



Original Article

# Patient- and Physician-Level Factors Associated With Adherence to C-CHANGE Recommendations in Primary Care Settings in Ontario

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## ABSTRACT

**Background:** We previously found large variation among family physicians in adherence to the Canadian Cardiovascular Harmonization of National Guidelines Endeavour (C-CHANGE). We assessed the role of patient- and physician-level factors in the variation in adherence to recommendations for managing cardiovascular disease risk factors. **Methods:** We conducted a retrospective study using multilevel logistic regression analyses with the Electronic Medical Record Administrative data Linked Database (EMRALD) housed at ICES in Ontario. Five quality indicators based on C-CHANGE guidelines were modelled. Effects of clustering and between-group variation, patient-level (socio-demographics, comorbidities) and physician-level characteristics (demographic and practice information) were assessed to determine odds ratios of receiving C-CHANGE recommended care.

## RÉSUMÉ

**Contexte :** Nous avons déjà constaté que l'observance des recommandations canadiennes en matière de prévention et de gestion des maladies cardiovasculaires de l'initiative C-CHANGE (*Canadian Cardiovascular Harmonization of National Guidelines Endeavour*) varie beaucoup d'un médecin de famille à l'autre. Nous avons évalué l'effet de caractéristiques des patients et des médecins sur l'observance de ces recommandations pour la gestion des facteurs de risque de maladies cardiovasculaires. **Méthodologie :** Nous avons mené une étude rétrospective reposant sur des analyses de régression logistique multiniveaux au sein de la base de données liée aux dossiers médicaux électroniques EMRALD (*Electronic Medical Record Administrative data Linked Database*) qui se trouve à l'ICES, en Ontario. Nous avons modélisé cinq

Cardiovascular disease (CVD) and its risk factors remain highly prevalent in Canada,<sup>1</sup> including substantial levels of obesity, diabetes, hypertension, and dyslipidemia.<sup>2</sup> Family physicians (FPs) have an important role in providing high-

quality care to help prevent, manage, and improve CVD. To this end, the Canadian Cardiovascular Harmonized National Guidelines Endeavour (C-CHANGE) has amalgamated 9 of Canada's cardiovascular-focused clinical practice guidelines to produce a harmonized set of key recommendations for primary care practitioners. In a previous study, we mapped 23 cardiovascular care recommendations to evaluable quality indicators (QIs) from the 2014 C-CHANGE guidelines.<sup>3,4</sup> The study used these QIs and primary care electronic medical records (EMRs) to measure adherence to the C-CHANGE guidelines. Despite the availability of guidelines based on best available evidence,<sup>3,5,6</sup> our results showed variable quality in several aspects of cardiovascular care in primary care settings in Ontario.

Received for publication May 11, 2020. Accepted July 11, 2020.

**Ethics Statement:** Ethics approval was obtained from the institutional review board at Sunnybrook Health Sciences Centre, Toronto, Ontario, Canada.

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See page 575 for disclosure information.

**Results:** In all, 324 Ontario physicians practicing in 41 clinics who provided care to 227,999 adult patients were studied. We found significant variation in quality indicators, with 15% to 39% of the total variation attributable to nonpatient factors. The largest variation was in performing 2-hour plasma glucose testing in prediabetic patients. Patient-level factors most frequently associated with recommendation adherence included sex, age, and multi-comorbidities. Women were more likely than men to have their body mass index measured, and their blood pressure controlled, but less likely to receive antiplatelet medications and liver-enzyme testing if overweight or obese.

**Conclusions:** The majority of variations in adherence were attributable to patient attributes, but a substantial proportion of unexplained variation was due to differences among physicians and clinics. This finding may signal suboptimal processes or structures and warrant further investigation to improve the quality of primary care management of cardiovascular disease in Ontario.

indicateurs de la qualité en nous basant sur les recommandations de l'initiative C-CHANGE. Nous avons évalué les effets de regroupement, de la variation entre les groupes, des caractéristiques des patients (données sociodémographiques, maladies concomitantes), des caractéristiques des médecins (données démographiques et renseignements sur la pratique) afin de déterminer les risques relatifs approchés associés aux soins conformes aux recommandations de l'initiative C-CHANGE.

