Preoperative testing before low-risk surgical procedures

Kyle R. Kirkham MD, Duminda N. Wijeysundera MD PhD, Ciara Pendrith MSc, Ryan Ng MSc, Jack V. Tu MD PhD, Andreas Laupacis MD MSc, Michael J. Schull MD MSc, Wendy Levinson MD, R. Sacha Bhatia MD MBA

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Abstract

Background: There is concern about increasing utilization of low-value health care services, including preoperative testing for low-risk surgical procedures. We investigated temporal trends, explanatory factors, and institutional and regional variation in the utilization of testing before low-risk procedures.

Methods: For this retrospective cohort study, we accessed linked population-based administrative databases from Ontario, Canada. A cohort of 1 546 223 patients 18 years or older underwent a total of 2 224 070 low-risk procedures, including endoscopy and ophthalmologic surgery, from Apr. 1, 2008, to Mar. 31, 2013, at 137 institutions in 14 health regions. We used hierarchical logistic regression models to assess patient- and institution-level factors associated with electrocardiography (ECG), transthoracic echocardiography, cardiac stress test or chest radiography within 60 days before the procedure.

Results: Endoscopy, ophthalmologic surgery and other low-risk procedures accounted for 40.1%, 34.2% and 25.7% of procedures, respectively. ECG and chest radiography were conducted before 31.0% (95% confidence interval [CI] 30.9%–31.1%) and 10.8% (95% CI 10.8%–10.8%) of procedures, respectively, whereas the rates of preoperative echocardiography and stress testing were 2.9% (95% CI 2.9%–2.9%) and 2.1% (95% CI 2.1%–2.1%), respectively. Significant variation was present across institutions, with the frequency of preoperative ECG ranging from 3.4% to 88.8%. Receipt of preoperative ECG and radiography were associated with older age (among patients 66–75 years of age, for ECG, adjusted odds ratio [OR] 18.3, 95% CI 17.6–19.0; for radiography, adjusted OR 2.9, 95% CI 2.8–3.0), preoperative anesthesia consultation (for ECG, adjusted OR 8.7, 95% CI 8.5–8.8; for radiography, adjusted OR 2.2, 95% CI 2.1–2.2) and preoperative medical consultation (for ECG, adjusted OR 6.8, 95% CI 6.7–6.9; for radiography, adjusted OR 3.6, 95% CI 3.5–3.6). The median ORs for receipt of preoperative ECG and radiography were 2.3 and 1.6, respectively.

Interpretation: Despite guideline recommendations to limit testing before low-risk surgical procedures, preoperative ECG and chest radiography were performed frequently. Significant variation across institutions remained after adjustment for patient- and institution-level factors.

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Correspondence to:
R. Sacha Bhatia,
sacha.bhatia@wchospital.ca

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In response to concerns about increasing utilization of low-value health care services, the American Board of Internal Medicine Foundation launched the Choosing Wisely campaign in the United States in 2012.[1] The goal of the campaign is to encourage conversations between physicians and patients about low-value care by defining "top 5" lists of tests, treatments and procedures that may be unnecessary or unsupported by evidence.[1] Subsequent Choosing Wisely campaigns have followed in other countries, including Canada starting in April 2014.[2,3] Of interest for health policymakers, payers and clinicians are current utilization rates for the procedures mentioned in these recommendations. Establishing baseline rates permits an understanding of the extent of the problem of low-value care, which in turn allows monitoring of the effect of initiatives such as Choosing Wisely on utilization rates over time.

One Choosing Wisely item included by many specialty societies is the recommendation to avoid routinely performing preoperative testing (including chest radiography, echocardiography and cardiac stress tests) for patients undergoing low-risk surgery.[4–6] This recommendation was previously included in the 2007 American College of Cardiology/American Heart Association guidelines on perioperative cardiovascular evaluation for noncardiac surgery[7] and was reconfirmed in a recent update.[8] Avoiding preoperative investigations in this setting is supported by

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evidence that routine testing in patients undergoing low-risk surgery does not improve outcomes or change management and may lead to further unnecessary downstream testing, cancellation of surgery, and increases in patient anxiety and cost.[7,9–12] To date, neither the rate of preoperative testing across a large and diverse jurisdiction nor the degree of variation at regional and institutional levels, where data may be "actionable," is well understood.

The objectives of this study were to determine utilization rates of preoperative tests before hospital-based low-risk surgical procedures at the jurisdictional, regional and institutional level. In addition, we aimed to evaluate temporal trends of preoperative testing over a 5-year period. We hypothesized that there would be significant regional and institutional variation in preoperative cardiac testing before low-risk surgery and that patients with prior cardiac comorbidities would have a higher rate of preoperative testing than those without such comorbidities.

Methods

Study design and data sources

We conducted a retrospective cohort study in Ontario, Canada, using population-based administrative health care databases. The datasets were linked using unique encoded identifiers and analyzed at the Institute for Clinical Evaluative Sciences. Using the Canadian Institute for Health Information's Discharge Abstract Database and Same-Day Surgery database, we identified all Ontario adults (≥ 18 yr) with an elective hospital admission between Apr. 1, 2008, and Mar. 31, 2013, who underwent one of the following surgical procedures on the date of admission: endoscopy, ophthalmologic surgery or other low-risk surgery (e.g., knee arthroscopy, hernia repair). Appendix 1, available at www.cmaj.ca/lookup/suppl/doi:10.1503/cmaj.150174/-/DC1, lists the procedures included, all of which have a low cardiac risk (i.e., estimated risk of myocardial infarction or cardiac death < 1%) and generally do not require preoperative cardiac testing.[7,8] We excluded patients with incomplete data for the index procedure or demographic characteristics and those who underwent the procedure during an existing inpatient admission or secondary to another higher-risk surgical procedure within the same hospital stay (e.g., endoscopy before colon surgery). Because we conducted a per-procedure analysis, we included all procedures for patients who underwent more than one eligible procedure during the study period.

