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

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Contributor's statement
All authors contributed substantially to the conception, design, and data interpretation of the this study; Manns provided data acquisition and funding for the study; Au conducted the analysis; Zare-Zadeh drafted the manuscript; all authors critically reviewed the manuscript. All authors agreed to act as guartors of the the work.

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None declared.

Disclaimer
This study is based in part on data provided by Alberta Health. The interpretation and conclusions contained herein are those of the researchers and do not necessarily represent the views of the Government of Alberta. Neither the Government of Alberta or Alberta Health express any opinion in relation to this study.

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Background: Choosing Wisely Canada (CWC) recommends avoiding non-invasive advanced cardiac testing (e.g., exercise stress testing, echocardiogram, and MPI) for preoperative assessment in low-risk patients scheduled to undergo non-cardiac surgery. In this study, we assessed the temporal trends in testing since 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 administrative health data from 2011-2019 in Alberta, Canada to identify patients undergoing non-cardiac elective surgery who had non-invasive advanced preoperative cardiac tests within 6 months prior to surgery. We excluded high-risk patients using the Revised Cardiac Risk Index (RCRI) and implemented a Poisson model to assess patient and temporal factors associated with testing.

Results: We identified 1,045,896 non-cardiac elective surgeries performed in 798,599 patients. Of these, only 2.4% of surgeries were preceded by advanced preoperative cardiac testing. Compared to 2012, the incidence of testing increased, and by 2019, patients were 1.3-fold (IRR 95% CI 1.2-1.4) more likely to receive an advanced preoperative test. Urban patients were over twice as likely to receive an advanced preoperative cardiac test compared with their rural counterparts. Preoperative ECG, while not part of the CWC reccomendations, was the most common preoperative cardiac test, preceding 17.1% of surgeries (n= 178,823).

Interpretation: Advanced preoperative cardiac testing was infrequent in low-risk Albertans undergoing low-risk non-cardiac surgeries. Despite CWC recommendations, the use of some tests is increasing and there is substantial variation across geographic areas. Ongoing monitoring is warranted.

Introduction

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 noted over-use of diagnostic and screening tests ranging between 17.9% to 38.7% (4), with 5% of physician visits between 2012-2015 resulting in at least one low-value service (2). Since 2014, Choosing Wisely Canada (CWC) has provided physicians and patients with recommendations to reduce wasteful medical testing (5). CWC calls upon physicians to avoid cardiac testing as a preoperative assessment in low-risk patients scheduled to undergo non-cardiac surgery. Evidence suggests 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 significant 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, where significant variation existed across institutions (10). In Alberta alone, between 2012-2015, preoperative non-invasive cardiac tests before non-cardiac surgeries were estimated at $5.2 million (2). Specific patient and provider factors are associated with the prevalence of low-value care, with patients of higher socioeconomic standing, older age, or greater contact with specialist care being more likely to receive low-value tests (2,4). Physician payment models may also be a driver of health care utilization, with fee-for-service (FFS) increasing utilization of elective visits and procedures compared to other payment models (11,12). Prior work in Ontario has described regional variation and temporal trends in low-value testing which predate the CWC recommendations (10). The objectives of the current study are to describe the trends in low-value testing since the introduction of the CWC reccomendations in 2014, and to describe the patient and provider factors associated with low-value testing.

Methods

Setting, study design, data source

We used data for this retrospective population-based cohort study from the Interdisciplinary Chronic Disease Collaboration (ICDC) data repository, an Alberta-wide database that includes linked administrative health data (provincial laboratory and linked patient-level administrative health data including demographics, vital statistics, physician claims, dispensed prescription medications, hospitalizations, emergency department and ambulatory visits) of >99% of Albertans between 1994-2019. This data repository was cleaned prior to investigator access, fully accessible to our analyst (Au) for cohort creation and analysis, and has been used in multiple observational studies using administrative data (13–17). This study followed the STROBE and RECORD reporting guidelines and was approved by the University of Calgary's Conjoint Health Research Ethics Board (Ethics ID: REB16-1575_REN4).

Cohort selection

Albertans 18 years and older undergoing elective non-cardiac surgery between April 1, 2011 and March 31, 2019 were identified using the Canadian Classification of Health Intervention codes from the Ambulatory Care and Hospitalization data sets (Supplemental Table 1). Surgeries occurring within 6 months after an initial surgery were excluded to eliminate staged procedures or procedures addressing post-operative complications.

The Revised Cardiac Risk Index (RCRI) was used to identify low-risk patients. The RCRI is a validated risk stratification tool suggested for preoperative use by the Canadian Cardiovascular Society (CCS) (18) and has been defined using administrative health data (19). Patients with an RCRI score <1 were considered low-risk. The RCRI includes six variables: history of ischemic heart disease, congestive heart failure, cerebrovascular disease, use of insulin therapy for diabetes, preoperative serum creatinine > 177 µmol/L (> 2.0 mg/dL), and high-risk surgery (intrathoracic, vascular, and intraperitoneal procedures) (18,19). Each patient's RCRI score was calculated for their respective surgery. Medical comorbidities were identified using validated code algorithms within physician claims and hospitalization datasets two years prior to the surgery date (20), while dispension of prescribed insulin, and the most recent serum creatinine (>177 µmol/L) were identified 100 and 91 days prior to the surgery date, respectively.