**Résultats :** L'étude a porté sur un total de 324 médecins ontariens pratiquant dans 41 cliniques et ayant prodigué des soins à 227 999 adultes. Nous avons observé une variation significative entre les indicateurs de qualité, et de 15 % à 39 % de la variation totale était attribuable aux caractéristiques non reliées aux patients. La variation la plus importante concernait le test d'hyperglycémie provoquée (2 heures) chez les patients prédiabétiques. Les caractéristiques des patients qui étaient le plus souvent associées à l'observance des recommandations étaient le sexe, l'âge et la présence de multiples maladies concomitantes. L'indice de masse corporelle et la pression artérielle étaient plus souvent mesurés chez les femmes que chez les hommes, mais les femmes étaient moins susceptibles de recevoir un traitement antiplaquettaire ou de subir une analyse des enzymes hépatiques si elles étaient en surpoids ou obèses.

**Conclusions :** La plus grande partie des variations dans l'observance des recommandations était liée aux caractéristiques des patients, mais une proportion importante de variations injustifiées était associée aux différences entre les médecins et entre les cliniques. Ces observations pourraient indiquer la présence de processus ou de structures sous-optimales et méritent une analyse approfondie qui permettra d'améliorer la qualité de la prise en charge des maladies cardiovasculaires par les médecins de soins primaires en Ontario.

Adherence to QIs derived from previous iterations of C-CHANGE guidelines has been associated with fewer cardiovascular events.<sup>7,8</sup> To further study CVD care and identify characteristics of populations that may benefit from future guideline implementation efforts, we assessed patterns of clinical practice in the primary care setting. In this study, we focused on gaps in care, choosing specific QIs with a low level of adherence and a high level of variance at the FP level. We also set out to determine if there were patient or FP characteristics associated with patients receiving guideline-adherent care.

## Methods

### Data sources and study population

We conducted a retrospective cross-sectional study of factors related to guideline adherence using the Electronic Medical Record Administrative data Linked Database (EMRALD) held at ICES (formerly the Institute for Clinical Evaluative Sciences) in Ontario, Canada.<sup>9,10</sup> We based the analysis on a study cohort previously described and derived from EMRALD. As a measure to ensure optimal data quality and completeness, we excluded data contributed by FPs who had used the Telus PS Suite EMR for less than 18 months.<sup>11,12</sup> We further excluded the data of patients under the age of 18 years, as well as patients without a valid postal code, as this precluded the collection of neighbourhood income-quintile data. The data were de-identified and linked,

using unique encoded identifiers, and analyzed at ICES. ICES is an independent, non-profit research institute whose legal status under Ontario's health information privacy law allows it to collect and analyze healthcare and demographic data, without consent, for health system evaluation and improvement. Ethics approval was obtained from the institutional review board at Sunnybrook Health Sciences Centre, Toronto, Ontario, Canada.

### Outcome variables—C-CHANGE QIs

We evaluated all of the previously measured C-CHANGE QIs<sup>4</sup> for adherence at the patient and FP levels and selected one QI for each of the 5 C-CHANGE guideline categories: body habitus; diagnostic strategy; risk factors; treatment target; pharmacologic therapies. Among the QIs that are applicable for adults and remained in the updated 2018 C-CHANGE guidelines, we selected 5 QIs in each category to evaluate further based on the criteria of low level of adherence (based on lowest ranking of adherence in each of the 5 categories at the population level) and high level of variance at the FP level (based on largest interquartile range of adherence among FPs when the adherence was calculated for each FP's roster). These QIs are summarized in Table 1.