We collected patient demographic characteristics from the Registered Persons Database and used neighbourhood income quintile to estimate patients' socioeconomic status. We obtained the surgical setting (inpatient or outpatient) and the institution number from the Discharge Abstract Database and the Same-Day Surgery database. Using validated data algorithms, we identified patients with chronic obstructive pulmonary disease, asthma and the following cardiac risk factors: hypertension, diabetes mellitus and hyperlipidemia.[13–16] We used codes from the International Statistical Classification of Diseases and Related Health Problems, 10th revision, for hospital admissions within 2 years before the index procedure to identify the following comorbidities: coronary artery disease, heart failure, atrial fibrillation, other cardiac arrhythmia, cardiac valvular disease, chronic renal disease, previous cerebrovascular disease, peripheral arterial disease and venous thromboembolism. Comorbidities identified from the index surgery included cardiac valvular disease, chronic renal disease and venous thromboembolism. We used the Discharge Abstract Database and the Ontario Health Insurance Plan (OHIP) claims database to identify the following cardiac procedures performed within 10 years before the index procedure: aortic valve replacement, mitral valve replacement, coronary artery revascularization and device implantation. We used OHIP claims to identify preoperative outpatient anesthesia consultation within 60 days before the index procedure.[17] Using a validated algorithm, we identified preoperative medical consultations (cardiology, endocrinology, general internal medicine, geriatric medicine and nephrology) within 60 days of the index procedure from OHIP claims and the Institute for Clinical Evaluative Sciences Physician Database.[18]

Outcomes

We used OHIP claims to identify patients who underwent electrocardiography (ECG), transthoracic echocardiography, cardiac stress testing and chest radiography before their procedures. These tests encompass the range of cardiothoracic investigations advised against in the Choosing Wisely Canada recommendations of the Canadian Cardiovascular Society, the Canadian Association of General Surgeons and the Canadian Society of Internal Medicine,[4–6] with ECG included for completeness. Tests occurring within 60 days before the index date were considered preoperative.[17] Although institutional policies vary, tests conducted between 30 and 60 days before surgical procedures are generally considered current, and their results are accepted for preoperative evaluation.

Analyses

We compared patient characteristics across procedure categories (endoscopy, ophthalmologic surgery and low-risk surgeries) using analysis of variance and the χ^2 test as appropriate. We assessed rates of preoperative ECG, transthoracic echocardiography, stress testing and chest radiography for the overall study cohort and by procedure category.

Initially, we determined regional and institutional variation with unadjusted rates of preoperative testing for all procedures combined. Regional variation was assessed across Ontario's 14 Local Health Integration Networks, which are geographically organized administrative regions. Institutions were included in the analysis if they had 250 or more procedures in at least one category and 500 or more procedures overall. Subgroup analyses were conducted by procedure category for institutions with at least 250 procedures for that category. We calculated descriptive statistics for each procedure category and all procedures combined.

We developed hierarchical random-intercept multivariable logistic regression models to separately assess the adjusted associations of patient- and institution-level factors with preoperative ECG and chest radiography. Adjusted analyses were not performed for preoperative echocardiography and stress tests, as the event rates were too low for stable regression modelling. Institution was included as a random effect to account for random differences in rates of preoperative testing across hospitals. Patient-level factors were procedure category, age, sex, rural or urban residence, neighbourhood income quintile, comorbidities, cardiac risk factors, prior cardiac procedures, preoperative anesthesia consultation and preoperative medical consultation. Institution-level factors were hospital teaching status and total surgical volume tertile (low and high v. intermediate).

We assessed institutional variation in rates of preoperative ECG and chest radiography using the median odds ratio (OR).[19] The median OR compares the adjusted odds of preoperative testing for 2 patients with the same covariates at 2 randomly selected institutions and can be interpreted as the median value of these ORs.[19] The median OR always has a value greater than or equal to 1.0 because it involves comparing randomly selected pairs of higher-ranked versus lower-ranked institutions.[19] It characterizes heterogeneity across institutions, is adjusted for patient-level covariates and may be directly compared with ORs of fixed-effect patient-level factors.[19] For example, a value of 1.50 for ECG suggests 50% adjusted higher odds of undergoing preoperative ECG if the same patient has surgery at one randomly selected institution as opposed to another.

To estimate adjusted institutional testing rates for ECG and chest radiography, we predicted the probabilities of testing for each patient using logistic regression models that adjusted for patient- and procedure-level factors (see Appendix 2, available at www.cmaj.ca/lookup/suppl/doi:10.1503/cmaj.150174/-/DC1 for the model ORs). These probabilities were summed to estimate the expected event count for each institution. We indirectly standardized these institutional rates by multiplying the observed to expected event count ratio for each institution by the overall mean event rate for the whole cohort.

Results

Study cohort

Assembly of the final cohort, which consisted of 1 546 223 patients who underwent 2 224 070 distinct procedures at 137 institutions between Apr. 1, 2008, and Mar. 31, 2013, is described in Figure 1. The annual volume of all procedures decreased from 474 241 in 2008/09 to 404 488 in 2012/13. Endoscopy accounted for 40.1% of procedures, whereas ophthalmologic and other low-risk surgery accounted for 34.2% and 25.7%, respectively.

