Preoperative Laboratory Investigations

Rates and Variability Prior to Low-risk Surgical Procedures

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ABSTRACT

Background: Increasing attention has been focused on low-value healthcare services. Through Choosing Wisely campaigns, routine laboratory testing before low-risk surgery has been discouraged in the absence of clinical indications. The authors investigated rates, determinants, and institutional variation in laboratory testing before low-risk procedures.

Methods: Patients who underwent ophthalmologic surgeries or predefined low-risk surgeries in Ontario, Canada, between April 1, 2008, and March 31, 2013, were identified from population-based administrative databases. Preoperative blood work was defined as a complete blood count, prothrombin time, partial thromboplastin, or basic metabolic panel within 60 days before an index procedure. Adjusted associations between patient and institutional factors and preoperative testing were assessed with hierarchical multivariable logistic regression. Institutional variation was characterized using the median odds ratio.

Results: The cohort included 906,902 patients who underwent 1,330,466 procedures (57.1% ophthalmologic and 42.9% low-risk surgery) at 119 institutions. Preoperative blood work preceded 400,058 (30.1%) procedures. The unadjusted institutional rate of preoperative blood work varied widely (0.0 to 98.1%). In regression modeling, significant predictors of preoperative testing included atrial fibrillation (adjusted odds ratio [AOR], 2.58; 95% CI, 2.51 to 2.66), preoperative medical consultation (AOR, 1.68; 95% CI, 1.65 to 1.71), previous mitral valve replacement (AOR, 2.33; 95% CI, 2.10 to 2.58), and liver disease (AOR, 1.69; 95% CI, 1.55 to 1.84). The median odds ratio for interinstitutional variation was 2.43.

Conclusions: Results of this study suggest that testing is associated with a range of clinical covariates. However, an association was similarly identified with preoperative consultation, and significant variation between institutions exists across the jurisdiction. **(Anesthesiology 2016; 124:804-14)**

In recent years, attention has focused on the issue of low-value healthcare services. In particular, the frequency of tests, treatments, or procedures that offer limited benefit to patients or may cause them harm has been questioned.[1,2] In response to concerns of overutilization, the American Board of Internal Medicine Foundation launched the Choosing Wisely (CW) campaign in the United States during 2012.[3] This grassroots, physician-led campaign seeks to encourage conversations between physicians and patients about care that may be unnecessary.[3,4] The campaign is centered on physician-defined "top five lists" of tests, treatments, and procedures that should be questioned.[3,4] Subsequent international CW campaigns have launched in countries including Canada in April 2014.[5,6]

What We Already Know about This Topic

- Routine laboratory testing before low-risk surgery has been discouraged in the absence of clinical indications
- The authors, therefore, conducted a retrospective analysis of rates, determinants, and institutional variation in laboratory testing before low risk procedures

What This Article Tells Us That Is New

- The cohort included more than 900,000 patients in 119 hospitals who had ophthalmologic and other low-risk procedures
- Various risk factors and medical consultation increased use of preoperative testing
- The amount of testing varied widely among institutions

Corresponding article on page 755. Supplemental Digital Content is available for this article. Direct URL citations appear in the printed text and are available in both the HTML and PDF versions of this article. Links to the digital files are provided in the HTML text of this article on the Journal's Web site (www.anesthesiology.org). R.S.B. 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. R.S.B., K.R.K., and D.N.W. helped in study concept and design. R.S.B. and R.N. helped in acquisition of data. All authors helped in analysis and interpretation of data. R.S.B., K.R.K., and C.P. helped in drafting of the manuscript. All authors helped in critical revision of the manuscript for important intellectual content. R.N. helped in statistical analysis. R.S.B. obtained funding. R.S.B., K.R.K., and D.N.W. helped in study supervision.

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Several CW lists include guidance on preoperative testing, such as the recommendation by the American Society of Anesthesiologists against "laboratory studies in patients without significant systemic disease (American Society of Anesthesiologists I or II) undergoing low-risk surgery."[7] This recommendation specifically includes complete blood count (CBC), basic or comprehensive metabolic panel, and coagulation studies developed through a comprehensive literature and membership survey process.[8] A similar approach is echoed by the American Society for Clinical Pathology[9] and the Canadian Association of Pathologists, which states: "avoid routine preoperative laboratory testing for low risk surgeries without a clinical indication."[10] The inclusion of recommendations to avoid routine laboratory testing before low-risk surgery is in line with published guidelines from the American Society of Anesthesiologists and Canadian Anesthesiologists Society, which acknowledge wide ranges in the published rates of abnormal results from preoperative CBC, coagulation panels, and serum chemistries with little evidence of changes in clinical management or patient outcomes in this surgical population.[11,12] Previous investigations have shown that these preoperative laboratory tests are typically normal before low-risk ambulatory surgery,[13–15] and abnormal results lead to a change in the management in as few as 3% of patients.[15–17] Indeed, randomized controlled trials in both ophthalmologic and ambulatory surgical populations have demonstrated no difference in intraoperative or postoperative patient outcomes whether preoperative testing is conducted.[18,19]

Although recommendations to change clinical practice around low-value care decisions may affect bedside decision-making, the impact of such campaigns depends greatly on current rates and regional or institutional variation in practice. Therefore, current utilization rates for procedures included in the CW recommendations are of significant interest for health policy makers, payers, and clinicians. Establishing baseline rates permits an understanding of the extent of the problem of low-value care and enables initiatives such as CW to be evaluated over time.