### Explanatory variables

The following patient and FP characteristics were examined to reveal their association with guideline-based care. Patient attributes: These included age groups, sex, rurality of

**Table 1. Description of modelled quality indicators (QIs)**

QI	Domain	Original C-CHANGE recommendation	Adapted QI	Inclusion/exclusion criteria
1. BMI recorded	Body habitus	Height, weight, and waist circumference should be measured, and BMI calculated, for all adults (CABPS; OC)	Patient has their BMI recorded in the EMR: % of adults with a BMI recorded (lookback: duration of EMR record); height, weight, and waist circumference should be measured, and BMI calculated, for all adults	Include: All patients meeting study criteria
2. Liver-enzyme tests in patients with high BMI	Diagnostic strategies	Additional investigations, such as liver-enzyme tests, and sleep studies (when appropriate), to screen for and exclude other common overweight/obesity-related health problems (CABPS; OC)	Patient with a BMI $\geq 25.0$ kg/m <sup>2</sup> has had a liver-enzyme test in the last 3 years: % of patients with a BMI $\geq 25.0$ , with a liver test (lookback: 3 y); additional investigations, such as liver-enzyme tests, urinalysis, and sleep studies (when appropriate), to screen for and exclude other common overweight/obesity-related health problems	Include: Patients with a BMI measurement Exclude: Patients whose most recent BMI measurement is $\leq 25$ kg/m <sup>2</sup>
3. 2hPG	Risk-factor screening	Testing with 2hPG in a 75 g OGTT may be considered in individuals with FPG 6.1-6.9 mmol/L and/or A1C 6.0%-6.4% in order to identify individuals with IGT or diabetes (DC)	Patient who has not been previously diagnosed with diabetes who has had FPG of 6.1-6.9 mmol/L and/or HbA1c of 6.0%-6.4%, has received a 2hPG OGTT: % of patients age $\geq 18$ y with FPG 6.1-6.9 and/or HbA1c 6.0%-6.4%, and a 2hPG test (lookback: duration of EMR record); testing with 2hPG in a 75 g OGTT should be undertaken in individuals with FPG 6.1-6.9 mmol/L and/or A1c 6.0%-6.4% in order to identify individuals with IGT or diabetes	Include: Patients with FPG of 6.1-6.9 mmol/L and/or HbA1c of 6.0%-6.4% Exclude: Patients with diabetes
4. BP target for patients with diabetes	Treatment targets	Persons with diabetes mellitus should be treated to attain systolic BP of $< 130$ mm Hg and diastolic BP of $< 80$ mm Hg (these target BP levels are the same as BP treatment thresholds; DC)	Patient with diabetes who has a most recent BP of $< 130/80$ mm Hg in the last year: % of patients with diabetes with most recent BP $< 130/80$ mm Hg (lookback: 1 y); persons with diabetes mellitus should be treated to attain systolic BPs $< 130$ mm Hg and diastolic BPs $< 80$ mm Hg (these target BP levels are the same as the BP treatment thresholds)	Include: Patients with a BP reading from within 1 y of date of data collection Exclude: Patients without diabetes
5. Antiplatelet medication	Pharmacologic and/or procedural therapy for CVD risk-reduction coronary	Antiplatelet therapy: all patients with ischemic stroke or transient ischemic attack should be prescribed antiplatelet therapy for secondary prevention of recurrent stroke, unless there is an indication for anticoagulation	Patient with CAD who has a prescription for an antiplatelet agent in the last 18 mo: % of patients with CAD and a prescription for antiplatelet agents (lookback: 18 mo); patients with documented CAD, in absence of specific contraindications or documented intolerance, should be treated with antiplatelet agents; for patients with a history of chronic stable angina, remote PCI, or CABG, ASA (75 mg P.O. to 162 mg) P.O. daily indefinitely	Exclude: Patients without CAD