Outcome

The primary outcome was the number and proportion of low-risk patients having advanced non-invasive preoperative cardiac tests, including exercise stress testing, transthoracic echocardiography, stress myocardial perfusion imaging (MPI), and 12-lead surface

electrocardiogram (ECG) occurring in the six-month period before the index surgery. The first three advanced non-invasive cardiac tests are targeted within the CWC recommendations (5), while ECGs (though not part of the CWC recommendations) were included as an exploratory outcome.

Covariates

Patient characteristics such as age, sex, and rural/urban status were collected from the Interdisciplinary Chronic Disease Collaboration Data Repository registry file (21), and comorbidities were identified by applying validated algorithms to physician claims and hospital data (20). As an indicator of socioeconomic status, we used the neighborhood level income based on postal code. Patient surgery characteristics, including surgical site and type were identified through the Discharge & Abstract Database.

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

Preoperative cardiovascular tests were identified using physician claims data, up-to 6-months before the index surgery date (21) (Supplemental Table 2). The cost of cardiovascular testing was based on the Alberta schedule of medical benefits (for physician claims) and the amount paid by Alberta Health to testing facilities for procedures.

Statistical analysis

We assessed the association of cardiac tests with unadjusted patient, surgical, and physician characteristics by estimating rate ratios (RRs) and testing for significance using chi-square tests. For patients who had a preoperative visit with a specialist, we explored whether use of cardiac testing varied across payment models using chi-square tests. We also estimated the association between time and testing rates adjusted for age, sex, and location to determine the impact of the 2014 CWC recommendations (5). Incidence rate ratios (IRRs) were estimated using a Poisson model with an included patient random effect to account for clustering of multiple procedures for some patients. Missing data were defined as a variable category (only 4 baseline characteristic variables had any missing data). All statistical tests were significant with a p-value of less than 0.05.

Results

Patient characteristics

Overall, the study identified 1,257,285 Albertans undergoing 2,260,710 non-cardiac elective surgeries (Figure 1). After exclusions, the final study cohort consisted of 798,599 low-risk Albertans undergoing 1,045,896 non-cardiac elective surgeries between April 1, 2011 and March 31, 2019 (Figure 1, Table 1). The average age of the study cohort was 47.9 ± 17.0 years, 53.6% (n= 427,891) were female, and 56.1% (n= 449,273) had ≥1 comorbidities. The most common comorbidities were hypertension (24.0%, n=191,397), chronic pain (15.5%, n= 123,511), and depression (10.8 %, n=86,544). Most surgeries took place in an urban setting (84.4%, n=673,992) with most patients having one surgery (76.5%, n= 610,625).

Surgical characteristics

Over the study period, the annual number of surgeries performed in patients with any preoperative risk increased from 219,685 to 243,987. However, among those with low preoperative risk, the number of surgeries decreased from 134,050 to 125,566. The most common types of procedures among the cohort of patients with low preoperative risk were musculoskeletal (25.2%, n=266,799), skin and soft tissue (20.8%, n=217,487), and ophthalmologic (14.9%, n=156,286) (Table 1).

Temporal trends in the primary outcome, use of non-invasive cardiac testing

Echocardiography was the most common advanced preoperative cardiac test (n= 19,042) with annual utilization between 1.5% to 1.9% of low-risk surgeries (Figure 2). Use of exercise stress testing (n= 4,711) remained stable, with preoperative testing before 0.4% of procedures. MPI testing was the least common preoperative test (n= 1,846), performed only before 0.2% of low-risk procedures with consistent use over time. Compared to 2012, the incidence of advanced testing increased during the study, and by 2019, patients were 1.3-fold (IRR 95% CI 1.2-1.4) more likely to receive an advanced preoperative test (Figure 4).

Preoperative ECG, while not included in the CWC recommendations, was the most common preoperative cardiac test (n= 182,331). Annual utilization peaked in 2012 at 18.1% but testing declined to 11.8% of low-risk surgeries by 2019, a decline driven by urban health zones (65.1% (urban) v. 12.3% (rural) decline) (Figure 2, 3).

Factors associated with the use of non-invasive cardiac testing

Patients with 2 or more comorbidities received more cardiac testing as compared to healthier individuals (4.9% v. 1.9%, p <0.001). Age is strongly associated with the incidence of overall preoperative testing. Compared to patients 40 years of age and below, patients 65 years

and older were 6.5-fold more likely to receive a preoperative cardiac test (IRR 95% CI 6.4-6.6, p <0.001). Urban patients were significantly more likely to receive advanced cardiac and ECG tests (Figure 4). We also noted variation across Alberta's geographically based health zones. When compared to zone 1 (baseline), zone 2 patients were 1.6-fold (IRR 95% CI 1.5-1.6, p <0.001) more likely to receive an advanced cardiac test, yet 1.5-fold (IRR 95% CI 1.5-1.5, p <0.001) less likely to receive an ECG.

Of the 117,390 patients who had a preoperative visit to a specialist, the physician's payment model or specialty was not associated with higher incidence of non-invasive cardiac testing, with patients seeing salary-based and FFS physicians experiencing comparable rates of preoperative testing (RR payment model 1.0, 95% CI 0.9-1.0; p <0.001, specialty 1.0, 95% CI 0.9-1.1; p <0.001). At the surgery level, 6.9% of thoracic surgeries were preceded by preoperative testing, while testing in other surgery types ranged between 1.3 to 2.8% of procedures. Procedures were mainly outpatient (71.9%, n=752,758). However, compared to their outpatient counterparts, inpatients received more preoperative testing (3.0% v 1.8%, p <0.001).

