.9 (9.6)	0.4
Female sex	49 939 (52.1)	50 049 (52.2)	0.2
Neighborhood income, $			
Quintile 1 (highest)	20 192 (21.0)	20 101 (21.0)	0.2
Quintile 2	20 032 (20.9)	20 110 (21.0)	0.2
Quintile 3	18 909 (19.7)	18 895 (19.7)	0.04
Quintile 4	17 585 (18.3)	17 607 (18.4)	0.06
Quintile 5 (lowest)	18 707 (19.5)	18 699 (19.5)	0.02
Missing	501 (0.5)	514 (0.5)	0.2
Hospital type			
Teaching	32 932 (34.3)	32 850 (34.2)	0.2
High-volume nonteaching	22 252 (23.2)	22 268 (23.2)	0.04
Mid-volume nonteaching	20 156 (21.0)	20 203 (21.1)	0.1
Low-volume nonteaching	20 586 (21.5)	20 605 (21.5)	0.05
Procedure			
AAA repair	3367 (3.5)	3350 (3.5)	0.09
Carotid endarterectomy	4370 (4.6)	4404 (4.6)	0.2
Peripheral vascular bypass	5867 (6.1)	5953 (6.2)	0.4
Total hip replacement	25 679 (26.8)	25 782 (26.9)	0.2
Total knee replacement	34 368 (35.8)	34 386 (35.8)	0.04
Large-bowel resection	13 787 (14.4)	13 595 (14.2)	0.6
Gastrectomy or esophagectomy	1709 (1.8)	1711 (1.8)	0.02
Liver resection	426 (0.4)	432 (0.5)	0.09
Whipple procedure	331 (0.3)	317 (0.3)	0.3
Nephrectomy	2602 (2.7)	2617 (2.7)	0.1
Cystectomy	707 (0.7)	694 (0.7)	0.2
Pneumonectomy or lobectomy	2713 (2.8)	2685 (2.8)	0.2
Comorbid disease			
Coronary artery disease	10 850 (11.3)	10 850 (11.3)	<0.01
Congestive heart failure	2646 (2.8)	2762 (2.9)	0.7
Cerebrovascular disease	4839 (5.0)	4939 (5.1)	0.5
Peripheral vascular disease	7440 (7.8)	7422 (7.7)	0.07
Atrial fibrillation	3447 (3.6)	3320 (3.5)	0.7
Cardiac valvular condition			
Aortic stenosis	226 (0.2)	222 (0.2)	0.09
Need for anticoagulation[b]	393 (0.4)	383 (0.4)	0.2
Thromboembolic disease	1206 (1.3)	1179 (1.2)	0.3
Hypertension	56 507 (58.9)	56 715 (59.1)	0.4
Diabetes mellitus	19 699 (20.5)	19 725 (20.6)	0.07
Pulmonary disease	5488 (5.7)	5491 (5.7)	0.01
Dialysis or renal disease	1378 (1.4)	1328 (1.4)	0.4
Rheumatologic disease	2808 (2.9)	2802 (2.9)	0.04
Liver disease	421 (0.4)	438 (0.5)	0.3
Dementia	411 (0.4)	405 (0.4)	0.1
Malignant disease			
Primary	12 975 (13.5)	12 924 (13.5)	0.2
Metastatic	4598 (4.8)	4567 (4.8)	0.2
Other consultations			
Anesthesia[c]	37 851 (39.5)	37 866 (39.5)	0.03
Intraoperative monitoring			
Arterial line	26 404 (27.5)	26 255 (27.4)	0.3
Central venous line	6564 (6.8)	6476 (6.8)	0.4
Pulmonary artery catheter	3094 (3.2)	3040 (3.2)	0.3

Abbreviation: AAA, abdominal aortic aneurysm.
[a] Because of rounding, percentages may not total 100.
[b] History of mitral stenosis, mechanical aortic valve replacement, or mechanical mitral valve replacement.
[c] Outpatient anesthesia consultation within 60 days before surgery.

high-risk patients,[2] was used less often in the consultation arm. In addition, previous studies using these same administrative data found that perioperative interventions that are preferentially used in higher-risk patients (eg, epidural anesthesia and anesthesia consultation)[2,18] were nonetheless associated with benefit after risk adjustment. These previous results suggest that our data sources do contain sufficient information to adjust for confounding

