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Research

Low-value preoperative cardiac testing before low-risk surgical procedures: a population-based cohort study

Siavash Zare-Zadeh BHSc, Braden J. Manns MD MSc, Derek S. Chew MD MSc, Tyrone G. Harrison MD, Flora Au MA, Amity E. Quinn PhD

Abstract

Background: Choosing Wisely Canada (CWC) recommends avoiding noninvasive advanced cardiac testing (e.g., exercise stress testing [EST], echocardiography and myocardial perfusion imaging [MPI]) for preoperative assessment in patients scheduled to undergo low-risk noncardiac surgery. In this study, we assessed the temporal trends in testing, overlapping with the introduction of the CWC recommendations in 2014, and patient and provider factors associated with low-value testing.

Methods: In this population-based retrospective cohort study, we used linked health administrative data in Alberta, Canada, to identify adult patients who underwent elective noncardiac surgery between Apr. 1, 2011, and Mar. 31, 2019, who had preoperative noninvasive advanced cardiac tests (EST, echocardiography or MPI) within 6 months before surgery. We included electrocardiography as an exploratory outcome. We excluded patients at high risk using the Revised Cardiac Risk Index (score ≥ 1 considered to indicate high risk), and modelled patient and temporal factors associated with the number of tests.

Results: We identified 1 045 896 elective noncardiac operations performed in 798 599 patients and 25 599 advanced preoperative cardiac tests; 2.1% of operations were preceded by advanced cardiac testing. The incidence of testing increased over the study period, and, by 2018/19, patients were 1.3 times (95% confidence interval 1.2–1.4) more likely to receive a preoperative advanced test compared to 2011/12. Urban patients were more likely to receive a preoperative advanced cardiac test than their rural counterparts. Electrocardiography was the most common preoperative cardiac test, preceding 182 128 procedures (17.4%).

Interpretation: Preoperative advanced cardiac testing was infrequent in adult Albertans who underwent low-risk elective noncardiac operations. Despite CWC recommendations, the use of some tests appears to be increasing, and there was substantial variation across geographic areas.

Low-value care poses a considerable financial burden to the health care system.[1,2] The Institute of Medicine estimated that 30% of annual health care spending in the United States is wasteful.[3] Canadian studies have shown overuse of diagnostic and screening tests ranging between 17.9% and 38.7%,[4] with 5% of physician visits in 2012–2015 resulting in at least 1 low-value service.[2] Since 2014, Choosing Wisely Canada (CWC) has provided physicians and patients with recommendations to reduce wasteful medical testing.[5] This campaign calls on physicians to avoid cardiac testing as a preoperative assessment in patients scheduled to undergo low-risk noncardiac surgery. Evidence suggests that low-value preoperative testing does not improve patient outcomes and may lead to cancellations and delays, which, in turn, may harm the patient.[6,7] Low-value testing may also lead to false-positive results, which inadvertently induce a downstream cascade of additional costly tests, some of which can lead to major adverse events (e.g., coronary angiography),[8,9] especially when not indicated.

Low-value preoperative testing has been described in Ontario, Canada's most populous province, with significant variation across institutions.[10] In the province of Alberta, between 2012 and 2015, the cost of noninvasive cardiac tests before noncardiac operations was estimated at $5.2 million.[2] Specific patient and provider factors are associated with the prevalence of low-value care: patients of higher socioeconomic standing, older patients and those with greater contact with specialist care are more likely to receive unnecessary tests.[2,4] Physician payment models may also be a driver of use of health care services, with fee-for-service remuneration increasing the use of elective visits and procedures compared to other payment models.[11,12] Prior work in Ontario has shown regional variation and temporal trends in low-value testing that predate the CWC recommendations.[10] The objectives of the current study were to describe the trends in

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Correspondence to: Braden Manns, Braden.Manns@albertahealthservices.ca

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preoperative advanced noninvasive cardiac testing, overlapping with the introduction of the CWC recommendations, in 2014, and to describe patient and provider factors and costs associated with such testing.

Methods

Setting, study design and data source

We used data for this retrospective population-based cohort study from the Interdisciplinary Chronic Disease Collaboration data repository, an Alberta-wide database that includes linked health administrative data (provincial laboratory and linked patient-level health administrative data including demographic characteristics, vital statistics, physician claims, dispensed prescription medications, hospital admissions, and emergency department and ambulatory visits) for more than 99% of Albertans between 1994 and 2019. The data repository was cleaned before investigator access, was fully accessible by our analyst (F.A.) for cohort creation and analysis, and has been employed in multiple observational studies using administrative data.[13–17] This study followed the STROBE[18] and RECORD[19] reporting guidelines.