Cost of non-invasive testing

Advanced tests cost the province an estimated $5.5 million between 2012 and 2019, with an annual cost of $0.6 million in 2019, not including the cost of followup tests/procedures for false positive tests. Additionally, ECGs were done before 17.4% of surgeries, resulting in a cost of $6.1 million.

Discussion

Our study demonstrates generally low use of advanced preoperative cardiac tests in Alberta, aligned with CWC recommendations. In our cohort, 2.4% of surgeries were preceded by an advanced preoperative cardiac test, with use variable and associated with patient-level factors. Despite this relatively low use, advanced tests cost the province an estimated $5.5 million between 2012 and 2019, and ECGs, which are not included in the CWC recommendation (5), cost an additional $6.1 million.

We did however note substantial health zone-level and age variation in the rate of preoperative testing, suggesting opportunities to reduce low-value testing. Urban patients were over twice as likely to receive an advanced preoperative cardiac test compared with their rural counterparts. Major variation was also noted between the province's urban zones in use of advanced cardiac testing and ECG, with substantially higher use of echocardiography in one urban zone and higher use of nuclear testing 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 (22,23). Patient age is another driver of testing, with middle and old age individuals more likely to receive advanced preoperative cardiac testing (Figure 4). This variation may possibly be driven by a misperception of risk related to age and frailty held by physicians. Overall, we noted a steady decline in ECG use with low use of advanced preoperative 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, reported echocardiogram and exercise stress testing rates below 3.0%, in line with our findings of less than 2.0% (10). Other Canadian studies have noted increased preoperative testing in older and comorbid patients, with variations at the surgery and physician level, and significant institution-level variation of preoperative testing, respectively (4,10). Bouck et al. identified low-risk surgeries and examined the frequency of preoperative ECG, echocardiogram, and chest radiography tests between 2011-2013 (4), noting a similar (17.9%) proportion of people receiving this type of testing within 60 days of the index procedure. Within Alberta, Thanh et al. examined the scope of preoperative cardiac testing between 2005 and 2007, which predates the CWC recommendations and our study period (24). Despite their study defining a cohort with all patients undergoing elective surgery except those with a cancer, trauma, or cardiac diagnosis, they noted that only 13.4% of patient undergoing surgery received an ECG (24).

Our study has important limitations to consider. First, in our cohort selection process, we used the RCRI to exclude high-risk patients. The RCRI was not originally designed for use

with administrative data and does not consider clinical findings which may warrant a preoperative cardiac test (i.e., abnormal heart sounds or symptoms). However, our use of the RCRI to risk strafy patients is in concordance with the CCS preoperative guidelines (18). Secondly, our definition of a low-risk procedure that was based on RCRI criteria did not consider other individual-level factors which may make preoperative testing appropriate, such as surgical urgency, sex, and age, leading to a potential overestimate of low-risk surgeries. However, with a high percentage of procedures being outpatient (71.9%) and a large cohort, our study appeared effective in excluding higher-risk surgeries. Third, the 180-day preoperative testing window may capture tests unrelated to the index procedure. However, we chose this time frame because visual examination of the data suggested most tests were ordered within 180 days of surgery. Despite differences in provincial health care delivery, these population-level results suggest low preoperative testing rates across Canada; however, geographic variation within Alberta suggests geographic variation in testing rates across Canada.

This study demonstrates that the rate of advanced non-invasive preoperative cardiac testing (including exercise stress testing, echocardiogram, and MPI) is low in low-risk Albertans undergoing elective non-cardiac surgeries. While ECG use was noted to be higher, its use was declining over time. Although overall testing was low, the high rates of use among low-risk older adults and variation by zone indicate ongoing monitoring of these testing metrics is warranted and future studies may further evaluate the factors driving this variation in practice.

Data-sharing statement

Study data are owned by the authors and held by the ICDC, a research team at the University of Calgary. Data inquiries should be directed to icdc@ucalgary.ca. Data requests would first have to be made to ICDC. If the request is accepted, a joint application would have to made to our ethics board and if granted, the data can be made available to qualified researchers.