Patient demographic, clinical and surgical characteristics

Demographic, clinical and surgical characteristics of the cohort are presented in Table 1. The mean age was 61.6 years, with those undergoing

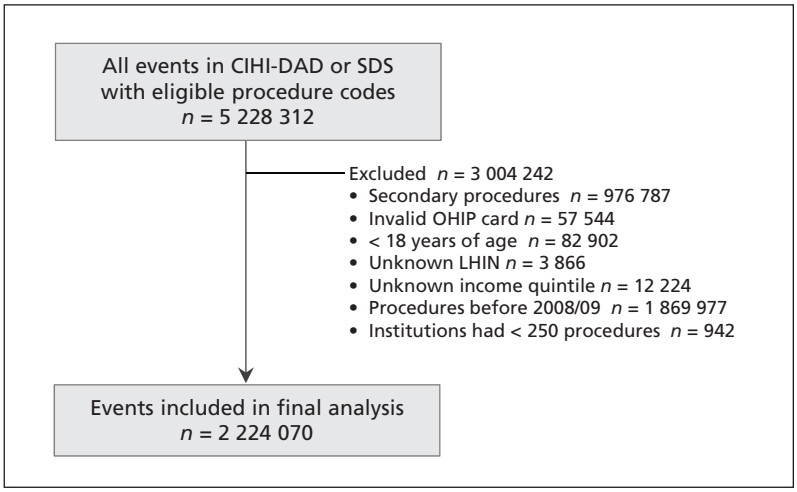

Figure 1: Study flow diagram. Data represent procedures included in the analysis (some patients underwent more than 1 procedure in the study period). CIHI = Canadian Institute for Health Information, DAD = Discharge Abstract Database, LHIN = Local Health Integration Network, OHIP = Ontario Health Insurance Plan, SDS = Same-Day Surgery database.

Table 1: Characteristics of the study cohort by procedure category

Characteristic*	Procedure; no. (%) of patients†			
	Endoscopy *n* = 892 644	Ophthalmologic surgery *n* = 759 906	Low-risk surgery *n* = 571 520	Overall *n* = 2 224 070
Proportion of procedures, %	40.1	34.2	25.7	100.0
Age, yr				
Mean ± SD	58.0 ± 14.2	70.8 ± 11.4	54.9 ± 16.9	61.6 ± 15.6
18–25	19 792 (2.2)	3 312 (0.4)	30 616 (5.4)	53 720 (2.4)
26–35	42 279 (4.7)	5 866 (0.8)	48 371 (8.5)	96 516 (4.3)
36–45	94 468 (10.6)	13 968 (1.8)	88 178 (15.4)	196 614 (8.8)
46–55	219 006 (24.5)	47 132 (6.2)	126 071 (22.1)	392 209 (17.6)
56–65	216 192 (24.2)	116 037 (15.3)	103 851 (18.2)	436 080 (19.6)
66–75	185 624 (20.8)	253 539 (33.4)	94 371 (16.5)	533 534 (24.0)
76–85	98 143 (11.0)	259 458 (34.1)	63 169 (11.1)	420 770 (18.9)
> 85	17 140 (1.9)	60 594 (8.0)	16 893 (3.0)	94 627 (4.3)
Sex, female	494 953 (55.4)	432 103 (56.9)	293 430 (51.3)	1 220 486 (54.9)
Rural–urban status				
Urban	542 194 (60.7)	493 190 (64.9)	365 993 (64.0)	1 401 377 (63.0)
Suburban	233 001 (26.1)	184 372 (24.3)	142 080 (24.9)	559 453 (25.2)
Rural	109 679 (12.3)	76 751 (10.1)	59 036 (10.3)	245 466 (11.0)
Missing	7 770 (0.9)	5 593 (0.7)	4 411 (0.8)	17 774 (0.8)
Neighbourhood income quintile				
1 (lowest)	150 477 (16.9)	148 162 (19.5)	100 650 (17.6)	399 289 (18.0)
2	169 475 (19.0)	158 352 (20.8)	111 146 (19.4)	438 973 (19.7)
3	177 422 (19.9)	152 269 (20.0)	114 399 (20.0)	444 090 (20.0)
4	194 595 (21.8)	152 948 (20.1)	123 138 (21.5)	470 681 (21.2)
5 (highest)	200 675 (22.5)	148 175 (19.5)	122 187 (21.4)	471 037 (21.2)
Surgical site				
Inpatient procedure	182 (<0.1)	2 502 (0.3)	90 188 (15.8)	92 872 (4.2)
Outpatient procedure	892 462 (>99.9)	757 404 (99.7)	481 332 (84.2)	2 131 198 (95.8)
Comorbidities				
Coronary artery disease	20 824 (2.3)	30 949 (4.1)	12 406 (2.2)	64 179 (2.9)
Atrial fibrillation or flutter	10 885 (1.2)	18 773 (2.5)	7 121 (1.2)	36 779 (1.7)
Other cardiac arrhythmia	4 227 (0.5)	6 929 (0.9)	2 716 (0.5)	13 872 (0.6)
Cardiac valvular disease	2 272 (0.3)	4 174 (0.5)	1 489 (0.3)	7 935 (0.4)
Cerebrovascular disease	3 465 (0.4)	7 050 (0.9)	2 387 (0.4)	12 902 (0.6)
Peripheral arterial disease	3 771 (0.4)	6 106 (0.8)	2 548 (0.4)	12 425 (0.6)
Venous thromboembolism	1 477 (0.2)	1 385 (0.2)	882 (0.2)	3 744 (0.2)
Heart failure	33 167 (3.7)	68 129 (9.0)	21 258 (3.7)	122 554 (5.5)
Myocardial infarction	6 388 (0.7)	9 529 (1.3)	3 539 (0.6)	19 456 (0.9)
Chronic renal disease	5 551 (0.6)	10 410 (1.4)	4 710 (0.8)	20 671 (0.9)
Asthma	133 034 (14.9)	106 252 (14.0)	88 580 (15.5)	327 866 (14.7)
COPD	127 959 (14.3)	161 236 (21.2)	77 121 (13.5)	366 316 (16.5)
Cardiac risk factors				
Diabetes mellitus	160 083 (17.9)	239 743 (31.5)	93 573 (16.4)	493 399 (22.2)
Hypertension	398 390 (44.6)	516 992 (68.0)	229 330 (40.1)	1 144 712 (51.5)
Hyperlipidemia	38 011 (4.3)	57 009 (7.5)	22 362 (3.9)	117 382 (5.3)
Prior cardiac procedures				
Aortic valve replacement	2 750 (0.3)	4 995 (0.7)	1 777 (0.3)	9 522 (0.4)
Mitral valve replacement	805 (0.1)	1 490 (0.2)	507 (0.1)	2 802 (0.1)
Coronary revascularization	32 346 (3.6)	49 468 (6.5)	19 020 (3.3)	100 834 (4.5)
Device implantation	7 015 (0.8)	14 760 (1.9)	4 777 (0.8)	26 552 (1.2)
Preoperative consultations				
Outpatient anesthesia	6 074 (0.7)	45 455 (6.0)	107 538 (18.8)	159 067 (7.2)
Medical consult	50 968 (5.7)	40 124 (5.3)	29 623 (5.2)	120 715 (5.4)