Cohort selection

We identified Albertans aged 18 years or older who underwent elective noncardiac surgery between Apr. 1, 2011, and Mar. 31, 2019, using the Canadian Classification of Health Interventions codes from the Ambulatory Care and Hospitalization data sets (Appendix 1, Supplemental Table S1, available at www.cmajopen.ca/content/11/3/E451/suppl/DC1). Surgical procedures occurring within 6 months after an initial index operation were excluded to eliminate staged procedures and procedures addressing postoperative complications. Additional operations beyond the exclusion period were included and treated as new index events.

We used the Revised Cardiac Risk Index (RCRI) to identify patients at low risk. The RCRI is a validated risk-stratification tool suggested for preoperative use by the Canadian Cardiovascular Society[20] and defined with the use of health administrative data.[21] The RCRI includes 6 variables: history of ischemic heart disease, history of congestive heart failure, history of cerebrovascular disease, use of insulin therapy for diabetes, preoperative serum creatinine level greater than 177 μmol/L and high-risk surgery (intrathoracic, vascular or intraperitoneal procedure).[20,21] We calculated each patient's RCRI score for their respective operation. Patients with an RCRI score less than 1 were considered to be at low risk.[21] We identified dispensing of prescribed insulin and the most recent serum creatinine level 100 and 91 days before the surgery date, respectively.

Outcome

The primary outcome was the number of preoperative advanced noninvasive cardiac tests, including exercise stress testing (EST), transthoracic echocardiography, stress myocardial perfusion imaging (MPI) and 12-lead surface electrocardiography (ECG), that patients received in the 6-month period before the index operation. The first 3 advanced noninvasive cardiac tests are targeted within the CWC recommendations,[5] and we included ECG (although not part of the CWC recommendations) as an exploratory outcome. We identified preoperative cardiovascular tests using physician claims data, up to 6 months before the index operation[22] (Appendix 1, Supplemental Table S2).

Other variables

We collected patient characteristics such as age, sex, and rural or urban status from the Interdisciplinary Chronic Disease Collaboration Data Repository registry file.[22] We identified medical comorbidities by applying validated code algorithms to physician claims and hospital admission data for the 2 years before the surgery date.[23] As an indicator of socioeconomic status, we used the neighbourhood level income based on postal code. We identified patient surgery characteristics, including surgical site and type, through the Canadian Institute for Health Information Discharge Abstract Database. Less than 1% of data on patient characteristics was missing.

We identified patients who saw a medical specialist (internist, cardiologist or anesthesiologist) in the 180 days before surgery (v. those who did not), assuming these visits were likely a preoperative assessment visit. We gathered physician characteristics, including age, sex, health zone, facility and payment model, from physician claims. For physician payment model, we categorized physicians by salary-based or fee-for-service reimbursement. For physicians using a fee-for-service model, we also identified the subset of physicians who could submit claims for the interpretation of cardiac tests.

We estimated the cost of cardiovascular testing by adding the amount paid reported in claims data by Alberta Health to testing facilities for all imaging procedures identified in this study. The fees and rules governing billing for imaging tests are reported in the Alberta Health Insurance Plan Schedule of Medical Benefits.[24]

Statistical analysis

We assessed the association of cardiac tests with observed patient, surgical and physician characteristics by estimating incidence rate ratios (IRRs) and testing for significance using χ^2 tests. For patients who had a preoperative visit with a specialist, we explored whether use of cardiac testing varied by payment model and specialty using χ^2 tests. We also estimated the association between time and testing rates adjusted for age, sex and location to examine the impact of the 2014 CWC recommendations.[5] We estimated IRRs using a Poisson model with an included patient random effect to account for clustering of multiple procedures for some patients. We defined missing data as a variable category (data were missing for only 4 baseline characteristic variables). Statistical tests giving a p value less than 0.05 were considered statistically significant. We completed all statistical analyses using Stata/MP 17.0 (StataCorp.).

Ethics approval

This study was approved by the University of Calgary's Conjoint Health Research Ethics Board (Ethics ID no. REB16-1575_REN4).

Results

Patient characteristics

We identified 1 257 285 adult Albertans who underwent 2 260 710 elective noncardiac surgical procedures between Apr. 1, 2011, and Mar. 31, 2019 (Figure 1). After exclusions, the final study cohort consisted of 798 599 patients at low risk who underwent 1 045 896 procedures. The average age of the study cohort was 47.9 years (standard deviation 17.0 yr), 427 891 patients (53.6%) were female, and 449 273 patients (56.3%) had 1 or more comorbidities (Table 1). The most common comorbidities were hypertension (191 397 patients [24.0%]), chronic pain (123 511 [15.5%]) and depression (86 544 [10.8%]). Most patients (673 992 [84.4%]) resided in an urban setting. The majority of patients (610 625 [76.5%]) had 1 operation, 142 935 (17.9%) had 2, and 45 039 (5.6%) had 3 or more.