Table 3. Processes of Care, Outcomes, and Medications in the Propensity Score–Matched Pairs[a]

	No. (%)		
	Consultation	No Consultation	RR (95% CI)[a]
Processes of Care and Outcomes			
No. of patients	95 926	95 926	
Related to medical consultation			
Preoperative testing[b]			
Echocardiogram	18 612 (19.4)	7899 (8.2)	2.36 (2.30-2.42)
Cardiac stress test	13 927 (14.5)	5808 (6.1)	2.40 (2.33-2.47)
Pulmonary function test	16 310 (17.0)	11 068 (11.5)	1.47 (1.44-1.51)
Preoperative cardiac procedures[b]			
Coronary angiogram	1665 (1.7)	511 (0.5)	3.26 (2.96-3.59)
Percutaneous coronary intervention	398 (0.4)	92 (0.1)	4.32 (3.45-5.42)
CABG surgery	385 (0.4)	247 (0.3)	1.56 (1.33-1.82)
Postoperative care[c]			
Admission to monitored bed	13 012 (13.6)	12 338 (12.9)	1.05 (1.03-1.08)
Mechanical ventilation	5822 (6.1)	5055 (5.3)	1.15 (1.11-1.19)
Clinical outcomes			
In-hospital acute stroke	436 (0.5)	399 (0.4)	1.09 (0.95-1.25)
30-d mortality	1363 (1.4)	1177 (1.2)	1.16 (1.07-1.25)
1-y mortality	5664 (5.9)	5221 (5.4)	1.08 (1.04-1.12)
Unrelated to medical consultation			
Preventive health measures[d]			
Screening mammography	6477 (6.8)	6541 (6.8)	0.99 (0.96-1.02)
Colon cancer screening[e]	22 007 (22.9)	21 264 (22.2)	1.03 (1.01-1.05)
Anesthesia management			
Epidural anesthesia	17 836 (18.6)	19 770 (20.6)	0.90 (0.89-0.92)
Clinical outcomes			
In-hospital wound infection	6419 (6.7)	6505 (6.8)	0.98 (0.95-1.02)
Medications[f]			
No. of patients	66 090	66 090	
Preoperative medications			
β-Blocker use[g]	15 141 (22.9)	11 547 (17.5)	1.31 (1.28-1.34)
New β-blocker use[h]	3818 (5.8)	1527 (2.3)	2.50 (2.36-2.65)
Statin use[g]	12 268 (18.6)	10 886 (16.5)	1.13 (1.10-1.15)
New statin use[h]	1968 (3.0)	1372 (2.1)	1.43 (1.34-1.54)
Postoperative medications[i]			
Warfarin sodium	10 970 (16.6)	12 034 (18.2)	0.91 (0.89-0.93)
Low-molecular-weight heparins	690 (1.0)	858 (1.3)	0.80 (0.73-0.89)

Abbreviations: CABG, coronary artery bypass graft; CI, confidence interval; RR, relative risk.
[a] Differences are expressed as the event rate in the exposure (preoperative medical consultation) arm relative to the event rate in the control (no consultation) arm.
[b] Within 180 days before surgery.
[c] Within 5 days after surgery.
[d] Within 2 years before hospital admission for surgery.
[e] Colonoscopy or fecal occult blood testing.
[f] Applied only to subgroup 66 years or older.
[g] Prescription within 100 days before surgery.
[h] Prescription within 100 days before surgery, but no prescription during period 180 days to 1 year (365 days) before surgery.
[i] Prescription within 30 days after discharge from hospital.

by indication. Our sensitivity analyses also suggest that an unmeasured binary confounder would have to be present in at least 20% of the consultation arm (as compared with 10% of the no-consultation arm) and be associated with high risk (odds ratio for 30-day mortality of ≥2.00) to render our findings statistically nonsignificant (Table 5). For comparison, congestive heart failure, a measurable major risk factor with an adjusted odds ratio of 2.1,[30] is present in approximately 5% of patients.