ASA, acetylsalicylic acid; BMI, body mass index; BP, blood pressure; CABG, coronary artery bypass grafting; CABPS, Canadian Association of Bariatric Physicians and Surgeons; CAD, coronary artery disease; C-CHANGE, Canadian Cardiovascular Harmonization of National Guidelines Endeavour; CVD, cardiovascular disease; DC, Diabetes Canada; EMR, electronic medical record; FPG, fasting plasma glucose; HSF, Heart and Stroke Foundation; IGT, impaired glucose tolerance; OC, Obesity Canada; OGTT, oral glucose tolerance test; PCI, percutaneous coronary intervention; 2hPG, 2-hour plasma glucose test.

residence (rural vs non-rural), socioeconomic status (approximated by neighbourhood income quintiles), comorbidity index (based on resource utilization bands calculated from the Johns Hopkins Adjusted Clinical Group Case Mix System<sup>13</sup>), body mass index (BMI) category, and medical history. Patients' medical history was either based on previously validated

algorithms (presence or absence of atrial fibrillation,<sup>14</sup> chronic kidney disease (CKD),<sup>9</sup> coronary artery disease [CAD],<sup>10</sup> diabetes,<sup>15,16</sup> hypertension,<sup>9</sup> stroke,<sup>17</sup> or congestive heart failure [CHF]<sup>18</sup>).

FP attributes: These covariates included number of years in practice (every 5 years beyond 10), sex, place of medical

training (Canada vs international medical graduate), and the size of their patient roster (measured per 100 patients for roster sizes of > 500).

## Analysis

Statistical models were constructed using EMR and administrative data to determine any provider-specific or patient-specific characteristics that correlate with provision or receipt of C-CHANGE recommendations. Nonindependent observations and clustering of the data were accounted for by creating a 3-level nested model with patients (level 1) nested within FPs' rosters (level 2) who were nested in the clinics where they practiced (level 3). The 3-level hierarchical cross-sectional analysis fitted univariate dichotomous outcomes for each of the five QIs individually to explore the associations between the receipt of the C-CHANGE recommendations and explanatory variables. Four models were created for each of the 5 QIs.

Following the hierarchical generalized linear framework, and in order to calculate the group-level variation (intraclass correlation),<sup>19-21</sup> models were first fitted in (i) a naïve (empty) model without any covariates (intercept-only) to assess for group effects at each level and to be used as a reference for comparing the size of contextual variation in rates of receiving recommended care. The naïve model shows the probability of patients meeting the QI criteria as a function of the FP or clinic to which the patient is rostered (accounted for by FP-level and clinic-level random intercepts). Hierarchical models were developed by sequentially adding the level-1 or level-2 explanatory variables as fixed effects to the empty models. This included (ii) a model including only patient attributes; (iii) a model including only FP attributes; and (iv) the complete model with patient and physician attributes. We estimated the effect of patient-level characteristics in the outcomes with group-specific random effects and random intercepts at the FP level. This approach accounted for the clustered nature of the data and allowed us to explore contextual effects on the receipt of recommended care. Bias-corrected Akaike's information criteria<sup>22</sup> were used for comparing and identifying the model that best accounted for the data.

We measured group-level heterogeneity and the magnitude of the effect of clustering by calculating the variance partition coefficients and the median odds ratios (MORs). The variance partition coefficient estimates the proportion of the total variability observed that can be explained by differences among patients, FP rosters, or clinics. The MOR indicates how much a patient's odds of being provided the recommended care would increase if the patient moved to a different FPs roster or clinic that had higher odds of providing the care. A higher MOR (> 1) means there is more variation among different clusters (FP rosters or clinics). This analysis was repeated for the 5 dichotomous outcomes.

We assessed the interaction of patient and FP sex according to the composition of the dyads, to explore their effects on the QIs. Unadjusted effects were calculated by performing  $\chi^2$  tests on the different dyads (female patient—female FP, female patient—male FP, male patient—female FP, male patient—male FP). Unadjusted effects were also compared between sex-concordant dyads (female patient cared for by a female FP or male patient cared for by a male FP) and sex-discordant dyads. We calculated the adjusted predicted probabilities (and standard

errors) of meeting the QI criteria for each of the patient—FP dyads while accounting for all other explanatory variables included in the full generalized linear mixed model. The inverse links of the least-square means with observed margins were used to calculate the adjusted predicted probabilities.