Therefore, we undertook a population-based study in Ontario, Canada, to determine the utilization rates of preoperative laboratory testing before hospital-based low-risk surgical procedures at a provincial and institutional level. In addition, the study evaluated the temporal trends for preoperative testing rates during a 5-yr period. We hypothesized that significant institutional variation exists in the ordering of preoperative blood tests that is not explained by patient comorbidity.

Materials and Methods

Population-based administrative healthcare databases were used to conduct a retrospective cohort analysis in Ontario, Canada. The included datasets were analyzed at the Institute for Clinical Evaluative Sciences and were linked by using unique encoded patient identifiers. Research ethics approval was received from Sunnybrook Health Sciences Centre, Toronto, Ontario, Canada. As all data were pooled at the institutional level, the requirement for informed consent was waived. The specific databases accessed during this study included the Canadian Institute for Health Information Discharge Abstract Database (DAD; hospital admissions) and Same Day Surgery database (outpatient surgery), Ontario Health Insurance Plan (OHIP) database (physician service and laboratory claims), the Registered Persons Database (demographics), the Institute for Clinical Evaluative Sciences Physician Database (physician demographics and specialty), and the Canadian census.

The study cohort consisted of all Ontario adult patients (18 yr of age or older), with an elective hospital admission, who underwent an eligible ophthalmologic or other low-risk surgery (*e.g.*, hernia repair, knee arthroscopy). The cohort period was defined from April 1, 2008, to March 31, 2013, inclusive from the DAD and Same Day Surgery database. The full list of eligible procedures is in included in Supplemental Digital Content 1, http://links.lww.com/ALN/B240. Patients with incomplete demographic information or data pertaining to their index procedure were excluded. Similarly, patients who underwent an eligible procedure during an existing inpatient hospitalization were excluded. The analysis was conducted per procedure and included all procedures for patients who underwent multiple eligible procedures during the study period.

Patient demographic information was captured from the Registered Persons Database, with neighborhood income quintile used to estimate patient socioeconomic status. We used validated data algorithms to identify patients with asthma, chronic obstructive pulmonary disorder, congestive heart failure, previous myocardial infarction, diabetes mellitus, and hypertension.[20–25] Diagnostic codes in DAD entries and OHIP claims in the 2 yr before index procedure[26] were used to capture the following comorbidities: liver disease, anemia, gastrointestinal bleeds, other hematologic disorders, hyperlipidemia, coronary artery disease, atrial fibrillation, other cardiac arrhythmia, cardiac valvular disease, cerebrovascular disease, and peripheral vascular disease. We used diagnostic (*International Classification of Diseases*, 10th revision codes from hospital admissions in the 2 yr before and including the index procedure admission to identify patients with venous thromboembolism and chronic renal disease. Hospital admission procedure and OHIP billing codes in the 10 yr before index procedure were used to determine whether patients had received any of the following procedures: aortic

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valve replacement, mitral valve replacement, coronary artery revascularization, and device implantation. Preoperative outpatient anesthesia billings in the 60 days before index procedure were identified from OHIP billing claims.[27] By using a validated algorithm, preoperative medical consultations were defined as claims for cardiology, endocrinology, general internal medicine, geriatric medicine, or nephrology visit within 60 days of the index date.[28]

Outcomes

Ontario Health Insurance Plan laboratory claims within 60 days before index procedure were used to identify patients with our primary outcome: receipt of preoperative blood work. This was defined as at least one claim for one of the following laboratory tests: CBC, prothrombin time (PT), partial thromboplastin time (PTT), and basic metabolic panel. These tests include those laboratory tests advised against in the CW Canada recommendations of the Canadian Association of Pathologists[10] and the US CW recommendations of the American Society for Clinical Pathology and American Society of Anesthesiologists.[9] Although institutional policies vary, tests conducted within 60 days before surgical procedures are generally considered current and accepted for preoperative evaluation.

Statistical Analysis

All analyses were performed using SAS version 9.3 (SAS Institute, USA) and were planned *a priori*. A two-sided α level of 0.05 was considered for statistical significance. We compared patient characteristics across procedure categories (ophthalmologic or low-risk surgical procedures) and by receipt of preoperative testing using ANOVA and the chi-square test, where appropriate. The rates of preoperative blood work and specific laboratory tests were assessed for the overall cohort and by procedure category.

We compared regional and institutional variation for preoperative blood work and each test for all procedures combined. A hospital was included in our institutional comparisons if they had a minimum of 250 procedures in at least 1 procedure category and at least 500 or more procedures overall. Subgroup analyses were performed by procedure type among hospitals meeting minimum procedure volume for that category.

To assess the adjusted associations of patient- and institutional-level factors with preoperative blood work, we developed a hierarchical random intercept multivariable logistic regression model. We included all patient-level covariates: age, sex, rural/urban residence, neighborhood income quintile, comorbidities, risk factors, previous cardiac procedures, preoperative anesthesia consultation, preoperative medical consultation, and procedure type. Institutional variation was characterized using the median odds ratio (MOR), which compares the adjusted odds of preoperative blood work for two patients with the same covariates from two randomly selected institutions.[29] The MOR is interpreted as the median value of these odds ratios and is always greater than or equal to 1 because it compares a higher ranked institution *versus* a lower ranked institution.[29] It is adjusted for patient-level factors, quantifies the variation between institutions, and is directly comparable with fixed-effects odds ratios.[29] For example, a MOR of 1.50 suggests 50% higher adjusted odds of preoperative blood work if a patient received treatment at one randomly selected institution compared with another.