Note: COPD = chronic obstructive pulmonary disease, SD = standard deviation.
*For all characteristics (except prior cardiac procedures), $p < 0.001$ across procedure categories.
†Except where indicated otherwise.

ophthalmologic surgery being older than those undergoing endoscopy or low-risk surgery. The comorbidity burden was generally low, particularly for cardiac comorbidities. Most procedures (95.8%) were performed in an outpatient setting. The proportion of inpatient procedures was higher for low-risk surgeries than for endoscopy and ophthalmologic surgery (15.8% v. <0.1% v. 0.3%, $p < 0.001$).

The rates of outpatient preoperative anesthesia and medical consultation were 7.2% and 5.4%, respectively, with the highest rate of preoperative anesthesia occurring before low-risk surgeries and the highest rate of medical consultation before endoscopy.

Temporal trends

Table 2 and Appendix 3 (available at www.cmaj.ca/lookup/suppl/doi:10.1503/cmaj.150174/-/DC1) describe annual and overall rates of preoperative testing from 2008/09 to 2012/13 for the whole cohort and by procedure category. The rate of ECG testing before all procedures was 31.0%, with the highest frequency among patients undergoing low-risk surgery, followed by ophthalmologic and endoscopic procedures (54.6% v. 32.0% v. 15.1%, $p < 0.001$). Chest radiography was performed before 10.8% of procedures, with the highest frequency among patients undergoing low-risk surgery, followed by endoscopic and ophthalmologic procedures (19.0% v. 9.0% v.

Table 2: Temporal trends in rates of various types of preoperative testing from 2008/09 to 2012/13

Type of testing and year	Procedure; % of cases with preoperative test (95% CI)			
	Endoscopy	Ophthalmologic surgery	Low-risk surgery	Overall
Electrocardiography				
2008/09	15.7 (15.6–15.9)	42.4 (42.1–42.6)	54.1 (53.8–54.3)	34.5 (34.3–34.6)
2009/10	16.0 (15.8–16.1)	39.3 (39.1–39.6)	54.9 (54.6–55.1)	33.9 (33.8–34.1)
2010/11	15.2 (15.0–15.4)	30.5 (30.3–30.7)	55.5 (55.2–55.8)	30.7 (30.6–30.8)
2011/12	14.6 (14.5–14.8)	23.8 (23.6–24.0)	55.7 (55.4–56.0)	28.4 (28.2–28.5)
2012/13	13.5 (13.3–13.7)	21.9 (21.6–22.1)	52.8 (52.5–53.1)	26.9 (26.7–27.0)
All years	15.1 (15.0–15.2)	32.0 (31.9–32.1)	54.6 (54.5–54.7)	31.0 (30.9–31.1)
Echocardiography*				
2008/09	2.4 (2.4–2.5)	3.1 (3.0–3.2)	2.5 (2.5–2.6)	2.7 (2.7–2.7)
2009/10	2.7 (2.6–2.8)	3.4 (3.4–3.5)	2.6 (2.5–2.7)	2.9 (2.9–3.0)
2010/11	2.7 (2.6–2.8)	3.2 (3.1–3.3)	2.9 (2.8–3.0)	2.9 (2.9–3.0)
2011/12	2.8 (2.7–2.9)	3.3 (3.2–3.4)	2.9 (2.8–3.0)	3.0 (2.9–3.0)
2012/13	2.8 (2.7–2.9)	3.1 (3.0–3.2)	2.8 (2.7–2.9)	2.9 (2.8–3.0)
All years	2.7 (2.7–2.7)	3.2 (3.2–3.2)	2.7 (2.7–2.7)	2.9 (2.9–2.9)
Stress test				
2008/09	2.1 (2.0–2.1)	1.8 (1.7–1.9)	1.9 (1.9–2.0)	1.9 (1.9–2.0)
2009/10	2.2 (2.2–2.3)	1.8 (1.7–1.9)	2.3 (2.2–2.4)	2.1 (2.1–2.1)
2010/11	2.3 (2.2–2.4)	1.8 (1.7–1.8)	2.6 (2.5–2.7)	2.2 (2.2–2.2)
2011/12	2.3 (2.2–2.3)	1.8 (1.7–1.9)	2.7 (2.6–2.8)	2.2 (2.2–2.3)
2012/13	2.2 (2.1–2.3)	1.8 (1.7–1.8)	2.8 (2.7–2.9)	2.2 (2.2–2.3)
All years	2.2 (2.2–2.2)	1.8 (1.8–1.8)	2.5 (2.5–2.5)	2.1 (2.1–2.1)
Chest radiography				
2008/09	8.9 (8.8–9.1)	7.4 (7.2–7.5)	19.9 (19.7–20.2)	11.1 (11.0–11.2)
2009/10	9.2 (9.1–9.4)	7.2 (7.1–7.3)	20.0 (19.8–20.2)	11.3 (11.2–11.4)
2010/11	9.0 (8.9–9.2)	6.6 (6.5–6.7)	19.4 (19.2–19.6)	10.8 (10.7–10.9)
2011/12	8.8 (8.7–9.0)	6.0 (5.9–6.1)	18.6 (18.4–18.8)	10.4 (10.3–10.5)
2012/13	8.8 (8.6–8.9)	5.9 (5.8–6.1)	17.1 (16.9–17.3)	10.1 (10.0–10.2)
All years	9.0 (8.9–9.1)	6.7 (6.6–6.8)	19.0 (18.9–19.1)	10.8 (10.8–10.8)

Note: CI = confidence interval.
*Transthoracic echocardiography.