Surgical characteristics

Over the study period, the annual number of operations performed in patients at low preoperative risk decreased from 134 050 to 125 566. The most common types of procedure during the study period among patients at low preoperative risk were musculoskeletal (266 454), skin and soft tissue (217 134) and ophthalmologic (156 223) (Table 1).

The majority of procedures (752 758 [72.0%]) were outpatient. However, a higher proportion of inpatients than outpatients received preoperative testing (7172 [2.4%] v. 11 397 [1.5%]) ($p < 0.001$).

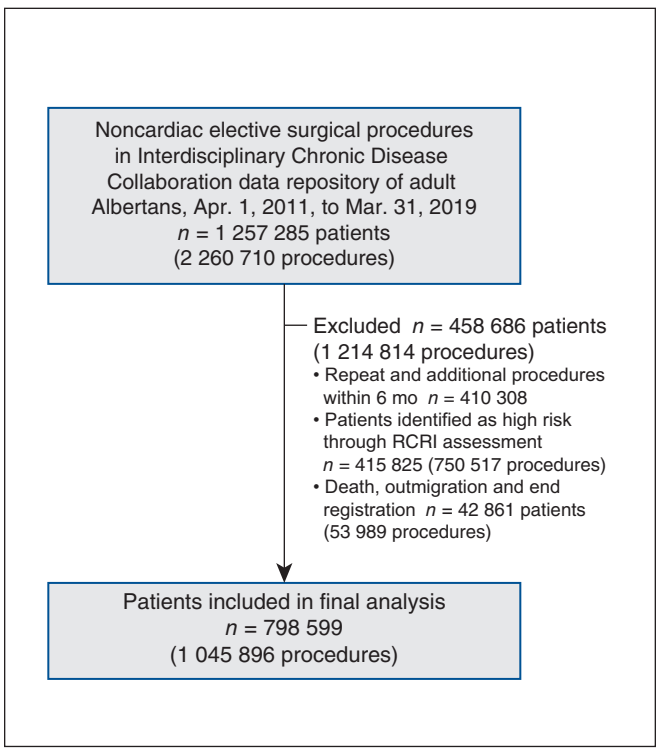

Figure 1: Flow diagram showing patient selection. Note: RCRI = Revised Cardiac Risk Index.

Temporal trends in use of noninvasive cardiac testing

In total, 25 529 advanced preoperative cardiac tests were completed during the study period (Appendix 1, Supplemental Table S3). Among those who received any advanced preoperative test, 16 514 received only 1 preoperative test. Echocardiography was the most common test (n = 19 042), occurring before 1.5%–1.9% of procedures (Figure 2). Preoperative use of EST (n = 4704) remained stable over the study period, with testing before 0.4% of procedures. Myocardial perfusion imaging was the least common preoperative test (n = 1846), performed before 0.2% of procedures, with consistent use over time. The incidence of advanced testing increased over the study period, and, by 2018/19, patients were 1.3 times (95% confidence interval [CI] 1.2–1.4) more likely to receive an advanced test compared to 2011/12 (Figure 3).

Electrocardiography, although not included in the CWC recommendations, was the most common preoperative cardiac test (n = 182 128 [17.4%]) (Appendix 1, Supplemental Table S3). Annual use peaked in 2011/12, at 18.1 tests per 100 operations, and then declined to 11.8 by 2018/19, a decline driven by urban health zones (decline 65.1% urban v. 12.3% rural) (Figure 2, Figure 4).

Factors associated with use of noninvasive cardiac testing

Age was strongly associated with the incidence of overall preoperative testing (Appendix 1, Supplemental Table S3). Compared to patients aged 40 years or younger, those aged 65 years or older were more than 6 times more likely to receive a preoperative cardiac test (IRR 6.5, 95% CI 6.4–6.6) (Appendix 1, Supplemental Table S4). Urban patients were significantly more likely than rural patients to receive advanced cardiac tests and ECG (Figure 4). We also noted variation across Alberta's geographically based health zones. Compared to patients in urban zone 1 (reference group), those in urban zone 2 were 1.6 times (95% CI 1.5–1.6) more likely to receive an advanced cardiac test.