Sensitivity analyses were performed to further assess a number of factors. An analysis was applied to evaluate a shorter 30-day preoperative window for included testing. An additional sensitivity analysis was performed with known or suspected coagulopathy patients removed from the study cohort. These patients included those with diagnoses of atrial fibrillation, previous mitral or aortic valve replacement, previous venous thromboembolism, or chronic liver disease. Another sensitivity analysis was conducted to consider the effect of clustering of events across individuals by performing a per-patient analysis rather than a per-procedure analysis as in our primary analyses.

Results

Assembly of the study cohort is described in figure 1 with final cohort demographics, and clinical characteristics are summarized in table 1 (see Supplemental Digital Content 2, http://links.lww.com/ALN/B241, for cohort characteristics by procedure category). Between April 1, 2008, and March 31, 2013, a total of 906,902 distinct patients underwent 1,330,466 procedures (57.1% ophthalmologic surgeries).

The cohort had a mean age of 64 yr and was 54.5% women. Patients undergoing ophthalmologic surgery were older (71 yr) than other low-risk surgery (55 yr). The large majority of procedures were performed on an outpatient basis (93.0%) with nearly all inpatient procedures in the low-risk surgery group (ophthalmologic surgery 0.3% *vs*. low-risk surgery 15.8%; $P < 0.0001$). The burden of comorbidities was generally low although hypertension was present in 56.1% and diabetes in 25.0% cases. Preoperative consultations by medical specialist or anesthesiologist occurred before 5.2 and 11.5% of procedures, respectively. The proportions of patients who underwent testing and the number tests conducted per patient are illustrated in figure 2.

Preoperative Testing Rates and Temporal Trends

Laboratory testing rates over time for the overall cohort and by procedure category are displayed in figure 2 for any testing and in Supplemental Digital Content 2, http://links.lww.com/ALN/B241, for specific investigations. During the study period, annual procedure volume decreased from a maximum of 281,189 in fiscal year 2008/2009 to a low of 245,333 in 2012/2013. Overall, the frequency of exposure to any preoperative laboratory test during the study period was 30.1% (95% CI, 30.0 to 30.1). Basic metabolic panel was the most frequently conducted test before 25.0% of procedures followed by CBC (23.7%) and PT (5.9%).

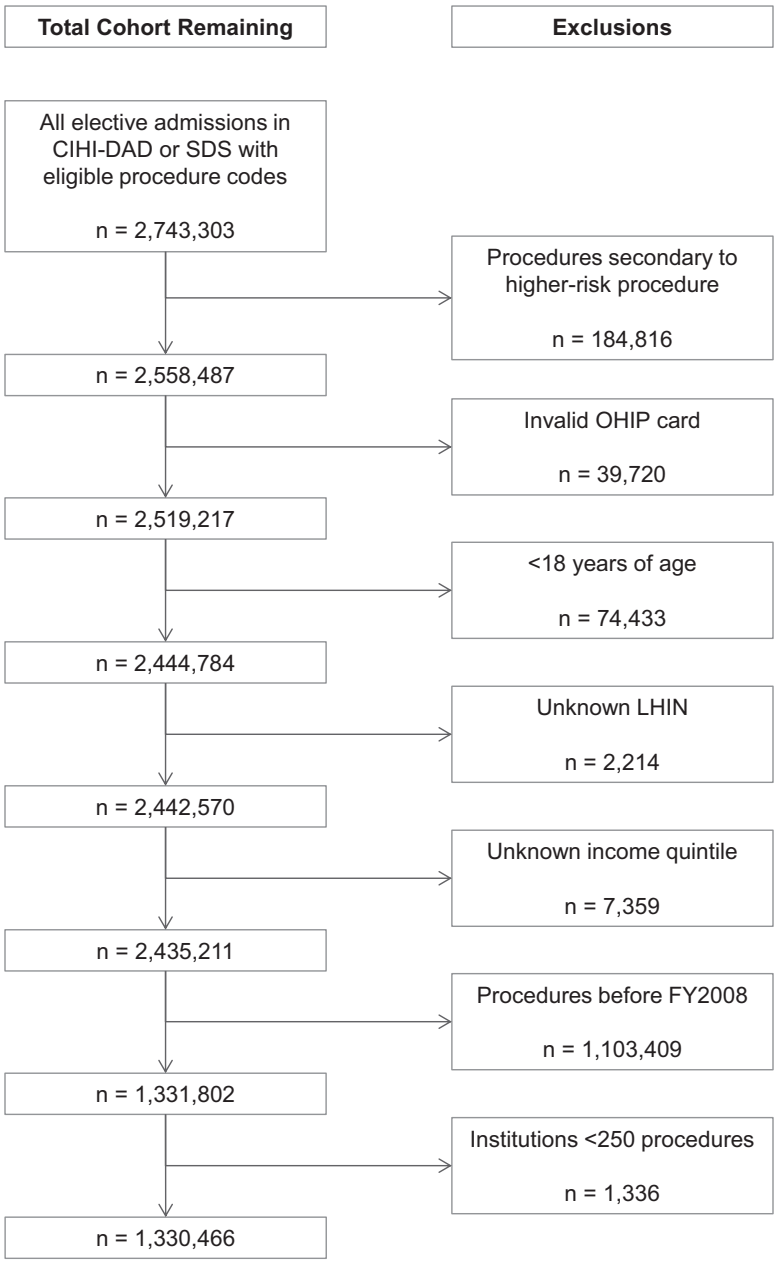

Fig. 1. Study flow diagram. CIHI-DAD = Canadian Institute for Health Information Discharge Abstract database; FY = fiscal year; LHIN = Local Health Integration Network; OHIP = Ontario Health Insurance Plan; SDS = Same Day Surgery database.