Several factors may, in combination, explain why consultation was associated with slightly increased mortality. First, initiation of β-blocker therapy was significantly higher among patients who had undergone consultation. As described previously, this practice may have inadvertently led to increased mortality and stroke. Second, for reasons that are unclear, consultation was associated with decreased use of epidural anesthesia. This reduction may be important because systematic reviews[31] and population-based studies[2] have shown epidural anesthesia to be associated with improved postoperative survival. Third, consultation was associated with low rates of outpatient postoperative thromboprophylaxis, which were also significantly lower than those in the control arm. Unfortunately, our data sources do not contain information about thromboprophylaxis administered in the hospital; furthermore, administrative data do not accurately capture episodes of postoperative venous thromboembolism.[32] The basis for these decreased rates is unclear and warrants further research. Potential explanations include internists' preference for shorter in-

Table 4. Association of Consultation With Postoperative Mortality Within Subgroups

	30-d Mortality		1-y Mortality	
	RR (95%CI)	Interaction, *P* Value[a]	RR (95% CI)	Interaction, *P* Value[a]
Entire matched cohort	1.16 (1.07-1.25)	NA	1.08 (1.04-1.12)	NA
Subgroups				
Hospital type				
Teaching	1.17 (1.02-1.35)	.93	1.10 (1.03-1.17)	.85
High-volume nonteaching	1.23 (1.01-1.51)		1.06 (0.97-1.16)	
Mid-volume nonteaching	1.22 (1.01-1.48)		1.05 (0.97-1.14)	
Low-volume nonteaching	1.14 (0.96-1.35)		1.06 (0.98-1.15)	
Time				
1994-1999	1.16 (1.03-1.30)	.54	1.07 (1.02-1.13)	.94
2000-2004	1.22 (1.08-1.39)		1.07 (1.01-1.13)	
Sex				
Female	1.24 (1.07-1.44)	.47	1.06 (0.99-1.13)	.57
Male	1.16 (1.04-1.29)		1.08 (1.03-1.13)	
Ischemic heart disease				
Present	1.12 (0.94-1.35)	.74	1.13 (1.04-1.24)	.23
Absent	1.17 (1.07-1.27)		1.07 (1.03-1.11)	
Diabetes mellitus				
Present	1.20 (1.01-1.43)	.88	1.01 (0.94-1.09)	.11
Absent	1.18 (1.07-1.31)		1.09 (1.04-1.14)	
Revised cardiac risk index				
0 Points	1.11 (0.89-1.39)	.39	1.10 (0.99-1.22)	.55
1-2 Points	1.22 (1.11-1.35)		1.07 (1.02-1.12)	
≥3 Points	0.99 (0.71-1.36)		0.99 (0.85-1.15)	
Pulmonary disease				
Present	1.24 (0.85-1.82)	.78	1.04 (0.89-1.22)	.75
Absent	1.18 (1.09-1.29)		1.07 (1.03-1.12)	
Procedure				
Vascular	1.27 (1.06-1.52)	.70	1.12 (1.02-1.23)	.65
Abdominal or thoracic	1.17 (1.05-1.31)		1.06 (1.01-1.11)	
Orthopedic	1.14 (0.94-1.37)		1.07 (0.98-1.16)	
Anesthesia consultation[b]				
Present	1.15 (1.01-1.31)	.56	1.08 (1.01-1.14)	.83
Absent	1.21 (1.09-1.36)		1.07 (1.02-1.12)	

Abbreviations: CI, confidence interval; NA, not applicable; RR, relative risk.
[a] Tests whether treatment effects differed significantly between subgroups.
[b] Outpatient anesthesia consultation within 60 days before surgery.