Among the 117 390 patients who had a visit to a specialist in the 6 months before surgery, neither the physician's payment model (IRR 1.0, 95% CI 0.9–1.0) nor their specialty (IRR 1.0, 95% CI 0.9–1.1) was associated with a higher incidence of noninvasive cardiac testing, with comparable rates of testing among patients who saw salary-based physicians and those who saw fee-for-service physicians. When we limited the timing of preoperative visits to specialists to within 3 months before surgery, 98 895 patients had such a visit, and those who saw fee-for-service physicians (v. salary) and cardiologists (v. internal medicine) were significantly more likely to receive preoperative cardiac testing (payment model: IRR 1.1, 95% CI 1.0–1.1; specialty: IRR 1.2, 95% CI 1.1–1.3), although the difference may not have been clinically meaningful.

Cost of noninvasive cardiac testing

Advanced tests cost the province an estimated $5.5 million in 2011/12–2018/19, with an annual cost of $0.6 million in 2018/19, not including the cost of follow-up tests and procedures for tests with false-positive results. In addition, 182 128 ECG procedures were done (Appendix 1, Supplemental Table S3), at a cost of $6.1 million.

Table 1: Patient and surgical characteristics of adult Albertans at low risk who underwent elective noncardiac surgery between 2011/12 and 2018/19, by preoperative noninvasive cardiac tests within 6 months of the index procedure

Characteristic	No. (%) of patients/operations*			
	Overall	Advanced tests only†	Electrocardiography only	No test
Patients				
No. of patients	798 599	21 787	118 923	657 889
Age, mean ± SD, yr	47.9 ± 17.0	58.7 ± 15.3	57.7 ± 14.5	45.8 ± 16.8
Age category, yr				
< 40	293 926 (36.8)	2885 (13.2)	14 785 (12.4)	276 256 (42.0)
40–49	144 349 (18.1)	2925 (13.4)	17 699 (14.9)	123 725 (18.8)
50–59	151 177 (18.9)	4987 (22.9)	31 346 (26.4)	114 844 (17.5)
60–69	115 147 (14.2)	5508 (25.3)	31 123 (26.2)	78 516 (11.9)
≥ 70	90 931 (11.4)	5412 (24.8)	23 824 (20.0)	61 695 (9.4)
Missing	3069 (0.4)	70 (0.3)	146 (0.1)	2853 (0.4)
Sex				
Female	427 891 (53.6)	12 761 (58.6)	66 358 (55.8)	348 772 (53.0)
Male	367 639 (46.0)	8956 (41.1)	52 419 (44.1)	306 264 (46.6)
Missing	3069 (0.4)	70 (0.3)	146 (0.1)	2853 (0.4)
Income quintile				
1st (lowest)	170 481 (21.4)	4701 (21.6)	23 696 (19.9)	142 084 (21.6)
2nd	167 606 (21.0)	4553 (20.9)	25 340 (21.3)	137 713 (20.9)
3rd	153 408 (19.2)	4149 (19.0)	22 471 (18.9)	126 788 (19.3)
4th	146 729 (18.4)	3923 (18.0)	21 962 (18.5)	120 884 (18.4)
5th (highest)	147 012 (18.4)	4140 (19.0)	24 243 (20.4)	118 629 (18.0)
Missing	13 362 (1.6)	321 (1.5)	1211 (1.0)	11 831 (1.8)
Location				
Urban	673 992 (84.4)	19 057 (87.5)	110 082 (92.6)	544 854 (82.8)
Rural	119 038 (14.9)	2595 (11.9)	8407 (7.1)	108 036 (16.4)
Missing	5568 (0.7)	135 (0.6)	434 (0.4)	4999 (0.8)
No. of elective noncardiac operations				
1	610 625 (76.5)	11 701 (53.7)	73 524 (61.8)	525 400 (79.9)
2	142 935 (17.9)	6521 (29.9)	31 867 (26.8)	104 556 (15.9)
≥ 3	45 039 (5.6)	3574 (16.4)	13 532 (11.4)	27 933 (4.3)
No. of comorbidities‡				
0	349 326 (43.7)	4447 (20.4)	31 763 (26.7)	313 116 (47.6)
1	222 765 (27.9)	6220 (28.6)	37 176 (31.3)	179 369 (27.3)
2	127 074 (15.9)	5377 (24.7)	27 191 (22.9)	94 506 (14.4)
≥ 3	85 200 (10.7)	4783 (22.0)	19 651 (16.5)	60 766 (9.2)
≥ 5	14 234 (1.8)	960 (4.4)	3142 (2.6)	10 132 (1.5)
Surgery	1 045 896	22 297	133 177	890 422
Surgery type				
Musculoskeletal	266 454 (25.5)	6470 (29.0)	51 323 (38.5)	208 661 (23.4)
Ophthalmologic	156 233 (14.9)	4366 (19.6)	26 788 (20.1)	125 079 (14.0)
Head and neck	84 946 (8.1)	1544 (6.9)	11 053 (8.3)	72 349 (8.1)
Skin and soft tissue	217 134 (20.8)	2810 (12.6)	11 882 (8.9)	202 442 (22.7)
Thoracic	4498 (0.4)	312 (1.4)	529 (0.4)	3657 (0.4)
Other§	316 631 (30.3)	6795 (30.5)	31 602 (26.6)	278 234 (31.2)