Throughout the study period, the rate of any preoperative laboratory test decreased from 30.7% in 2008/2009 to 27.9% in 2012/2013 ($P < 0.0001$).

Institutional Variation

Figures 3 and 4 illustrate the rates of preoperative laboratory testing administered across the full institutional cohort of 119 sites for the overall patient cohort. The rate of exposure to any preoperative laboratory test ranged from a low of 0.0 (95% CI, 0.0 to 0.7) to 98.2% (95% CI, 97.4 to 98.7). Basic metabolic panel varied from 0.0 (95% CI, 0.0 to 0.7) to 74.8% (95% CI, 74.2 to 75.5), 0.0 (95% CI, 0.0 to 0.7) to 98.0% (95% CI, 97.3 to 98.6) for CBC, and a low of 0.0 (95% CI, 0.0 to 0.7) to a high of 23.8% for PT (95% CI, 23.1 to 24.5).

Adjusted Analyses

Associations between testing and patient or institutional factors are included in table 2. Preoperative laboratory testing was associated with several comorbid conditions including heart failure, venous thromboembolism, and hepatic disease; however, some comorbidities, such as coronary artery disease and valvular disease, were associated with lower odds of preoperative testing. The strongest association was observed with a history of atrial fibrillation with an adjusted odds ratio (AOR) of 2.58 (95% CI, 2.51 to 2.66). The odds of

Table 1. Characteristics of Study Cohort Stratified by Receipt of Preoperative Testing

Characteristic	No Blood Work, N (%)	Any Blood Work, N (%)	Overall, N (%)
N	930,408 (69.9)	400,058 (30.1)	1,330,466
Female sex*	509,611 (54.8)	215,517 (53.9)	725,128 (54.5)
Age (yr), mean (SD)*	62.4 (16.6)	67.7 (14.3)	64.0 (16.1)
18–25	29,539 (3.2)	4,364 (1.1)	33,903 (2.5)
26–35	45,187 (4.9)	9,009 (2.3)	54,196 (4.1)
36–45	81,418 (8.8)	20,635 (5.2)	102,053 (7.7)
46–55	132,509 (14.2)	40,539 (10.1)	173,048 (13.0)
56–64	158,548 (17.0)	61,140 (15.3)	219,688 (16.5)
65–74	232,839 (25.0)	114,851 (28.7)	347,690 (26.1)
75–84	203,141 (21.8)	119,290 (29.8)	322,431 (24.2)
≥ 85	47,227 (5.1)	30,230 (7.6)	77,457 (5.8)
Residence*			
Rural	104,426 (11.2)	30,722 (7.7)	135,148 (10.2)
Suburban	233,240 (25.1)	92,954 (23.2)	326,194 (24.5)
Urban	584,794 (62.9)	274,373 (68.6)	859,167 (64.6)
Missing	7,948 (0.9)	2,009 (0.5)	9,957 (0.7)
Neighborhood income quintile*			
Q1 (lowest)	171,209 (18.4)	77,460 (19.4)	248,669 (18.7)
Q2	185,185 (19.9)	84,153 (21.0)	269,338 (20.2)
Q3	186,142 (20.0)	80,386 (20.1)	266,528 (20.0)
Q4	194,763 (20.9)	81,171 (20.3)	275,934 (20.7)
Q5 (highest)	193,109 (20.8)	76,888 (19.2)	269,997 (20.3)
Comorbidities			
Coronary artery disease*	23,824 (2.6)	19,486 (4.9)	43,310 (3.3)
Atrial fibrillation/flutter*	9,295 (1.0)	16,578 (4.1)	25,873 (1.9)
Other cardiac arrhythmia*	4,946 (0.5)	4,683 (1.2)	9,629 (0.7)
Cardiac valvular disease*	2,604 (0.3)	3,053 (0.8)	5,657 (0.4)
Cerebrovascular disease*	5,078 (0.5)	4,352 (1.1)	9,430 (0.7)
Peripheral vascular disease*	4,920 (0.5)	3,729 (0.9)	8,649 (0.7)
Venous thromboembolism*	1,023 (0.1)	1,244 (0.3)	2,267 (0.2)
Heart failure*	44,085 (4.7)	45,242 (11.3)	89,327 (6.7)
Myocardial infarction*	7,381 (0.8)	5,673 (1.4)	13,054 (1.0)
Chronic renal disease*	7,814 (0.8)	7,301 (1.8)	15,115 (1.1)
Liver disease*	1,246 (0.1)	1,260 (0.3)	2,506 (0.2)
Anemia*	18,526 (2.0)	16,792 (4.2)	35,318 (2.7)
Gastrointestinal bleeds*	7,063 (0.8)	5,449 (1.4)	12,512 (0.9)
Other blood diseases*	3,694 (0.4)	3,306 (0.8)	7,000 (0.5)
Asthma*	133,519 (14.4)	61,177 (15.3)	194,696 (14.6)
COPD*	155,211 (16.7)	82,919 (20.7)	238,130 (17.9)
Cardiac risk factors			
Diabetes*	194,193 (20.9)	138,869 (34.7)	333,062 (25.0)
Hypertension*	479,752 (51.6)	266,079 (66.5)	745,831 (56.1)
Hyperlipidemia*	45,170 (4.9)	34,140 (8.5)	79,310 (6.0)
Previous cardiac procedures			
Aortic valve replacement*	3,117 (0.3)	3,651 (0.9)	6,768 (0.5)
Mitral valve replacement*	637 (0.1)	1,360 (0.3)	1,997 (0.2)
Coronary revascularization*	40,394 (4.3)	28,038 (7.0)	68,432 (5.1)
Device implantation*	8,625 (0.9)	10,897 (2.7)	19,522 (1.5)
Type of surgical procedure*			
Ophthalmologic surgery	506,818 (54.5)	252,826 (63.2)	759,644 (57.1)
Low-risk surgery	423,590 (45.5)	147,232 (36.8)	570,822 (42.9)
Surgical site*			
Inpatient procedure	63,737 (6.9)	28,950 (7.2)	92,687 (7.0)
Same day surgery	866,671 (93.1)	371,108 (92.8)	1,237,779 (93.0)
Preoperative consultation			
Anesthesia*	104,032 (11.2)	48,959 (12.2)	152,991 (11.5)
Medical*	36,923 (4.0)	32,802 (8.2)	69,725 (5.2)