6.7%, $p < 0.001$). Provincial rates of preoperative transthoracic echocardiography and stress testing were 2.9% and 2.1%, respectively.

Regional and institutional variation in preoperative testing

Across Local Health Integration Networks, the proportion of patients who underwent preoperative ECG ranged from 21.0% (95% CI 20.7%–21.2%) to 38.7% (95% CI 38.5%–38.9%). For preoperative chest radiography, the range was 7.5% (95% CI 7.4%–7.7%) to 15.1% (95% CI 14.8%–15.4%). Ordering of preoperative transthoracic echocardiography ranged from 1.6% (95% CI 1.6%–1.7%) to 4.2% (95% CI 4.1%–4.3%) and of preoperative stress tests, from 1.4% (95% CI 1.3–1.5) to 2.9% (95% CI 2.8%–3.0%).

The unadjusted rates of preoperative ECG and chest radiography for all procedures ranged from 3.4% to 88.8% and from 1.6% to 51.0%, respectively (Figure 2). The unadjusted rates of preoperative transthoracic echocardiography and stress tests were 0.3% to 5.3% and 0.3% to 4.6%, respectively (Figure 2). Figures 3 and 4 show the indirect standardized rates of preoperative ECG and chest radiography, respectively, across the 137 institutions over the study period.

Adjusted analyses

Table 3 shows the adjusted associations of patient- and institution-level factors with receipt of preoperative ECG and chest radiography. Preoperative testing was associated with older age, and the adjusted odds of preoperative ECG among patients aged 66–75 years was 18.3 (95% CI 17.6–19.0) relative to patients aged 18–25 years. Several cardiac comorbidities were associated with preoperative ECG, but the effect sizes were small. There were strong associations between preoperative ECG and preoperative

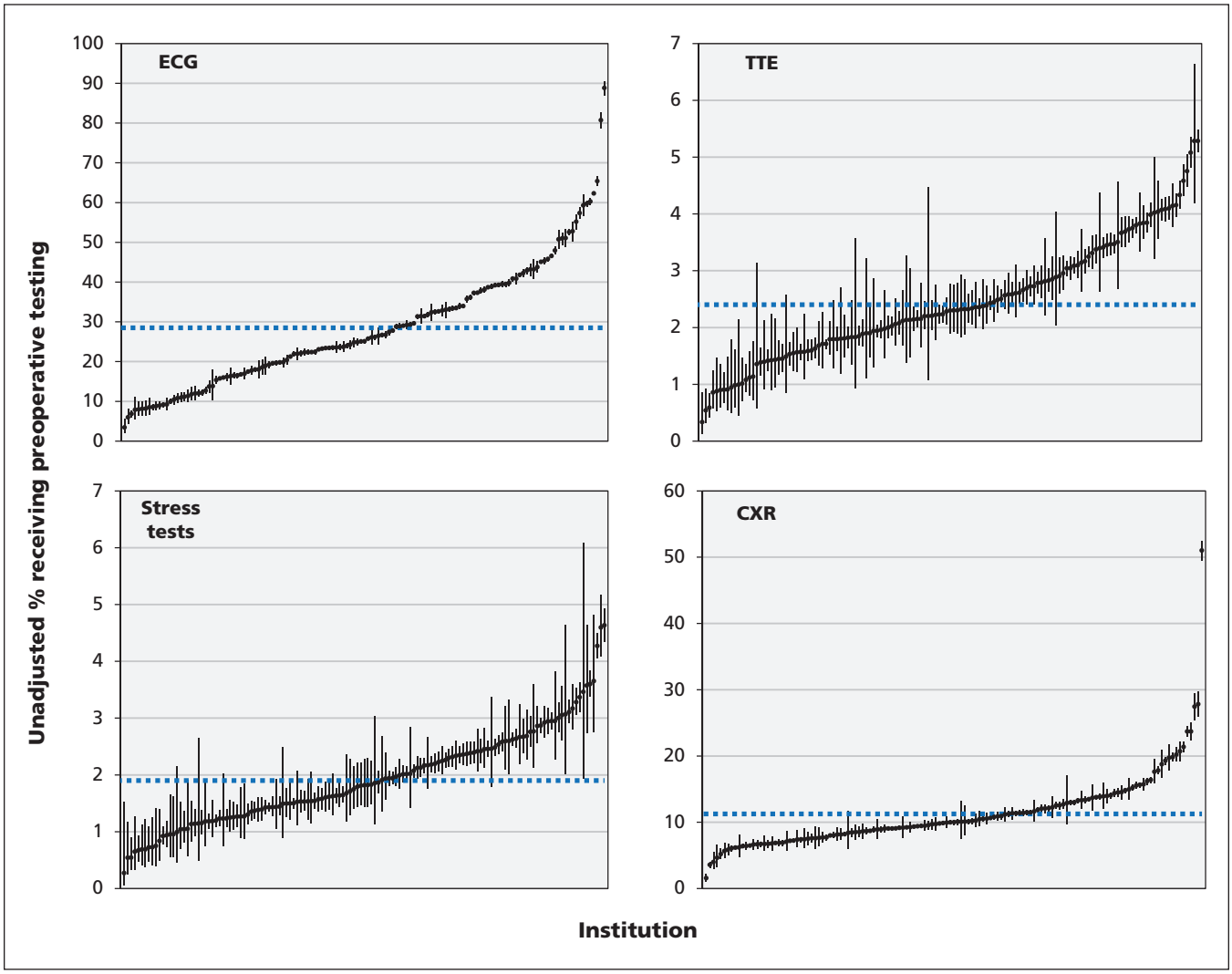

Figure 2: Institutional variation in preoperative testing for the 4 preoperative procedures. Each point represents the unadjusted rate of testing for a single institution, with vertical lines representing 95% confidence intervals. The dashed horizontal lines denote mean rates of testing across all institutions. CXR = chest radiography, ECG = electrocardiography, TTE = transthoracic echocardiography.