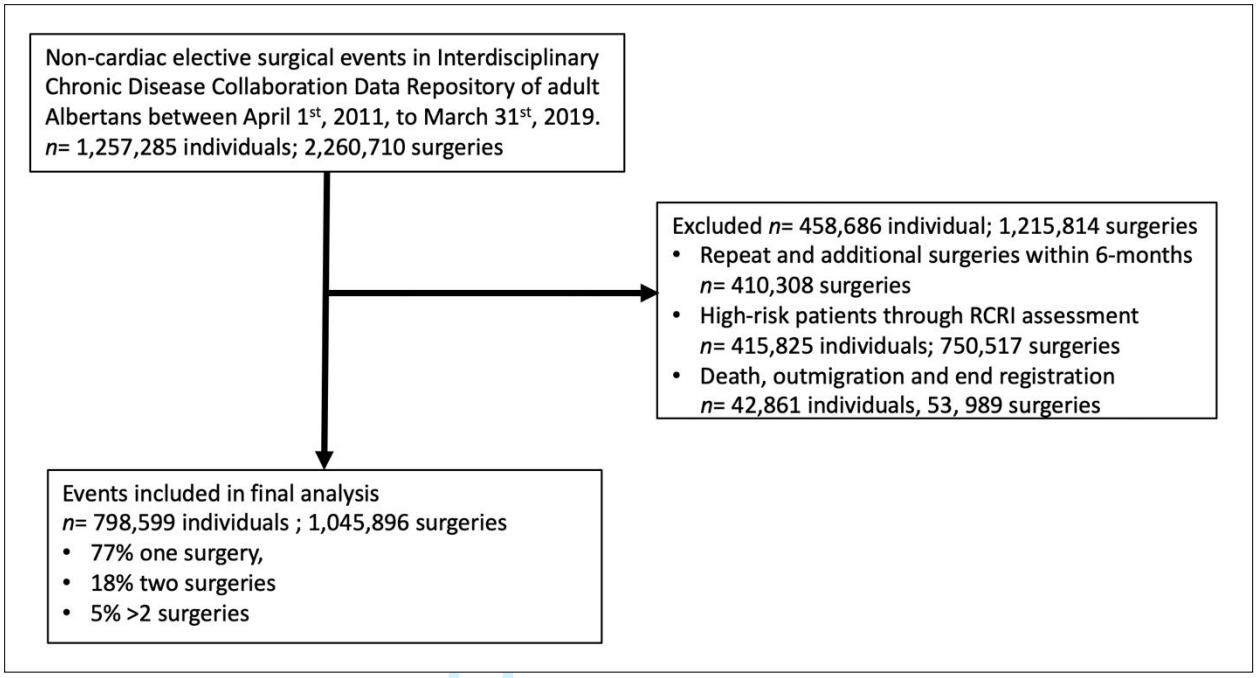

Figure 1: Study flow diagram.

Table 1: Patient and surgical characteristics of low-risk adult Albertans undergoing elective non-cardiac surgery based on preoperative non-invasive cardiac tests within 6-months of index procedure.

Characteristic	Overall	Advanced (+/−ECG)	ECG	No Test
Patient-level (n)	798,599	21,787	118,923	657,889
Age				
Mean ± SD	47.9 (17.0)	58.7 (15.3)	57.7 (14.5)	45.8 (16.8)
<40	36.8 (293,926)	13.2 (2,885)	12.4 (14,785)	42.0 (276,256)
40-49	18.1 (144,349)	13.4 (2,925)	14.9 (17,699)	18.8 (123,725)
50-59	18.9 (151,177)	22.9 (4,987)	26.4 (31,346)	17.5 (114,844)
60-69	14.2 (115,147)	25.3 (5,508)	26.2 (31,123)	11.9 (78,516)
≥ 70	11.4 (90,931)	24.8 (5,412)	20.0 (23,824)	9.4 (61,695)
Missing	0.4 (3,069)	0.3 (70)	0.1 (146)	0.4 (2,853)
Sex				
Female	53.6 (427,891)	58.6 (12,761)	55.8 (66,358)	53.0 (348,772)
Male	46.0 (367,639)	41.1 (8,956)	44.1 (52,419)	46.6 (306,264)
Missing	0.4 (3,069)	0.3 (70)	0.1 (146)	0.4 (2,853)
Income quintile				
1st [lowest]	21.4 (170,481)	21.6 (4,701)	19.9 (23,696)	21.6 (142,084)
2nd	21.0 (167,606)	20.9 (4,553)	21.3 (25,340)	20.9 (137,713)
3rd	19.2 (153,408)	19.0 (4,149)	18.9 (22,471)	19.3 (126,788)
4th	18.4 (146,729)	18.0 (3,923)	18.5 (21,962)	18.4 (120,884)
5th [highest]	18.4 (147,012)	19.0 (4,140)	20.4 (24,243)	18.0(118,629)
Missing	1.6 (13,362)	1.5 (321)	1.0 (1,211)	1.8 (11,831)
Location				
Urban	84.4 (673,993)	87.5 (19,057)	92.6 (110,082)	82.8 (544,854)
Rural	14.9 (119,038)	11.9 (2,595)	7.1 (8,407)	16.4 (108,036)
Missing	0.7 (5,568)	0.6 (135)	0.4 (434)	0.8 (4,999)
Number of non-cardiac elective surgeries				
1	76.5 (610,625)	53.7 (11,701)	61.8 (73,524)	79.9 (525,400)
2	17.9 (142,935)	29.9 (6,521)	26.8 (31,867)	15.9 (104,556)
≥ 3	5.6 (45,039)	16.4 (3,574)	11.4 (13,532)	4.3 (27,933)
Comorbidities				
0 comorbidity	43.7 (349,326)	20.4 (4,447)	26.7 (31,763)	47.6 (313,116)
1 comorbidity	27.9 (222,765)	28.6 (6,220)	31.3 (37,176)	27.3 (179,369)
2 comorbidities	15.9 (127,074)	24.7 (5,377)	22.9 (27,191)	14.4 (94,506)
≥ 3 or 4 comorbidities	10.7 (85,200)	22.0 (4,783)	16.5 (19,651)	9.2 (60,766)
≥ 5 or more comorbidities	1.8 (14,234)	4.4 (960)	2.6 (3,142)	1.5 (10,132)
Surgery type (Overall number of surgeries n= 1,045,896)				

Musculoskeletal	25.5 (266,454)	29.0 (6,470)	38.5 (51,313)	23.4 (208,661)
Ophthalmology	14.9 (156,233)	19.6 (4,366)	20.1 (26,788)	14.0 (125,079)
Head & Neck	8.1 (84,946)	6.9 (1,544)	8.3 (11,053)	8.1 (72,349)
Skin & Soft Tissue	20.8 (217,134)	12.6 (2,810)	8.9 (11,882)	22.7 (202,442)
Thoracic	0.4 (4,498)	1.4 (312)	0.4 (529)	0.4 (3,657)
Other	30.3 (316,631)	30.5 (6,795)	26.6 (31,602)	31.2 (278,234)