Table 5. Effect of an Unmeasured Confounder on the Estimated Association of Preoperative Medical Consultation With 30-Day Mortality

		Adjusted Association of Consultation With Mortality,[c] OR (95% CI), by Risk Associated With Unmeasured Confounder[d]			
$P_{consult}$,%[a]	$P_{no\ consult}$,%[b]	OR 1.25	OR 1.50	OR 2.00	OR 2.50
0	0.0	1.16 (1.07-1.26)[e]	1.16 (1.07-1.26)[e]	1.16 (1.07-1.26)[e]	1.16 (1.07-1.26)[e]
10	6.7	1.15 (1.06-1.25)	1.14 (1.05-1.24)	1.13 (1.04-1.22)	1.11 (1.02-1.21)
10	5.0	1.15 (1.06-1.24)	1.13 (1.04-1.23)	1.11 (1.02-1.20)	1.08 (1.01-1.17)
20	13.3	1.14 (1.05-1.24)	1.12 (1.04-1.22)	1.10 (1.01-1.19)	1.07 (0.99-1.16)
20	10.0	1.13 (1.05-1.23)	1.11 (1.02-1.20)	1.06 (0.98-1.15)	1.03 (0.95-1.11)
30	20.0	1.13 (1.05-1.23)	1.11 (1.02-1.21)	1.07 (0.99-1.16)	1.04 (0.96-1.13)
30	15.0	1.12 (1.03-1.22)	1.08 (1.00-1.18)	1.03 (0.95-1.11)	0.98 (0.90-1.06)
40	26.7	1.12 (1.04-1.22)	1.10 (1.01-1.19)	1.05 (0.97-1.14)	1.02 (0.94-1.10)
40	20.0	1.11 (1.02-1.20)	1.06 (0.98-1.15)	0.99 (0.92-1.08)	0.94 (0.87-1.02)

Abbreviations: CI, confidence interval; OR, odds ratio.
[a] Prevalence of unmeasured confounder among individuals who underwent preoperative medical consultation.
[b] Prevalence of unmeasured confounder among individuals who did not undergo preoperative medical consultation.
[c] These adjusted associations assume that the unmeasured confounder is binary, is independent of measured confounders, and does not interact with the exposure.[24]
[d] Assumed adjusted association of unmeasured confounder with 30-day mortality.
[e] In scenarios that assumed the absence of any unmeasured confounder, a conditional logistic regression model was used to estimate the adjusted OR.

hospital courses of thromboprophylaxis or internists' postoperative discontinuation of long-term anticoagulant therapy that was previously initiated by patients' primary care providers.

In sensitivity analyses, the association of consultation with mortality was increased in magnitude when only consultations performed by specialists or within 1 to 7 days of surgery were considered. These findings should be viewed cautiously, especially given their widely overlapping confidence intervals with other definitions of preoperative medical consultation (eTable 2). Nonetheless, the findings are also plausible. For example, specialists, especially cardiologists, may be more aggressive in adhering to recommendations for perioperative β-blockade,[33] thereby inadvertently increasing postoperative mortality.[26] In addition, specialists may be more likely to focus on a narrow aspect of perioperative risk (eg, cardiac risk) rather than consider the wider spectrum for perioperative medical issues, such as pulmonary complications, thromboembolic episodes, and adequate glucose control. Consultations performed shortly before surgery would have afforded less time for preoperative optimization. They may have also provided little time for dose titration of β-blockade. Some authors have suggested that such β-blocker regimens are especially prone to adverse effects.[34]

The increased mortality associated with preoperative medical consultation in our study raises the question as to whether these consultations are required at all. We would caution against this interpretation. Compared with anesthesiologists and surgeons, internists are better trained to address medical problems in surgical patients, such as glucose control in diabetic patients or exacerbations of chronic obstructive pulmonary disease. In addition, our results demonstrate that internists are willing to actively participate in perioperative care. Specifically, we found that consultation was associated with significantly increased rates of perioperative interventions and testing. Despite this clear potential for consultation to improve outcomes, at least 2 major issues limit its effectiveness. There are limited data for consultants to refer to when determining which tests and interventions are actually helpful. For example, routine β-blockade had previously been recommended for any surgical patient with risk factors[35] largely on the basis of 2 small randomized trials.[36,37] As described earlier, this approach may instead have caused harm.[26] In addition, some related processes of care can be improved. For example, the most common specialized test associated with consultation was echocardiography, despite the minimal prognostic information that it adds.[28] In summary, our findings should not be interpreted as a justification for abandoning preoperative consultation but rather as a stimulus to examine it more closely and conduct more high-quality research to establish which aspects of perioperative care do more good than harm.