Characterization of the study cohort as defined by all covariates. Values given as frequencies (%) unless stated otherwise.

* $P < 0.001$.

COPD = chronic obstructive pulmonary disorder.

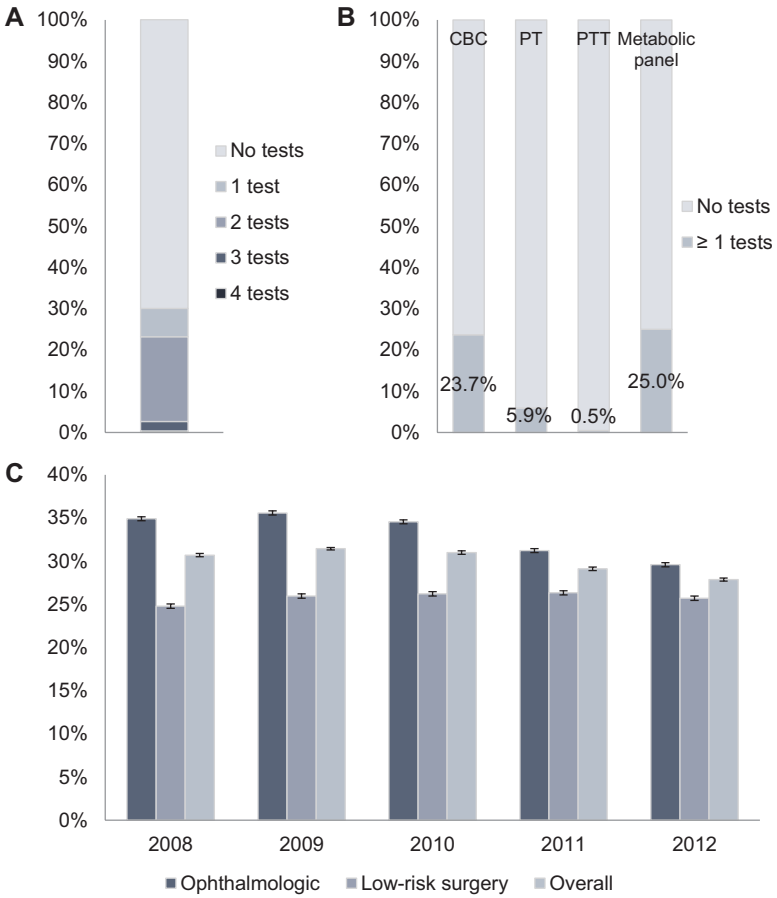

Fig. 2. Utilization of preoperative testing. (*A*) Distribution of patients by number of preoperative tests. (*B*) Proportion of patients receiving specific preoperative laboratory tests. (*C*) Annual proportions of patients in the overall cohort and by procedure type exposed to any preoperative laboratory investigation. CBC = complete blood count; PT = prothrombin time; PTT = partial thromboplastin time.

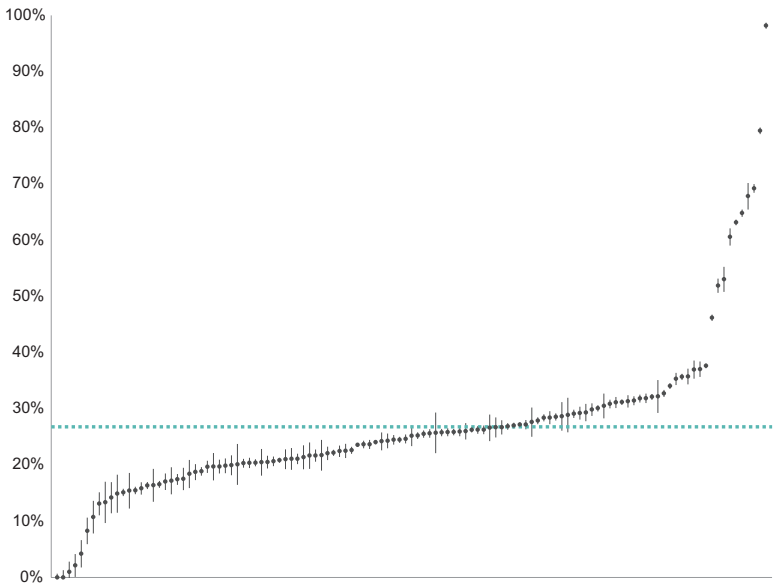

Fig. 3. Unadjusted institutional variation in exposure to any preoperative blood work. Points represent unadjusted proportions of receiving any preoperative blood work across 119 institutions. *Vertical lines* represent exact binomial 95% CIs. The *dashed line* denotes the mean testing rate across all institutions (26.8%). Range = 0.0 to 98.2%.