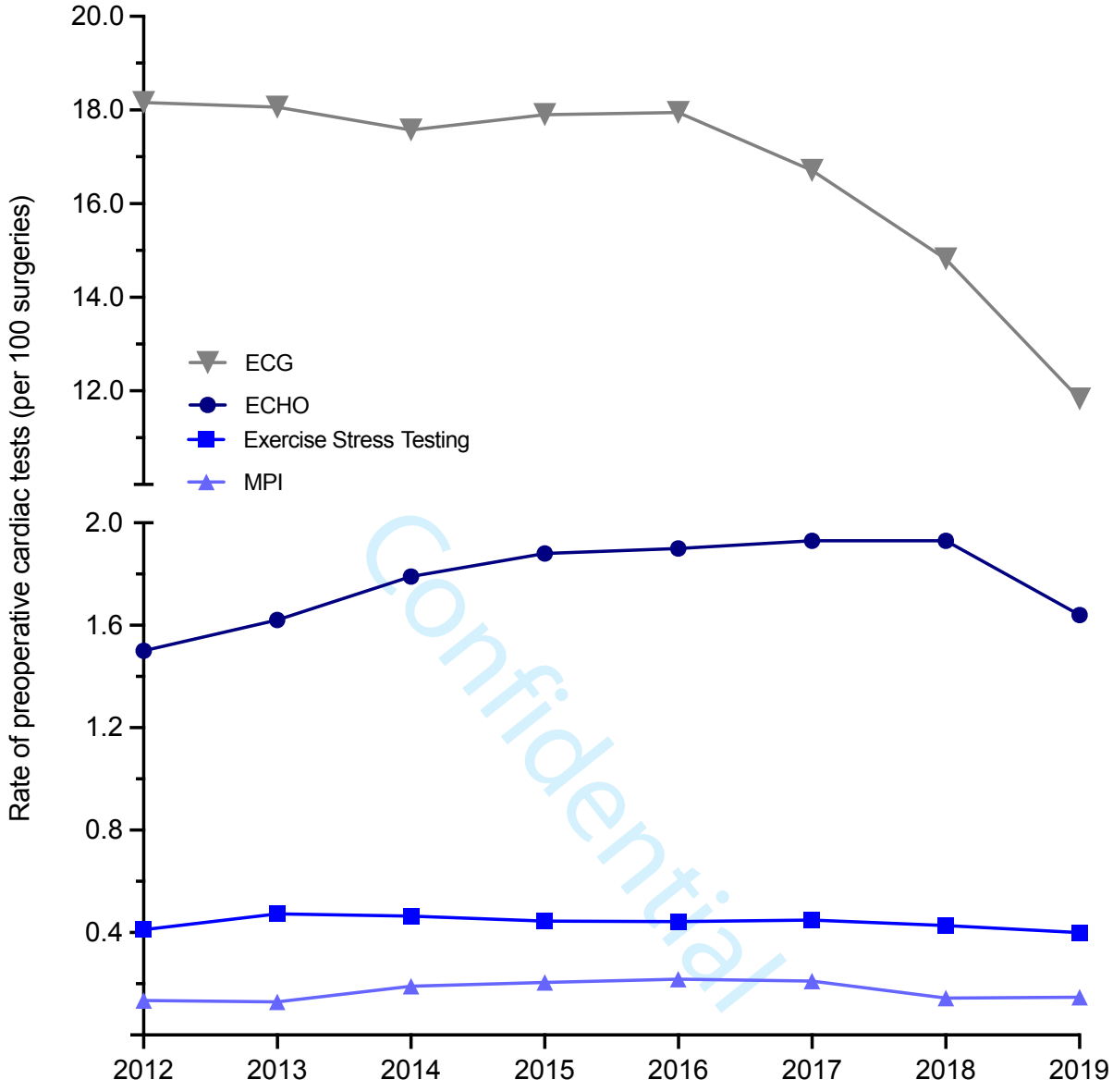

Figure 2: Rate of preoperative non-invasive cardiac tests per 100 surgeries.