Our study has several limitations. First, as an observational study, our results demonstrate an association between consultations and outcomes but do not prove causation. Similar cohort studies using different samples of surgical patients are therefore needed to confirm our findings. However, alternative study designs also have limitations. Randomized trials, although better suited to proving causality, are likely unfeasible. Many surgeons would simply not permit older patients with comorbid disease to be randomized to the no-consultation arm.

Second, the increase in mortality associated with consultation, albeit statistically significant, was small. Specifically, the numbers needed to harm were 516 at 30 days and 227 at 1 year. Nonetheless, the criterion by which consultation should be judged, especially when administered to almost 40% of patients in the cohort, is whether it reduces mortality. On the basis of multiple sensitivity analyses, our results suggest that, even if some residual confounding was present, consultation was unlikely to have conferred a major benefit.

Third, our data sources cannot account for patients who had their surgery canceled after being deemed unfit for surgery by the consulting internist. Nonetheless, such cancellations are very rare, occurring after approximately 1% to 2% of preoperative consultations.[38,39]

Fourth, the estimated associations between consultation and outcomes are valid for the matched cohort but not necessarily for unmatched individuals. Unmatched individuals who underwent consultation had very high perioperative risks, based on significant burdens of comorbid disease, and risks of 30-day mortality that were double that of the matched cohort (eTable 3). Thus, the absence of benefits from consultation may not be generalizable to such very-high-risk surgical patients. However, these unmatched patients represented only 8.4% of individuals who underwent preoperative medical consultation.

Fifth, our cohort only included elective intermediate- to high-risk surgeries. Nonetheless, urgent or emergent procedures are unlikely to be delayed to facilitate preoperative consultation. In addition, patients undergoing low-risk ambulatory surgery are at very low risk of major complications[40] and unlikely to benefit from consultation.

Finally, administrative data sources do not adequately capture some postoperative complications (eg, myocardial infarction),[14] causes of death, detailed clinical information, and in-hospital processes of care (eg, inpatient medications). Such information may help to better describe how consultation can alter outcomes. Future multicenter studies of preoperative consultation should therefore include more detailed measurements of these processes of care.

Our study warrants comparison with a single-center cohort study that evaluated outcomes associated with perioperative medical consultation.[4] These previous results mirror our own in that consultation was associated with increased hospital stay and a trend toward increased complications. Conversely, the investigators did not find any significant differences in related processes of care, such as β-blockade or glucose control. Nonetheless, these findings may be explained by limited statistical power and the investigators' definition of perioperative consultation. Specifically, the exposure was defined as any consultation within 1 day of surgery,[4] thereby excluding cases in which patients were seen days to weeks before surgery to help facilitate preoperative risk stratification and optimization.

Our findings suggest 2 broad areas for research in perioperative medicine. As noted earlier, similar multicenter cohort studies should be conducted with other data sets to confirm our findings in Ontario. Where possible, these studies should include detailed information on outpatient and inpatient processes of care to better understand the mechanisms by which consultation influences outcomes. In addition, our findings emphasize the need for more high-quality research to identify efficacious approaches for decreasing perioperative risk. In the absence of such data, consultants have only limited avenues for improving the outcomes of surgical patients.

In conclusion, in this analysis of administrative databases, preoperative medical consultation was associated with increased mortality and hospital stay after major elective noncardiac surgery, as well as with increases in preoperative pharmacologic interventions and testing. These findings were stable across a range of subgroups and sensitivity analyses. Further research is needed to confirm our findings in different populations, define mechanisms by which consultation influences outcomes, and identify efficacious interventions to decrease perioperative risk.