receiving a preoperative test were higher with increasing age with an AOR for age 85 yr or older of 2.98 (95% CI, 2.87 to 3.10) relative to the reference group of 18 to 25 yr olds. Preoperative anesthesia consultation was not associated with an increased AOR; however, preoperative medical specialist visit was associated with increased frequency of testing (AOR, 1.68; 95% CI, 1.65 to 1.71). Teaching hospital status was not a significant predictor. Procedure volume was associated with preoperative testing, but the effect size was small. The MOR for preoperative laboratory testing was determined to be 2.43, meaning that the odds of a given patient receiving testing at one randomly chosen higher ranked institution was 2.4 times that at another randomly selected lower ranked institution.

Sensitivity Analyses

Restricting the analysis to tests conducted in the 30 days before the surgery date decreased the rate of any preoperative blood work to 19.9% (95% CI, 19.8 to 20.0). Preoperative basic metabolic panel, CBC, and PT decreased to 15.5 (95% CI, 15.5 to 15.6), 15.0 (95% CI, 14.9 to 15.0), and 4.9% (95% CI, 4.8 to 4.9), respectively. Variability between institutions did not change when restricting the preoperative period; institutional rates of any preoperative laboratory investigations ranged from 0.0 (95% CI, 0.0 to 0.7) to 97.2% (95% CI, 96.3 to 97.9). Regression results were similar to the primary analysis (see Supplemental Digital Content 3, http://links.lww.com/ALN/B242, for full results from 30-day sensitivity analysis). When we excluded patients with atrial fibrillation, previous mitral or aortic valve replacement, previous venous thromboembolism, or chronic liver disease, rates of any preoperative investigation was 29.2% (95% CI, 29.1 to 29.3). The rates of preoperative basic metabolic panel and CBC were 24.6 (95% CI, 24.6 to 24.7) and 23.4% (95% CI, 23.3 to 23.5), respectively. The rates of preoperative PT and PTT were 4.9 (95% CI, 4.8 to 4.9%) and 0.5% (95% CI 0.4 to 0.5%), respectively. Institutional variation in preoperative testing did not change. The results from the sensitivity analysis considering the effect of clustering across individuals with multiple procedures were similar to the primary analysis, and see Supplemental Digital Content 4, http://links.lww.com/ALN/B243, for full regression results from the per-patient analysis.

Discussion

Routine preoperative laboratory testing before low-risk surgical procedures has been discouraged by several clinical societies through the efforts of the CW campaign. The American Society of Anesthesiologists, the American Society for Clinical Pathology, and the Canadian Association of Pathologists have all suggested that preoperative testing including, CBC, coagulation studies, and metabolic panels, is not indicated in the absence of specific clinical indications.[7,9,10] Despite these recommendations, our large retrospective cohort study has demonstrated that laboratory investigations remain common practice. Although the rate of testing varied, with coagulation studies being particularly infrequently tested,

Table 2. Regression Results

Characteristic	AOR (95% CI)	*P* Value
Female	1.05 (1.04–1.06)	< 0.0001
Age (yr)		
18–25	1 (reference)	
26–35	1.37 (1.32–1.43)	< 0.0001
36–45	1.77 (1.70–1.84)	< 0.0001
46–55	2.04 (1.96–2.11)	< 0.0001
56–64	2.27 (2.19–2.36)	< 0.0001
65–74	2.64 (2.55–2.74)	< 0.0001
75–84	2.90 (2.80–3.01)	< 0.0001
≥ 85	2.98 (2.87–3.10)	< 0.0001
Residence		
Urban	1 (reference)	
Rural	0.71 (0.70–0.73)	< 0.0001
Suburban	1.00 (0.98–1.01)	0.44
Missing	0.64 (0.61–0.68)	< 0.0001
Neighborhood income quintile		
Q1 (lowest)	1 (reference)	
Q2	1.00 (0.99–1.02)	0.59
Q3	1.00 (0.99–1.02)	0.73
Q4	1.01 (0.99–1.02)	0.26
Q5 (highest)	0.99 (0.97–1.00)	0.06
Comorbidities		
Coronary artery disease	0.92 (0.90–0.95)	< 0.0001
Atrial fibrillation/flutter	2.58 (2.51–2.66)	< 0.0001
Other cardiac arrhythmia	0.91 (0.86–0.95)	< 0.0001
Cardiac valvular disease	0.89 (0.83–0.94)	0.0001
Cerebrovascular disease	1.15 (1.10–1.20)	< 0.0001
Peripheral vascular disease	0.94 (0.90–0.99)	0.01
Venous thromboembolism	1.96 (1.80–2.15)	< 0.0001
Heart failure	1.55 (1.52–1.57)	< 0.0001
Myocardial infarction	0.98 (0.93–1.02)	0.32
Chronic renal disease	0.99 (0.95–1.02)	0.46
Liver disease	1.69 (1.55–1.84)	< 0.0001
Anemia	1.41 (1.37–1.44)	< 0.0001
Gastrointestinal bleeds	1.14 (1.10–1.19)	< 0.0001
Other blood diseases	1.20 (1.13–1.26)	< 0.0001
Asthma	1.01 (1.00–1.03)	0.01
COPD	1.04 (1.03–1.06)	< 0.0001
Cardiac risk factors		
Diabetes	1.62 (1.60–1.63)	< 0.0001
Hypertension	1.25 (1.24–1.27)	< 0.0001
Hyperlipidemia	1.09 (1.07–1.11)	< 0.0001
Previous cardiac procedures		
Aortic valve replacement	1.42 (1.34–1.50)	< 0.0001
Mitral valve replacement	2.33 (2.10–2.58)	< 0.0001
Coronary revascularization	1.00 (0.98–1.02)	0.72
Device implantation	1.66 (1.61–1.71)	< 0.0001
Procedure		
Low-risk surgery	1 (reference)	
Ophthalmologic surgery	1.07 (1.05–1.08)	< 0.0001
Preoperative consultations		
Outpatient anesthesia	1.00 (0.98–1.01)	0.68
Medical	1.68 (1.65–1.71)	< 0.0001
Teaching hospital status	1.00 (0.97–1.04)	0.78
Hospital procedure volume		
Medium procedure volume	1.03 (1.00–1.06)	0.06
High procedure volume	1.06 (1.01–1.12)	0.03
Adjusted MOR	2.43	