anesthesia consultation (adjusted OR 8.7, 95% CI 8.5–8.8) and preoperative medical consultation (adjusted OR 6.8, 95% CI 6.7–6.9). Preoperative chest radiography was also significantly associated with preoperative anesthesia consultation (adjusted OR 2.2, 95% CI 2.1–2.2) and preoperative medical consultation (adjusted OR 3.6, 95% CI 3.5–3.6).

For preoperative ECG, the median OR was 2.3, which means that the odds of a patient receiving preoperative ECG at one randomly selected institution were 2.3 times those of receiving this form of testing at another randomly selected institution. The median OR for preoperative chest radiography was 1.6.

Interpretation

Cardiac investigations (including ECG, stress tests and transthoracic echocardiography) and chest radiography are not routinely indicated before low-risk surgical procedures, according to published guidelines and multiple Choosing Wisely specialty lists.[4–8] In this large retrospective cohort study, we found — despite existing recommendations — that testing before low-risk procedures was common. Although some tests occurred infrequently, ECG was performed before one-third of procedures. In addition, significant regional and institution-level variation was present, with a 30-fold difference between institutions with the lowest and highest rates of ordering tests. Institutional variation persisted despite modelling for patient-, procedure- and hospital-related factors, including institution type and surgical volume. After correction for such confounders, the median ORs related to procedure location (inpatient v. outpatient) exceeded the ORs for many clinically sensible patient characteristics. Our results suggest that the major drivers of preoperative testing are older age, procedure type, concurrent preoperative consultation and the institution at which the procedure was conducted. Interestingly, patient comorbidities, particularly cardiac comorbidities, were not major drivers of preoperative testing.

These findings support results from earlier investigations showing high rates of preoperative testing. Thanh and colleagues[20] found that rates of testing before elective noncardiac surgery were 13.4% for ECG and 23.2% for chest radiography. Similarly, in a study of the Medicare population in the United States, Sheffield and associates[21] found that the rate of stress testing before low- and intermediate-risk surgery was 6.4%. More recently, in an examination of the prevalence of practices targeted by the Choosing Wisely recommendations, also in the Medicare population, Schwartz and coworkers[22] found that the rate of preoperative stress testing before low- and intermediate-risk surgery was between 0.3% and 0.7%, that of transthoracic echocardiography between 0.3% and 0.8% and that of preoperative chest radiography between 1.6% and 5.5%. These authors also observed significant regional variation.[22]

Our results add a number of important contributions to the literature. First, unlike prior investigations, our study was restricted to low-risk, predominantly outpatient procedures. The decision to include only low-risk procedures was in line with

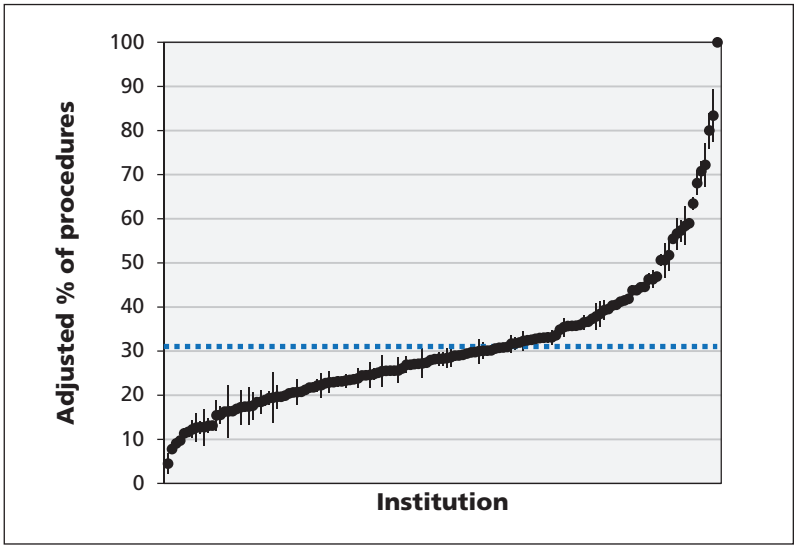

Figure 3: Indirect standardized rates of preoperative electrocardiography (ECG). Each point represents the indirect standardized rate of preoperative ECG for a single institution, and the associated vertical line represents the institution's 95% confidence interval for the testing rate. The dashed horizontal line denotes the mean rate of testing across all institutions.