Accepted for Publication: January 25, 2010.
Author Affiliations: Institute for Clinical Evaluative Sciences (Drs Wijeysundera, Austin, Hux, and Laupacis), Keenan Research Centre, Li Ka Shing Knowledge Institute of St Michael's Hospital (Drs Wijeysundera and Laupacis), Department of Anesthesia, Toronto General Hospital and University of Toronto (Drs Wijeysundera and Beattie), Department of Health Policy Management and Evaluation, University of Toronto (Drs Wijeysundera, Austin, Hux, and Laupacis), Department of Medicine, Sunnybrook Health Sciences Centre and University of Toronto (Dr Hux), and Department of Medicine, St Michael's Hospital and University of Toronto (Dr Laupacis), Toronto, Ontario, Canada.
Correspondence: Duminda N. Wijeysundera, MD, Department of Anesthesia, Toronto General Hospital and University of Toronto, EN 3-450, 200 Elizabeth St, Toronto, ON M5G 2C4, Canada (d.wijeysundera@utoronto.ca).
Author Contributions: Dr Wijeysundera had full access to all the data in the study and takes responsibility for the integrity of the data and the accuracy of the data analysis. *Study concept and design:* Wijeysundera, Beattie, Hux, and Laupacis. *Acquisition of data:* Wijeysundera and Beattie. *Analysis and interpretation of data:* Wijeysundera, Austin, and Beattie. *Drafting of the manuscript:* Wijeysundera. *Critical revision of the manuscript for important intellectual content:* Wijeysundera, Austin, Beattie, Hux, and Laupacis. *Statistical analysis:* Wijeysundera and Austin. *Obtained funding:* Wijeysundera and Beattie. *Administrative, technical, and material support:* Laupacis. *Study supervision:* Beattie and Laupacis.
Financial Disclosure: None reported.
Funding/Support: Dr Wijeysundera is supported in part by a Clinician-Scientist Award from the Canadian Institutes of Health Research. Drs Wijeysundera and Beattie are supported in part by Merit Awards from the Department of Anesthesia at the University of Toronto. Dr Austin is supported in part by a Career Investigator Award from the Heart and Stroke Foundation of Ontario. Dr Beattie is the R. Fraser Elliot Chair of Cardiac Anesthesia at the University Health Network. This study was supported in part by the Institute for Clinical Evaluative Sciences and the endowment fund of the R. Fraser Elliot Chair of Cardiac Anesthesia at the University Health Network. The Institute for Clinical Evaluative Sciences is supported in part by a grant from the Ontario Ministry of Health and Long-term Care.
Disclaimer: The sponsors had no role in the design and conduct of the study; in the collection, analysis, and interpretation of the data; or in the preparation, review, or approval of the manuscript. The opinions, results, and conclusions are those of the authors, and no endorsement by the Ontario Ministry of Health and Long-term Care or the Institute for Clinical Evaluative Sciences is intended or should be inferred.
Online-Only Material: The eTables are available at http://www.archinternmed.com.
Additional Contributions: Arthur Slutsky, MASc, MD, FRCPC, Muhammad Mamdani, PharmD, MA, MPH, and Chaim M. Bell, MD, PhD, FRCPC, provided helpful comments on earlier versions of the manuscript.

REFERENCES

1. Weiser TG, Regenbogen SE, Thompson KD, et al. An estimation of the global volume of surgery: a modelling strategy based on available data. *Lancet*. 2008; 372(9633):139-144.
2. Wijeysundera DN, Beattie WS, Austin PC, Hux JE, Laupacis A. Epidural anaesthesia and survival after intermediate-to-high risk non-cardiac surgery: a population-based cohort study. *Lancet*. 2008;372(9638):562-569.
3. Arozullah AM, Khuri SF, Henderson WG, Daley J; Participants in the National Veterans Affairs Surgical Quality Improvement Program. Development and validation of a multifactorial risk index for predicting postoperative pneumonia after major noncardiac surgery. *Ann Intern Med*. 2001;135(10):847-857.
4. Auerbach AD, Rasic MA, Sehgal N, Ide B, Stone B, Maselli J. Opportunity missed: medical consultation, resource use, and quality of care of patients undergoing major surgery. *Arch Intern Med*. 2007;167(21):2338-2344.
5. Macpherson DS, Lofgren RP. Outpatient internal medicine preoperative evaluation: a randomized clinical trial. *Med Care*. 1994;32(5):498-507.
6. Hux JE, Ivis F, Flintoft V, Bica A. Diabetes in Ontario: determination of prevalence and incidence using a validated administrative data algorithm. *Diabetes Care*. 2002;25(3):512-516.
7. Juurlink D, Preya C, Croxford R, et al. *Canadian Institute for Health Information Discharge Abstract Database: A Validation Study: ICES Investigative Report.* Toronto, ON: Institute for Clinical Evaluative Sciences; 2006. http://www.ices.on.ca/file/CIHI_DAD_Reabstractors_study.pdf. Accessed July 15, 2009.
8. Tu K, Campbell NRC, Chen ZL, Cauch-Dudek KJ, McAlister FA. Accuracy of administrative databases in identifying patients with hypertension. *Open Med*. 2007; 1(1):E18-E26. http://www.openmedicine.ca/article/view/17/35. Accessed July 15, 2009.
9. Williams JI, Young W. Appendix: a summary of studies on the quality of health care administrative databases in Canada. In: Goel V, Williams JI, Anderson GM, Blackstein-Hirsch P, Fooks C, Naylor CD, eds. *Patterns of Health Care in Ontario: The ICES Practice Atlas*. Ottawa, ON: Canadian Medical Association; 1996: 339-345. http://www.ices.on.ca/file/Practice2-appendix.pdf. Accessed September 1, 2009.
10. Fleisher LA, Beckman JA, Brown KA, et al; 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); 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; Society for Vascular Surgery. 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 [published corrections appear in *Circulation*. 2008;