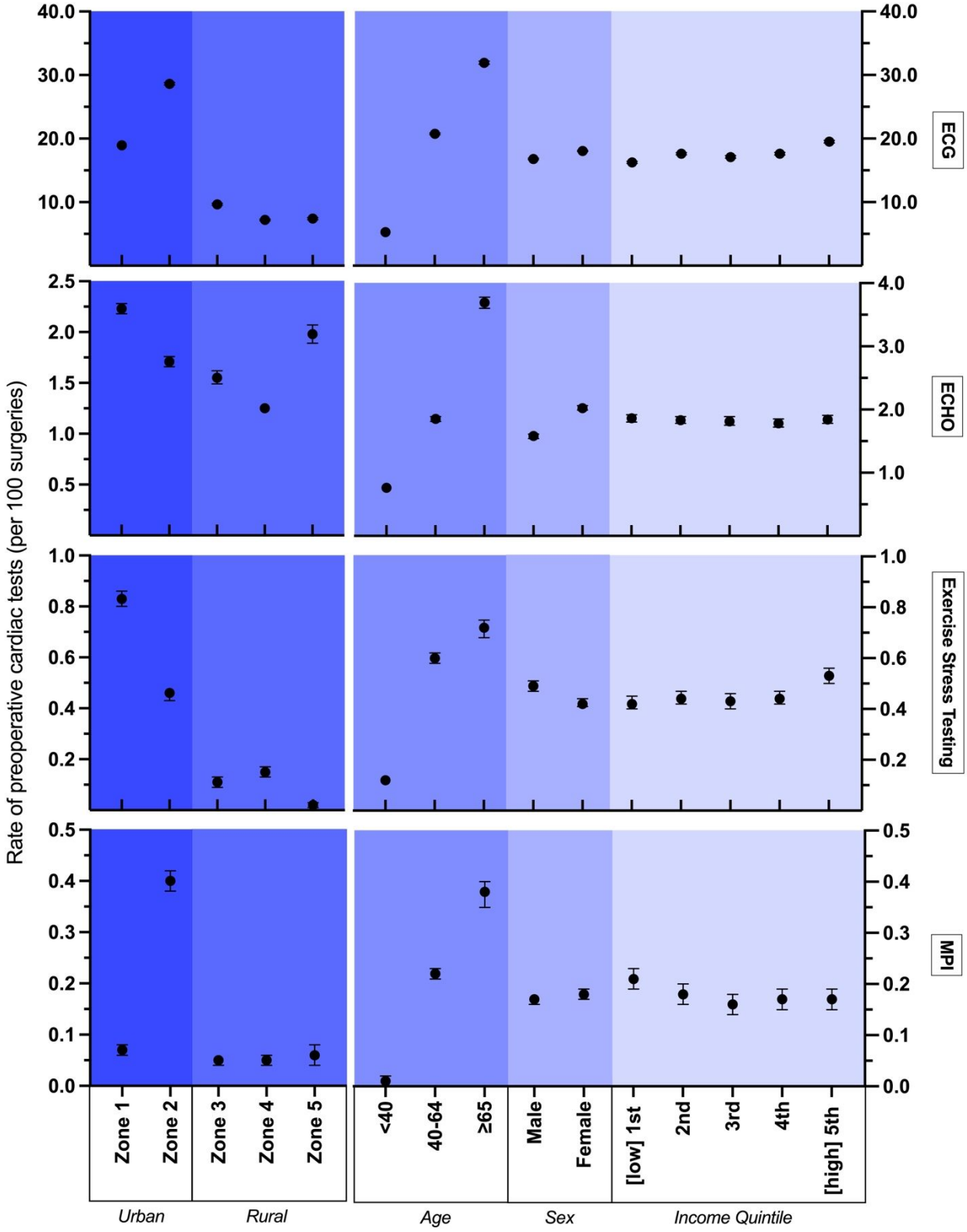

Figure 3: Unadjusted rates of non-invasive cardiac testing by patient and geographic characteristics.