Note: SD = standard deviation.
*Except where noted otherwise.
†Echocardiography, exercise stress testing and myocardial perfusion imaging.
‡Alcohol use disorder, asthma, atrial fibrillation, lymphoma, metastatic cancer, nonmetastatic cancer, heart failure, gout, pain, chronic obstructive pulmonary disease, hepatitis B, cirrhosis, dementia, depression, diabetes, epilepsy, hypertension, hyperthyroidism, inflammatory bowel disease, irritable bowel syndrome, multiple sclerosis, myocardial infarction, Parkinson disease, peptic ulcer disease, peripheral vascular disease, psoriasis, arthritis, schizophrenia, constipation and stroke.
§Intra-abdominal, lower urologic/gynecologic, vascular, breast, neurologic, retroperitoneal and anorectal.

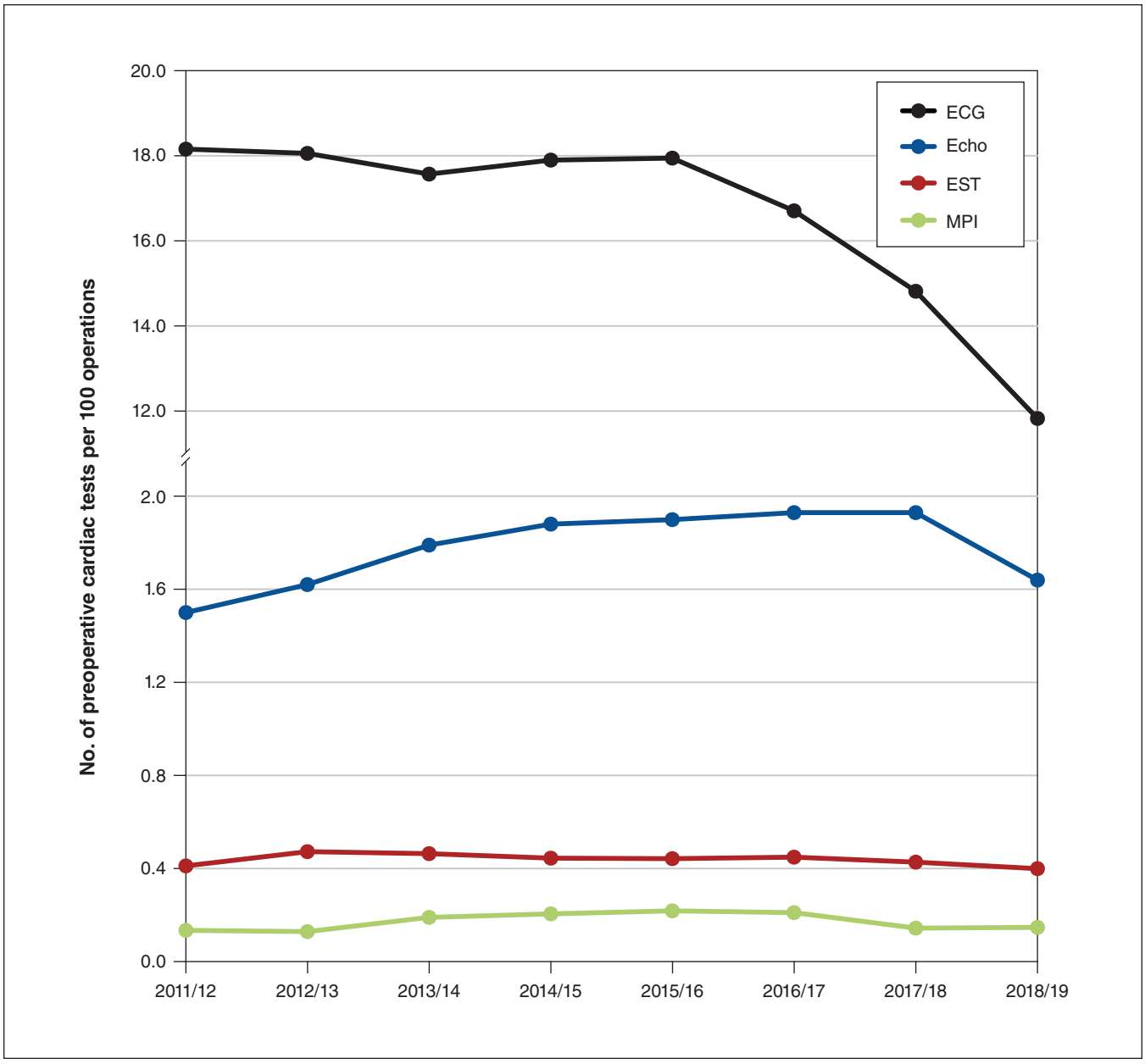

Figure 2: Unadjusted annual number of preoperative noninvasive cardiac tests per 100 operations in the 6 months before surgery, 2011/12–2018/19. Note: ECG = electrocardiography, Echo = echocardiography, EST = exercise stress testing, MPI = myocardial perfusion imaging.

Interpretation

Our study showed generally low use of preoperative advanced noninvasive cardiac tests in Alberta. In our cohort, 2.1% of operations were preceded by such a test, with use associated with patient-level factors. The use of preoperative testing was low during the entire study period, even in the 2 years preceding the 2014 CWC recommendations.[5] However, advanced tests cost the province an estimated $5.5 million between 2011/12 and 2018/19, and ECG, which is not included in the CWC recommendations, cost an additional $6.1 million.

We did, however, note substantial variation by health zone and by patient age in the rate of preoperative testing, which suggests potential opportunities to further reduce low-value testing. Urban patients were more likely to receive a preoperative advanced cardiac test than their rural counterparts. We also observed major variation between the province's urban zones in use of advanced cardiac testing and ECG, with substantially higher ECG use in 1 urban zone and higher use of MPI in the other urban zone. Our analysis was unable to determine the cause of this variation, but it is possible it relates to local departmental practices, differences in practice patterns of individual physicians or greater access to certain tests in urban settings.[25,26] Patient age was another driver of testing, with middle-aged and older patients more likely than younger patients to receive preoperative advanced cardiac testing. This variation may be