118(9):e143-e144 and *Circulation*. 2008;117(5):e154]. *Circulation*. 2007;116 (17):e418-e499. doi:10.1161/CIRCULATIONAHA.107.185699.

11. *Technical Supplement: Health Care in Canada 2005*. Ottawa, ON: Canadian Institute for Health Information, 2005. http://secure.cihi.ca/cihiweb/products/HCIC_Tech_Report_2005_e.pdf. Accessed July 15, 2009.
12. Bourne RB, DeBoer D, Hawker G, et al. Total hip and knee replacement. In: Tu JV, Pinfold SP, McColgan P, Laupacis A, eds. *Access to Health Service in Ontario: ICES Atlas*. Toronto, ON: Institute for Clinical Evaluative Sciences; 2005: 114-115. http://www.ices.on.ca/file/Chp5_v5.pdf. Accessed September 1, 2009.
13. Wijeysundera DN, Austin PC, Hux JE, Beattie WS, Buckley DN, Laupacis A. Development of an algorithm to identify preoperative medical consultations using administrative data. *Med Care*. 2009;47(12):1258-1264.
14. Romano PS, Schembri ME, Rainwater JA. Can administrative data be used to ascertain clinically significant postoperative complications? *Am J Med Qual*. 2002; 17(4):145-154.
15. Choudhry NK, Soumerai SB, Normand SL, Ross-Degnan D, Laupacis A, Anderson GM. Warfarin prescribing in atrial fibrillation: the impact of physician, patient, and hospital characteristics. *Am J Med*. 2006;119(7):607-615.
16. Quan H, Sundararajan V, Halfon P, et al. Coding algorithms for defining comorbidities in *ICD-9-CM* and *ICD-10* administrative data. *Med Care*. 2005;43(11): 1130-1139.
17. White RH, Gettner S, Newman JM, Trauner KB, Romano PS. Predictors of rehospitalization for symptomatic venous thromboembolism after total hip arthroplasty. *N Engl J Med*. 2000;343(24):1758-1764.
18. Wijeysundera DN, Austin PC, Beattie WS, Hux JE, Laupacis A. A population-based study of anesthesia consultation before major non-cardiac surgery. *Arch Intern Med*. 2009;169(6):595-602.
19. Rubin DB. The design versus the analysis of observational studies for causal effects: parallels with the design of randomized trials. *Stat Med*. 2007;26(1): 20-36.
20. Birkmeyer JD, Siewers AE, Finlayson EV, et al. Hospital volume and surgical mortality in the United States. *N Engl J Med*. 2002;346(15):1128-1137.
21. Austin PC. Propensity-score matching in the cardiovascular surgery literature from 2004 to 2006: a systematic review and suggestions for improvement. *J Thorac Cardiovasc Surg*. 2007;134(5):1128-1135.
22. Lee TH, Marcantonio ER, Mangione CM, et al. Derivation and prospective validation of a simple index for prediction of cardiac risk of major noncardiac surgery. *Circulation*. 1999;100(10):1043-1049.
23. Yokoe DS, Noskin GA, Cunnigham SM, et al. Enhanced identification of postoperative infections among inpatients. *Emerg Infect Dis*. 2004;10(11):1924-1930.
24. Lin DY, Psaty BM, Kronmal RA. Assessing the sensitivity of regression results to unmeasured confounders in observational studies. *Biometrics*. 1998;54 (3):948-963.
25. R Development Core Team. *R: A Language and Environment for Statistical Computing*. Vienna, Austria: R Foundation for Statistical Computing; 2009. http://www.R-project.org. Accessed July 15, 2009.
26. Devereaux PJ, Yang H, Yusuf S, et al; POISE Study Group. Effects of extended-release metoprolol succinate in patients undergoing non-cardiac surgery (POISE trial): a randomised controlled trial. *Lancet*. 2008;371(9627):1839-1847.