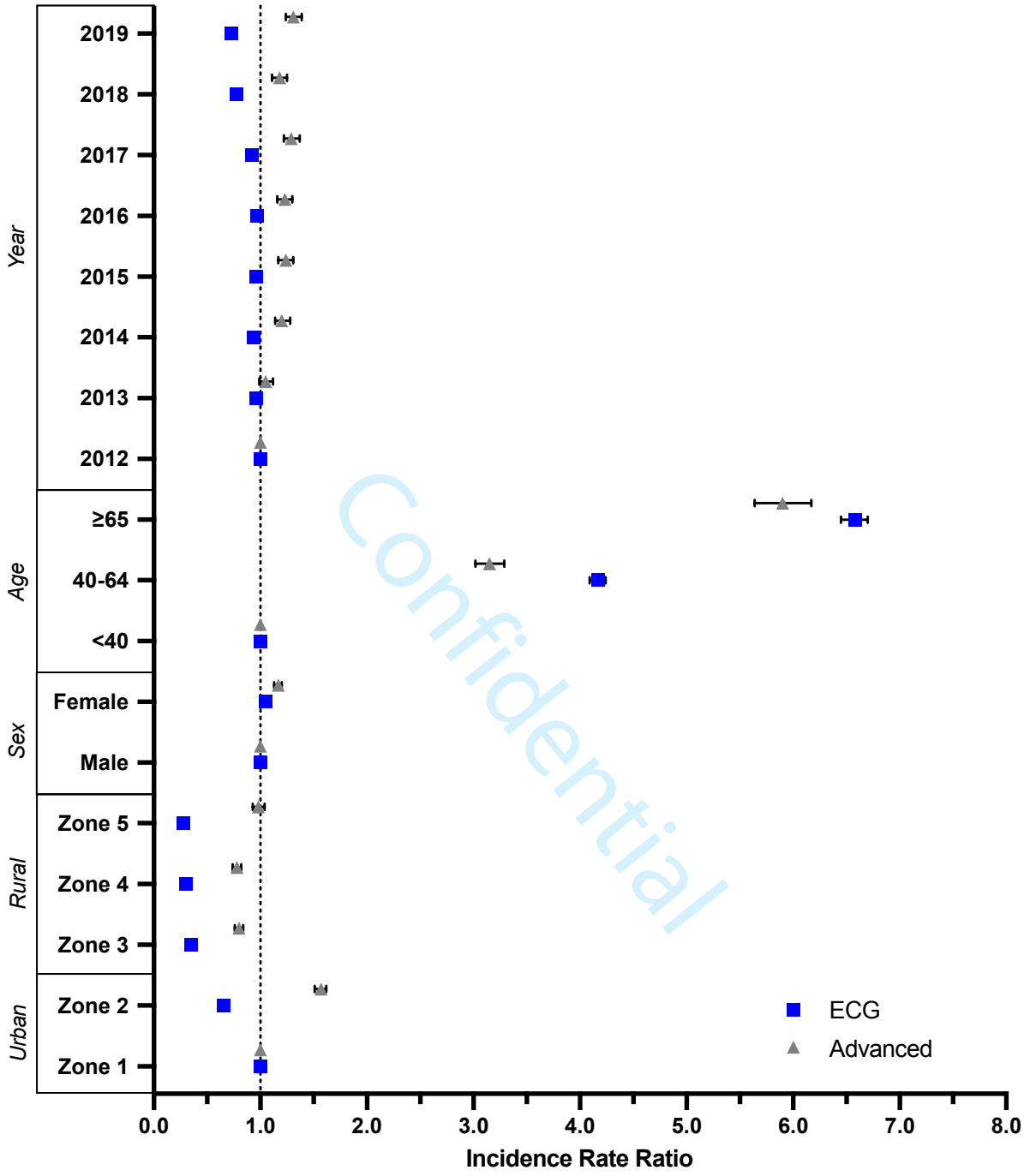

Figure 4: Adjusted incidence ratio of preoperative cardiac testing with characteristics at the patient and temporal level.

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Appendix

I. Supplemental Table 1: Canadian Classification of Health Interventions Codes to identify surgeries.
II. Supplemental Table 2: Physician Claim Procedure Codes to identify pre-operative visits.
III. Supplemental Table 3: Patient factors associated with non-invasive cardiac testing.
IV. Supplemental Table 4: Association of preoperative cardiac testing with characteristics at the patient and temporal level.

Supplemental Table 1: Canadian Classification of Health Interventions Codes to identify surgeries.

Intrathoracic	
Lung lobectomy, thoracoscopy approach	1.GR.87.XX, 1.GR.89.XX, 1.GR.91.XX
VATS lobectomy	1.GT.87.XX, 1.GR.89.XX
Vascular	
Carotid endarterectomy	1.JE.57.LA
Open Abdominal aortic aneurysm repair	1.KA.76.MZ, 1.KA.80.LA
Bypass, arteries of leg NEC	1.KG.76.MI
Bypass, artery with vein	1.KY.76.LA
Intraperitoneal	
Excision partial, stomach	1.NF.87.DG, 1.NF.87.DH, 1.NF.87.DJ, 1.NF.87.DL, 1.NF.87.DQ, 1.NF.87.LA, 1.NF.87.RG, 1.NF.87.RH, 1.NF.87.RJ, 1.NF.87.RK, 1.NF.87.RP 1.NF.87.SH, 1.NF.87.DZ
Reattachment, stomach	1.NF.82.RJ
Excision total, stomach	1.NF.89.GW, 1.NF.89.SG, 1.NF.89.TH
Excision radical, stomach	1.NF.91.RG, 1.NF.91.RJ, 1.NF.91.RP, 1.NF.91.SG
Excision partial, small intestine	1.NK.87.DA, 1.NK.87.DN, 1.NK.87.DP, 1.NK.87.DX, 1.NK.87.DY, 1.NK.87.LA, 1.NK.87.RE, 1.NK.87.RF, 1.NK.87.TF, 1.NK.87.TG
Excision partial, large intestine	1.NM.87.XX
Excision total, large intestine	1.NM.89.XX
Excision radical, large intestine	1.NM.91.XX
Release, small and large intestine	1.NP.72.XX
Excision total, appendix	1.NV.89.XX
Excision partial, spleen	1.OB.87.XX
Excision total, spleen	1.OB.89.XX
Excision partial, pancreas	1.OJ.87.XX
Excision total, pancreas	1.OK89.XX
Excision partial, kidney	1.PC.87.XX
Excision total, kidney	1.PC.89.XX
Excision radical, kidney	1.PC.91.XX
Excision partial, bladder	1.PM.87.XX
Excision total, bladder	1.PM.89.XX
Excision radical, bladder	1.PM.91.XX
Excision radical, prostate	1.QT.91.XX

Supplemental Table 2: Physician Claim Procedure Codes to identify pre-operative visits.

03.01L	Diagnostic interview and evaluation, unqualified
03.01O	Physician to Physician secure E-Consultation, consultant
03.03A	Comprehensive assessment of a patient's condition requiring a complete history, a complete physical examination appropriate to the physician's specialty, an appropriate record and advice to the patient
03.03F	Repeat office visit or scheduled outpatient visit in a regional facility, referred cases only
03.03N	Comprehensive evaluation including completion of forms to determine capacity as defined by the Personal Directives Act (PDA)
03.03FA	Prolonged repeat office or scheduled outpatient visit in a regional facility, referred cases only, full 15 minutes or portion thereof for the first call when only one call
03.04A	Comprehensive assessment of a patient's condition requiring a complete history, a complete physical examination appropriate to the physician's specialty, an appropriate record and advice to the patient
03.04M	Pre-operative history and physical examination in relation to an insured service
03.04N	Home visit, 1st patient, 0700-1700 weekdays (use time modifier)
03.07A	Minor consult
03.07B	Repeat consultation
03.08A	Comprehensive consultation - in office
03.08I	Prolonged cardiology, clinical immunology, endocrinology/metabolism, gastroenterology, hematology, infectious diseases, internal medicine, nephrology, physiatry, medical oncology, neurology, respiratory medicine or rheumatology consultation or visit, full 15 minutes or major portion there off or the first call when only one call is claimed

Supplemental Table 3: Patient factors associated with non-invasive cardiac testing.