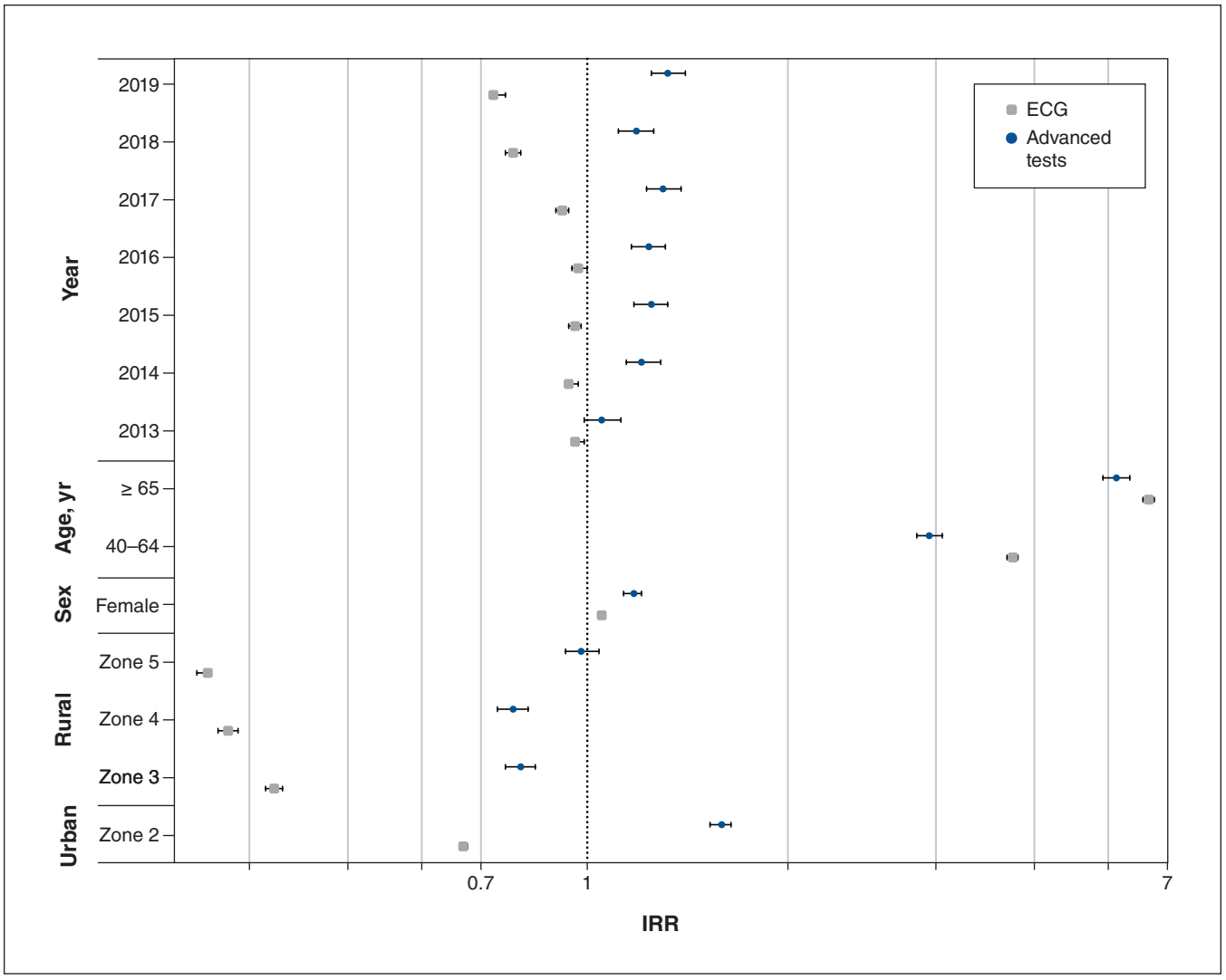

Figure 3: Adjusted incidence rate ratio (IRR) (log scale) of noninvasive cardiac testing with characteristics at the patient and temporal level. Reference groups include year 2011/12, age less than 40 years, male sex and urban zone 1. Error bars represent 95% confidence intervals. Note: ECG = electrocardiography.

driven by clinician misperception of risk related to age and frailty. Overall, we noted a steady decline in ECG use with low use of preoperative advanced tests, which provides less justification for novel campaigns to further reduce preoperative testing.

To contextualize the results of our study, a Canadian study based in Ontario showed echocardiography and EST rates less than 3.0%,[10] in line with our findings of less than 2.0%. Other Canadian studies have shown increased preoperative testing in older patients and those with comorbidities, with variation at the surgery and physician levels, and significant institution-level variation in preoperative testing, respectively.[4,10] Bouck and colleagues[4] examined the frequency of ECG, echocardiography and chest radiography before low-risk operations between 2011 and 2013, and noted a similar proportion (17.9%) of people receiving this type of testing within 60 days of the index procedure. In Alberta, Thanh and colleagues[27] examined the scope of preoperative cardiac testing between 2005 and 2007, which predates the CWC recommendations and our study period. Although they defined a cohort of all patients undergoing elective surgery except those with a cancer, trauma or cardiac diagnosis, they noted that 13.4% of patients undergoing surgery received ECG.

Limitations

In our cohort selection process, we used the RCRI to exclude patients at high risk. The RCRI was not originally designed for use with administrative data, and does not consider clinical findings or laboratory biomarkers (e.g., abnormal heart sounds or symptoms, preoperative NT-proBNP) that may warrant a preoperative cardiac test.[28] Furthermore, we may have underestimated risk because of limitations of administrative data, such as incomplete reporting of diagnoses by physicians in claims and inconsistencies in provincial billing coding. However, our use of the RCRI to risk stratify patients is in concordance with the Canadian Cardiovascular Society preoperative guidelines.[20] In addition, our definition of a low-risk procedure based on RCRI criteria did not consider other individual-level factors that may