27. Qaseem A, Snow V, Fitterman N, et al; Clinical Efficacy Assessment Subcommittee of the American College of Physicians. Risk assessment for and strategies to reduce perioperative pulmonary complications for patients undergoing noncardiothoracic surgery: a guideline from the American College of Physicians. *Ann Intern Med*. 2006;144(8):575-580.
28. Rohde LE, Polanczyk CA, Goldman L, Cook EF, Lee RT, Lee TH. Usefulness of transthoracic echocardiography as a tool for risk stratification of patients undergoing major noncardiac surgery. *Am J Cardiol*. 2001;87(5):505-509.
29. Smetana GW, Lawrence VA, Cornell JE; American College of Physicians. Preoperative pulmonary risk stratification for noncardiothoracic surgery: systematic review for the American College of Physicians. *Ann Intern Med*. 2006;144(8): 581-595.
30. Hernandez AF, Whellan DJ, Stroud S, Sun JL, O'Connor CM, Jollis JG. Outcomes in heart failure patients after major noncardiac surgery. *J Am Coll Cardiol*. 2004;44(7):1446-1453.
31. Rodgers A, Walker N, Schug S, et al. Reduction of postoperative mortality and morbidity with epidural or spinal anaesthesia: results from overview of randomised trials. *BMJ*. 2000;321(7275):1493.
32. White RH, Sadeghi B, Tancredi DJ, et al. How valid is the *ICD-9-CM* based AHRQ patient safety indicator for postoperative venous thromboembolism? *Med Care*. 2009;47(12):1237-1243.
33. Smetana GW, Landon BE, Bindman AB, et al. A comparison of outcomes resulting from generalist vs specialist care for a single discrete medical condition: a systematic review and methodologic critique. *Arch Intern Med*. 2007;167(1): 10-20.
34. Fleisher LA, Poldermans D. Perioperative β blockade: where do we go from here? *Lancet*. 2008;371(9627):1813-1814.
35. Grayburn PA, Hillis LD. Cardiac events in patients undergoing noncardiac surgery: shifting the paradigm from noninvasive risk stratification to therapy. *Ann Intern Med*. 2003;138(6):506-511.
36. Mangano DT, Layug EL, Wallace A, Tateo I; Multicenter Study of Perioperative Ischemia Research Group. Effect of atenolol on mortality and cardiovascular morbidity after noncardiac surgery. *N Engl J Med*. 1996;335(23):1713-1720.
37. Poldermans D, Boersma E, Bax JJ, et al; Dutch Echocardiographic Cardiac Risk Evaluation Applying Stress Echocardiography Study Group. The effect of bisoprolol on perioperative mortality and myocardial infarction in high-risk patients undergoing vascular surgery. *N Engl J Med*. 1999;341(24):1789-1794.
38. Correll DJ, Bader AM, Hull MW, Hsu C, Tsen LC, Hepner DL. Value of preoperative clinic visits in identifying issues with potential impact on operating room efficiency. *Anesthesiology*. 2006;105(6):1254-1259, discussion 6A.
39. Tsen LC, Segal S, Pothier M, Hartley LH, Bader AM. The effect of alterations in a preoperative assessment clinic on reducing the number and improving the yield of cardiology consultations. *Anesth Analg*. 2002;95(6):1563-1568.
40. Warner MA, Shields SE, Chute CG. Major morbidity and mortality within 1 month of ambulatory surgery and anesthesia. *JAMA*. 1993;270(12):1437-1441.