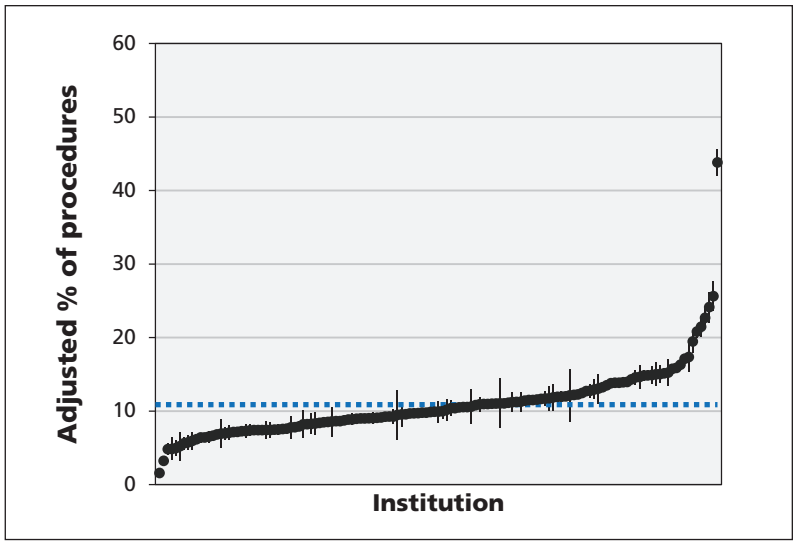

Figure 4: Indirect standardized rates of preoperative chest radiography. Each point represents the indirect standardized rate of preoperative chest radiography for a single institution, and the associated vertical line represents the 95% confidence interval for the testing rate. The dashed horizontal line denotes the mean rate of testing across all institutions.

Table 3: Association of preoperative testing with characteristics at patient and institutional levels

Characteristic	Preoperative test; adjusted OR* (95% CI)	
	Electrocardiography	Chest radiography
Age, yr		
18–25 (reference)	1.0	1.0
26–35	1.8 (1.7–1.9)	0.1 (0.1–0.1)
36–45	5.0 (4.8–5.2)	1.3 (1.3–1.4)
46–55	13.3 (12.8–13.9)	1.8 (1.8–1.9)
56–65	17.2 (16.6–17.9)	2.3 (2.2–2.4)
66–75	18.3 (17.6–19.0)	2.6 (2.5–2.7)
76–85	17.7 (17.0–18.4)	2.9 (2.8–3.0)
> 85	15.8 (15.1–16.4)	3.1 (3.0–3.3)
Sex, female	0.9 (0.9–1.0)	3.3 (3.2–3.5)
Rural–urban status		
Urban (reference)	1.0	1.0
Suburban	1.0 (1.0–1.0)	1.0 (1.0–1.0)
Rural	1.0 (1.0–1.0)	1.0 (1.0–1.1)
Missing	1.0 (0.9–1.0)	1.1 (1.0–1.2)
Neighbourhood income quintile		
1 (lowest) (reference)	1.0	1.0
2	1.0 (1.0–1.0)	0.9 (0.9–1.0)
3	1.0 (1.0–1.0)	0.9 (0.9–0.9)
4	1.0 (0.9–1.0)	0.9 (0.9–0.9)
5 (highest)	0.9 (0.9–0.9)	0.8 (0.8–0.9)
Procedure type		
Low-risk surgery (reference)	1.0	1.0
Endoscopy	0.1 (0.1–0.1)	0.4 (0.4–0.4)
Ophthalmologic surgery	0.2 (0.2–0.2)	0.2 (0.2–0.2)
Comorbidities		
Coronary artery disease	1.2 (1.2–1.3)	1.4 (1.4–1.4)
Atrial fibrillation or flutter	1.3 (1.3–1.4)	1.4 (1.3–1.4)
Other cardiac arrhythmia	1.3 (1.2–1.3)	1.2 (1.2–1.3)
Cardiac valvular disease	1.2 (1.1–1.3)	1.2 (1.1–1.3)
Cerebrovascular disease	1.1 (1.1–1.1)	1.2 (1.2–1.3)
Peripheral arterial disease	1.1 (1.0–1.1)	1.3 (1.2–1.4)
Venous thromboembolism	1.0 (1.0–1.1)	1.6 (1.5–1.8)
Heart failure	1.2 (1.2–1.2)	1.3 (1.3–1.3)
Myocardial infarction	1.1 (1.0–1.1)	1.0 (1.0–1.1)
Chronic renal disease	1.1 (1.1–1.2)	1.7 (1.6–1.7)
Asthma	1.0 (1.0–1.0)	1.2 (1.2–1.2)
COPD	1.0 (1.0–1.0)	1.5 (1.5–1.5)
Cardiac risk factors		
Diabetes mellitus	1.0 (1.0–1.0)	1.0 (1.0–1.0)
Hypertension	1.2 (1.2–1.2)	1.0 (1.0–1.1)
Hyperlipidemia	1.1 (1.0–1.1)	1.1 (1.1–1.1)
Prior cardiac procedures		
Aortic valve replacement	0.9 (0.9–1.0)	0.9 (0.8–0.9)
Mitral valve replacement	1.1 (1.0–1.2)	0.9 (0.8–1.0)
Coronary revascularization	1.1 (1.1–1.1)	0.9 (0.9–0.9)
Device implantation	1.2 (1.1–1.2)	1.1 (1.1–1.2)
Preoperative consultations		
Outpatient anesthesia consult	8.7 (8.5–8.8)	2.2 (2.1–2.2)
Medical consult	6.8 (6.7–6.9)	3.6 (3.5–3.6)
Teaching hospital	1.1 (0.9–1.2)	1.0 (1.0–1.0)
Procedure volume		
Low (reference)	1.0	1.0
Intermediate	1.2 (1.0–1.4)	1.0 (1.0–1.1)
High	1.4 (1.1–1.7)	1.1 (1.0–1.1)
Median OR	2.3	1.6

Note: CI = confidence interval, COPD = chronic obstructive pulmonary disease, OR = odds ratio.
*ORs from logistic regression with mutual adjustment for all other variables listed in the table.

current Choosing Wisely recommendations on preoperative testing and was intended to increase the specificity of the measure to detect low-value care. Second, prior studies of the US Medicare population included only patients over age 65, whereas our study examined all adults, thereby providing a more complete picture of test-ordering behaviour for this population.[22,23] Finally, whereas prior studies have shown regional variation in rates of preoperative testing, we assessed both regional and institution-specific rates and found substantial institution-level variation that persisted after adjustment for patient comorbidities. This latter point is critical, as interventions to modify test ordering are "actionable" predominantly at the institution and provider levels. Our finding emphasizes the need for re-evaluation of ordering decisions and clinical pathways for patients preparing for low-risk procedures. In particular, preoperative anesthesia and medical consultations have been shown to increase preoperative testing rates.[18] In a previous study, Wijeysundera and colleagues[24] showed substantial variation in preoperative medical consultation rates across institutions, albeit for major elective noncardiac surgery. This variation in preoperative consultation practices may underlie some of the variation we observed in institutional preoperative testing rates.