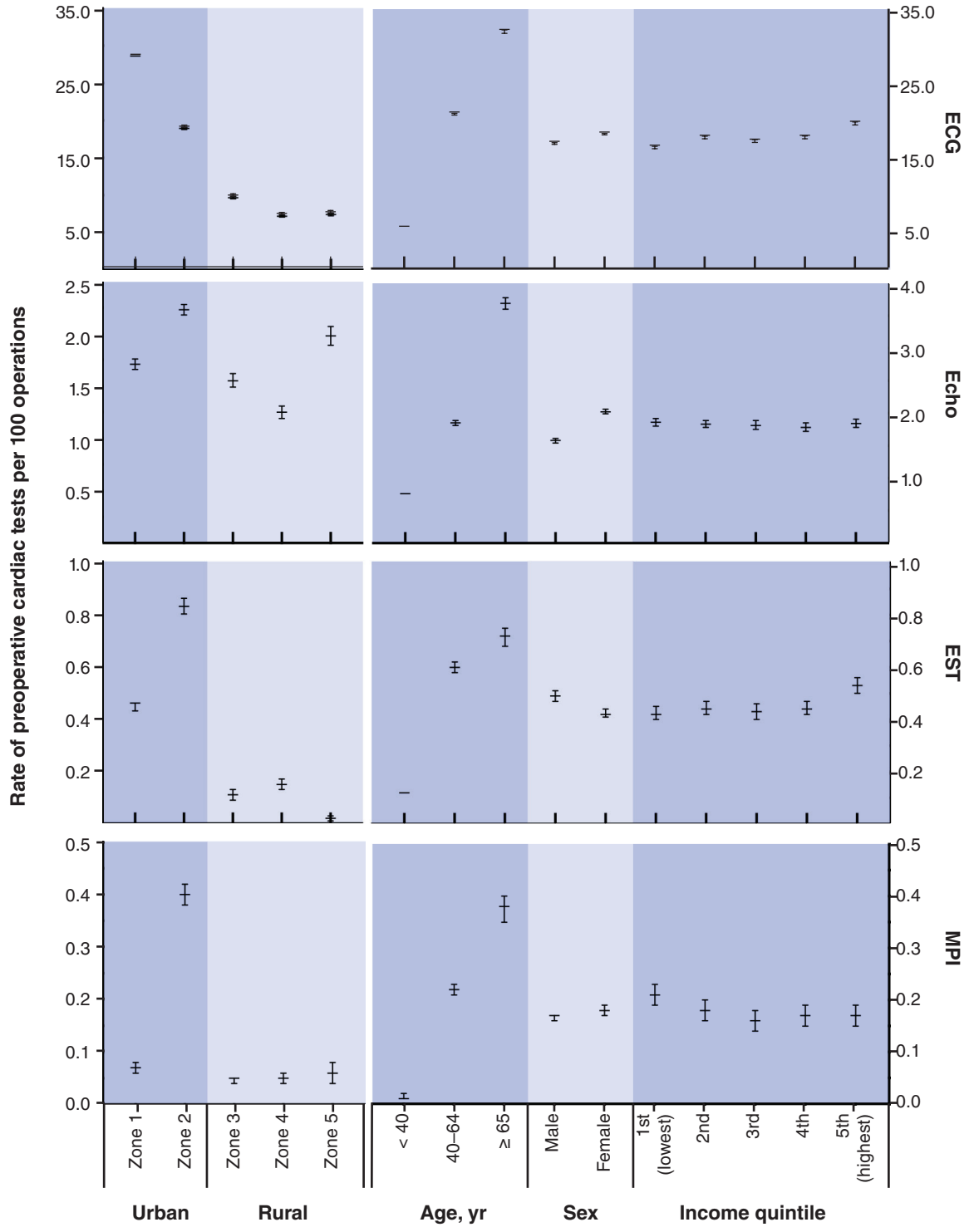

Figure 4: Unadjusted rates of noninvasive cardiac testing by patient and geographic characteristics. Error bars represent 95% confidence intervals. Note: ECG = electrocardiography, Echo = echocardiography, EST = exercise stress testing, MPI = myocardial perfusion imaging.

make preoperative testing appropriate, such as surgical urgency, sex and age, and this may have led to overestimation of low-risk operations. With a high proportion (71.9%) of procedures being outpatient and a large cohort, our study appeared effective in excluding higher-risk operations. However, we were unable to identify patients who had an indication for surgery and could identify only patients who had a completed procedure, which may have resulted in a selection bias. We did not consider contextual factors such as surgeon or local hospital practice patterns that may contribute to imaging use patterns or downstream use of medical resources (e.g., repeat testing, consultation to review imaging, delays in surgical booking date). It is possible the CIs presented here are too narrow because we did not include random effects to account for clustering within surgeon or surgery delivery site. Finally, the 6-month preoperative testing window may have captured tests unrelated to the index procedure. However, we chose this time frame because visual examination of the data suggested most tests were ordered within this period.

Conclusion

This study showed that the rate of preoperative advanced noninvasive cardiac testing (including EST, echocardiography and MPI) was low in healthy adult Albertans undergoing elective noncardiac operations. Although ECG use was higher, use declined over time. However, the high rates of testing among older adults at low risk and variation by zone indicate that ongoing monitoring of these testing metrics and their association with patient experiences may be warranted. Future studies may further evaluate the factors driving variation in testing practice, including exploring drivers of reductions in ECG use and increases in echocardiography use over time.

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Affiliations: Cumming School of Medicine (Zare-Zadeh, Manns, Chew, Harrison, Au), Department of Community Health Sciences (Manns, Harrison, Quinn), Libin Cardiovascular Institute (Manns, Chew) and O'Brien Institute for Public Health (Manns), University of Calgary, Calgary, Alta.

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