	Echocardiogram		Myocardial Perfusion Imaging		Exercise Stress Testing		Electrocardiogram	
	Number of Tests	Test per 100 Surgeries	Number of Tests	Test per 100 Surgeries	Number of Tests	Test per 100 Surgeries	Number of Tests	Test per 100 Surgeries
Age								
<40	2767	0.76 (0.73-0.79)	46	0.01 (0.01-0.02)	421	0.12 (0.10-0.13)	19274	5.29 (5.22-5.37)
40-64	8870	1.85 (1.81-1.89)	1052	0.22 (0.21-0.23)	2860	0.60 (0.58-0.62)	99354	20.76 (20.63-20.88)
≥65	7342	3.69 (3.60-3.78)	748	0.38 (0.35-0.40)	1423	0.72 (0.68-0.75)	63500	31.92 (31.68-32.17)
Sex								
Male	7439	1.58 (1.54-1.61)	800	0.17 (0.16-0.18)	2292	0.49 (0.47-0.51)	79250	16.79 (16.68-16.91)
Female	11540	2.02 (1.99-2.06)	1046	0.18 (0.17-0.19)	2412	0.42 (0.41-0.44)	102878	18.05 (17.94-18.16)
Income Quintile								
1st [lowest]	4168	1.86 (1.80- 1.92)	470	0.21 (0.19-0.23)	947	0.42 (0.40-0.45)	36438	16.26 (16.09-16.42)
2nd	4016	1.83 (1.78-1.89)	388	0.18 (0.16-0.20)	972	0.44 (0.42-0.47)	38664	17.61 (17.44-17.79)
3rd	3632	1.81 (1.75-1.89)	319	0.16 (0.14-0.18)	868	0.43 (0.40-0.46)	34239	17.07 (16.93-17.30)
4th	3404	1.78 (1.72-1.85)	322	0.17 (0.15-0.19)	847	0.44 (0.42-0.47)	33607	17.61 (17.43-17.80)
5th [highest]	3541	1.84 (1.78-1.91)	328	0.17 (0.15-0.19)	1015	0.53 (0.50-0.56)	37455	19.50 (19.30-19.70)
Rurality								
Urban	16493	1.88 (1.85-1.91)	1713	0.20 (0.19-0.20)	4373	0.50 (0.48-0.51)	169248	19.29 (19.20-19.39)
Rural	2433	1.50 (1.45-1.57)	127	0.08 (0.07-0.09)	314	0.19 (0.02-0.22)	12443	7.69 (7.56-7.83)
Zone								
1 (urban)	4890	1.71 (1.66-1.76)	208	0.07 (0.06-0.08)	1308	0.46 (0.43-0.48)	81950	28.63 (28.44-28.83)
2 (urban)	7961	2.23 (2.18-2.28)	1440	0.40 (0.38-0.42)	2971	0.83 (0.80-0.86)	67659	18.95 (18.80-19.09)
3 (rural)	2257	1.55 (1.49-1.62)	66	0.05 (0.04-0.06)	161	0.11 (0.09-0.13)	14047	9.66 (9.51-9.83)
4 (rural)	1950	1.25 (1.19-1.31)	73	0.05 (0.04-0.06)	238	0.15 (0.13-0.17)	11239	7.20 (7.07-7.33)
5 (rural)	1911	1.98 (1.89-2.07)	57	0.06 (0.04-0.08)	22	0.02 (0.01-0.03)	7167	7.42 (7.26-7.59)

Supplemental Table 4: Association of preoperative cardiac testing with characteristics at the patient and temporal level.

	Preoperative test; adjusted IRR* (95% CI)		
	Overall	**ECG**	**Advanced Test**
Sex			
Female	1.07 (1.06-1.08)	1.05 (1.04-1.06)	1.17 (1.13-1.20)
Age			
<40 (reference)	1.00	1.00	1.00
40-64	4.02 (3.95-4.09)	4.17 (4.09-4.24)	3.15 (3.02-3.29)
≥65	6.47 (6.35-6.59)	6.58 (6.45-6.70)	5.90 (5.64-6.17)
Zone			
1 (reference)	1.00	1.00	1.00
2	0.73 (0.72-0.74)	0.66 (0.66 -0.67)	1.57 (1.51-1.62)
3	0.38 (0.38-0.39)	0.35 (0.34-0.36)	0.80 (0.76-0.84)
4	0.33 (0.33-0.34)	0.30 (0.29-0.31)	0.78 (0.74-0.82)
5	0.33 (0.32-0.34)	0.28(0.27-0.28)	0.98 (0.93-1.04) *
Year			
2012 (reference)	1.00	1.00	1.00
2013	0.97 (0.95-1.00)	0.96 (0.95-0.99)	1.05 (0.99-1.12) *
2014	0.97 (0.95-0.99)	0.94 (0.93-0.97)	1.20 (1.14-1.28)
2015	0.98 (0.97-1.00) *	0.96 (0.94-0.98)	1.24 (1.17-1.31)
2016	1.00 (0.98-1.02) *	0.97 (0.95-1.00)	1.23 (1.16-1.30)
2017	0.95 (0.94-0.98)	0.92 (0.90-0.94)	1.29 (1.22-1.37)
2018	0.82 (0.80-0.84)	0.78 (0.76-0.80)	1.18 (1.11-1.25)
2019	0.79 (0.78-0.81)	0.73 (0.72-0.76)	1.31 (1.24-1.39)

Note: CI= confidence interval, IRR= incidence rate ratio. *All results are significant ($p < 0.05$), unless indicated.