AOR = adjusted odds ratio; COPD = chronic obstructive pulmonary disorder; MOR = median odds ratio.

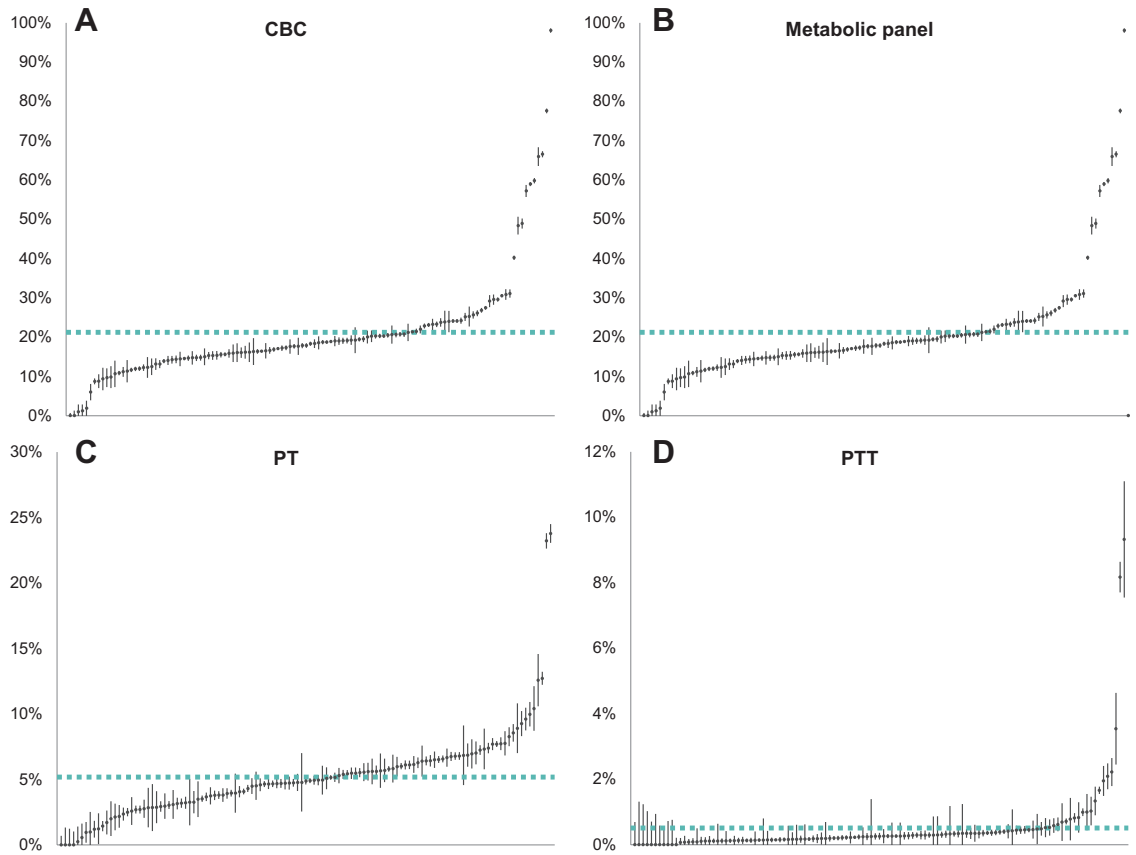

Fig. 4. Unadjusted institutional variation in preoperative (*A*) complete blood count (CBC), (*B*) metabolic panel, (*C*) prothrombin time (PT), and (*D*) partial thromboplastin time (PTT).

CBC and metabolic panels were conducted before nearly one quarter of procedures in this cohort.