Although the magnitude was small, reductions in the rates of ECG and chest radiography over time suggest increased penetrance of guideline recommendations and a response to other policy changes. In particular, the government of Ontario adjusted fee codes in 2010 to eliminate reimbursement for routine preoperative chest radiography and ECG before cataract surgery.[25] This change likely has resulted in reductions in the rates of ECG and chest radiography ordered before ophthalmologic surgery.

The results of our study have substantial importance for public policy. Choosing Wisely, a grass-roots, physician-led movement, aims to reduce unnecessary low-value practices by changing the attitudes of both physicians and patients. This approach may avoid the need for top–down mechanisms, such as delisting of services, which can restrict the shared decision-making between patients and physicians that allows for individualized care. Although administrative data do not provide the clinical granularity needed to determine the reason for each test ordered, it is clear that provincial-level consistency of preoperative ordering practices could be substantially improved. Although the optimal rate of preoperative testing cannot be defined from these administrative data, institutional rates of 88.8% for ECG and 51.0% for chest radiography would seem difficult to justify. The dramatic institution-level variation that we observed offers an opportunity for providers, administrators and policy-makers to not only explore underlying reasons for ordering tests but also improve ordering behaviour, particularly in those institutions that are significant outliers, where the impact of change may be greatest. Feeding institution-level data back to administrators and providers as a quality improvement measure can help raise provider awareness of the frequency of low-value care decisions and enable high-ordering institutions to examine and improve on local processes.

Limitations

This study had several limitations. First, administrative data do not encompass the clinical information, such as presence of symptoms or abnormal findings of a physical examination, that would be needed to determine the appropriateness of preoperative tests. Not all preoperative testing is of low value, and there are patients for whom these tests provide valuable clinical data. However, our selection of low-risk procedures and the low-risk clinical characteristics of the cohort make it unlikely that the majority of tests were ordered to evaluate new clinical symptoms or abnormal physical findings.

Second, there is no comprehensive, validated list of "low-risk" surgical procedures to guide such an investigation. We investigated very low risk procedures, including endoscopy, ophthalmologic surgery and the minimally invasive procedures listed in Appendix 1. The choice of procedures included is in line with the broad definition of "low-risk procedures" outlined in existing guidelines on perioperative cardiac evaluation.[7,8] Procedure groups were analyzed separately because of the heterogeneity of procedures. We made an effort to exclude more invasive procedures, and the high rate of outpatient surgery (95.8%) indicates our success in this regard.

Third, we included in our analysis all tests conducted within 60 days before the index procedure, and it is possible that these investigations were ordered for indications other than preoperative testing. Although testing during this 60-day period may have been due to unrelated indications, many institutions within the jurisdiction accept preprocedure testing within this period to meet local institutional guidelines for preoperative investigations. As such, the results of these tests would often be considered by perioperative physicians and would influence whether additional investigations were conducted.

Finally, we do not know what effect the results of testing had on surgical decisions or patient outcomes.

Despite these limitations, this study adds substantially to the literature on health care overuse

and suggests a need for improved alignment with guidelines in the use of preoperative testing before low-risk surgical procedures.

Conclusion

Rates of preoperative testing before low-risk procedures were higher than expected, given current guidelines and recommendations, with a significant degree of regional and institution-level variation across hospitals in a large, diverse jurisdiction with a single-payer health system. More study is needed to determine the underlying causes of this variation and to develop care pathways to reduce low-value preoperative testing.

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Affiliations: Department of Anesthesia and Pain Management (Kirkham), Toronto Western Hospital, University of Toronto, Toronto, Ont.; Department of Anesthesia (Kirkham) and Institute for Health System Solutions and Virtual Care (Pendrith, Bhatia), Women's College Hospital, Toronto, Ont.; Li Ka Shing Knowledge Institute (Wijeysundera, Laupacis), St. Michael's Hospital, Toronto, Ont.; Department of Anesthesia and Pain Management (Wijeysundera), Toronto General Hospital, University of Toronto, Toronto, Ont.; Department of Medicine (Wijeysundera, Tu, Laupacis, Schull, Levinson), University of Toronto, Toronto, Ont.; Institute for Clinical Evaluative Sciences (Ng, Tu, Laupacis, Schull, Bhatia), Toronto, Ont.; Division of Cardiology (Tu), Sunnybrook Schulich Heart Centre, Toronto, Ont.; Sunnybrook Research Institute (Schull), Toronto, Ont.; Division of Cardiology (Bhatia), University Health Network, Toronto, Ont.

Contributors: Sacha Bhatia had full access to all of the data in the study and takes responsibility for the integrity of the data and accuracy of the data analysis. Sacha Bhatia, Kyle Kirkham and Duminda Wijeysundera were responsible for study concept and design. Sacha Bhatia and Ryan Ng were responsible for acquisition of data. Ryan Ng performed the statistical analysis. All authors analyzed and interpreted the data. Sacha Bhatia, Kyle Kirkham and Ciara Pendrith drafted the manuscript. All authors critically revised the manuscript for important intellectual content and approved the final version to be published. Sacha Bhatia obtained funding. Sacha Bhatia, Kyle Kirkham and Duminda Wijeysundera supervised the study. All authors agree to serve as guarantors for the work.

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