Modeling conducted to assess for drivers of this laboratory testing demonstrated that some clinical indications contribute to testing decisions including a history of atrial fibrillation, mitral valve replacement, thromboembolism, and hepatic disease. These particular indications may fall outside recommendations regarding asymptomatic patients and, therefore, be clinically indicated with associated tests providing actionable clinical information. Interestingly, coronary artery disease and valvular disease were associated with lower odds of testing; however, these patients may be seen regularly by a cardiologist and receive routine blood testing outside the observation window. Most patient comorbidities had associations that were exceeded by underlying demographics such as age. In contrast, the MOR for institution of 2.4 suggests that location of surgery is one of the strongest factors influencing whether a patient receives testing before their procedures. Indeed, interinstitutional variability in testing rates revealed dramatic differences between the lowest ordering and the highest ordering institutions.

Our results are consistent with previous evidence from Bryson *et al.*[15] demonstrating testing rates in conflict with existing guidelines. These authors examined 294 patients undergoing elective surgery and found that noncompliance rates varied with the particular test and guideline examined but ranged from a low of 5% to a high of 98%.[15] Similarly, a large review of National Surgical Quality Improvement Program data for inguinal hernia repair in 2012 revealed that 54% of 25,149 patients with no clear indication for testing underwent at least one laboratory investigation.[30] Chen *et al.*[31] reported that preoperative testing before cataract surgery ranged from 11% for coagulation studies to 36% for chemistry panels. After controlling for comorbidities and demographics, the performing ophthalmologist and preoperative consult were the largest drivers of testing variation.[31]

In addition to recommendation on laboratory testing, CW lists from clinical societies including the American Society of Anesthesiologists, the American College of Cardiology, and the Canadian Cardiovascular Society have addressed the conduct of low-value cardiac investigations before low-risk surgery.[7,32,33] Similar to our findings for laboratory testing, a high rate of usage and interinstitutional variability has been recently demonstrated in this population for chest x-rays and cardiac testing, including electrocardiograms, stress tests, and echocardiograms.[34]

Our study adds a number of significant elements to previous work. First, we examine specifically a broad cohort of low-risk procedures in line with published CW recommendations. Consequently, our results more specifically

address the question of low-value care decisions across this cohort, where previous investigations have been limited in procedure scope. Furthermore, this study specifically aims to investigate the rates across hospital sites within a jurisdiction. Although previous studies have examined overall cohort rates[30] or single-institution[15] practice, our results demonstrate the wide variability between institutions, better illustrating the level at which interventions may be targeted to effect practice change.

This study's findings represent an important opportunity for policy makers and clinicians to reexamine current clinical practice. Low-value, but frequently employed, healthcare interventions like preoperative testing represent a significant cost to overburdened systems and expose patients to potential harm. Testing has been shown repeatedly to result in surgical delays and leads to escalating investigations despite the absence of a demonstrable change in perioperative management or outcomes.[30,35] Although, not all preoperative testing is low value, recent estimates in the United States have suggested that preoperative testing represents an annual cost of approximately $18 billion.[18] The CW physician-led campaign seeks to identify and reduce these types of low-value interventions and investigations by changing the conversation between physicians and patients. The shared decision-making element, however, in this relationship is pivotal as it avoids the need for top–down policy directives. Our data represent a starting point to assess the impact of this campaign over time.

Although administrative data are unable to provide the patient-level detail necessary to assess the clinical appropriateness of each test conducted, the dramatic interinstitutional variability suggests an opportunity for intervention. The CBC rates that range from 0.0 to 98.0% and metabolic panel rates from 0.0 to 74.8% are difficult to explain. Furthermore, when adjustment is made for institutional and patient factors, the MOR of 2.4 suggests that procedure location is the foremost driver of testing beyond the impact of any of the clinical factors examined. Creating a feedback mechanism at this level of data for institutions and grassroot-level care providers should be paired with campaigns such as CW to raise provider awareness and empower local efforts—where the impact is greatest—to address these wide discrepancies.

Several limitations should be considered when evaluating our data. First, many preoperative tests may be indicated. Although previous evidence suggests limited benefit in most cases, current recommendations revolve around asymptomatic or healthy patients and we are unable to link the occurrence of testing with patient presentation of symptoms or physical examination findings, and thus, the appropriateness of individual tests cannot be determined. Second, we set the threshold for including laboratory tests at 60 days before the index procedure. This period was chosen to ensure capture of testing that fall within the common period accepted by institutional guidelines as valid for preoperative use within Ontario. Although some tests conducted during this period may be due to unrelated investigations, this period was felt to appropriately balance the range of institutional policies,[36] and this range has been used in previously published research.[27,34,37] Third, it is possible that we are underestimating the number of laboratory tests performed, because laboratory tests done in hospital are not captured by administrative data, which may be unevenly distributed across the province. Finally, no validated and comprehensive list of "low-risk surgical procedures" exists. We chose to include low-risk procedures including ophthalmologic surgeries with a list of minimally invasive surgeries in line with the broad definition of low-risk described in recent guidelines on perioperative cardiac evaluation.[38,39] Our choice of procedures is supported by the extremely high ambulatory procedure rate (93.0%), and specific effort was made to exclude procedures of a more invasive nature. We included subgroup analysis by procedure type due to the heterogeneity of these populations.

In conclusion, despite current recommendations to avoid preoperative laboratory testing before low-risk surgery without clear clinical indications, investigations including CBC, PT, PTT, and metabolic panel tests are frequently performed. Significant interinstitutional variability within a diverse but single-payer health system exists that cannot be explained by patient or institutional factors alone. As part of any CW campaign, feeding data back to institutions regarding rates of preoperative testing mechanism can potentially reduce low-value care.

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Competing Interests

The authors declare no competing interests.

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