We analyzed coded data using SAS v9.2 (SAS Institute Inc, Cary, NC) and Microsoft Structured Query Language 2012 (Microsoft Corp, Redmond, WA). The hierarchical generalized linear mixed models with random effects were fitted with SAS PROC GLIMMIX with the Laplace method, logit link function, and Cholesky parameterization. The magnitudes of effects were exponentiated and measured as odds ratios (ORs) with corresponding 2-sided 95% confidence intervals (CIs). Associations were considered significant when the *P*-value was < 0.05.

## Results

### Study population characteristics

Our study population included 227,999 patients rostered to 324 FP practicing in 41 clinics. In-depth descriptions of the study population and study FP and how the QIs were measured at the patient level were provided in a previous study.<sup>4</sup> The study population's age distribution, level of comorbidity according to resource utilization bands, and prevalence of chronic conditions for each of the 5 QIs, as well as FP attributes, are summarized in Table 2.

### Variation in meeting criteria of QIs due to group effects

The measurements of components of variance and heterogeneity in the probability of patients meeting the 5 C-CHANGE QIs are summarized in Table 3. These include the proportion of total variability in QIs being met that were attributable to FP or clinic attributes, the median ORs at the FP and clinic level, and model-fit statistics for each of the 4 models corresponding to one of the 5 QIs.

Patient-level differences contributed the most to determining whether the QI criteria were met in all of the indicators. However, the hierarchical logistical multilevel regression models showed that the probability of C-CHANGE adherent care was strongly influenced by both patient and FP characteristics in all instances. In addition, there were significant amounts of variability in the odds of patients receiving C-CHANGE adherent care among FP rosters and clinics, with 15% or more of the proportion of total variability being attributable to nonpatient factors (FP- or clinic-level differences). The highest level of variability due to nonpatient factors was found in whether patients received a 2-hour plasma glucose test after receiving haemoglobin A1c or fasting plasma glucose test results that indicated prediabetes. The lowest level of variability among groups at both the FP and clinic levels was found in the outcome-based indicator of whether patients with diabetes achieved blood pressure targets of < 130 over 80 mm Hg.

Median ORs at the FP and clinic levels are depicted at the bottom of Figures 1 to 5 to show the variability due to group-level heterogeneity relative to measured attributes. The MORs were substantial at both the FP and clinic levels, ranging from 1.6 to 2.9, which suggests that there was unexplained

**Table 2. Characteristics of patients and FPs included in the analysis of factors associated with meeting 5 different C-CHANGE quality indicators**

Characteristics	Quality indicator*									
	1. BMI recorded		2. Liver-enzyme test		3. 2hPG		4. BP < 130/80 mm Hg, DM		5. Antiplatelet treatment	
Number of patients	N	%	n	%	n	%	n	%	n	%
Total number of patients	227,999	100.0	98,687	100.0	23,297	100.0	18,309	100.0	10,327	100
Quality indicator met	153,387	67.3	63,463	48.2	2218	9.2	6985	38.2	4934	47.7
Sex										
Female	129,420	56.8	53,691	54.4	12,134	52.1	8660	47.3	3468	33.6
Male	98,579	43.2	44,996	45.6	11,163	47.9	9649	52.7	6859	66.4
Age group, y										
18 to 34	56,989	25.0	15,277	15.5	542	2.3	468	2.6	11	0.1
35 to 49	63,868	28.0	26,917	27.3	3345	14.4	2191	12.0	414	4.0
50 to 64	61,557	27.0	32,559	33.0	9112	39.1	6603	36.1	2807	27.2
65 and over	45,585	20.0	23,934	24.3	10,298	44.2	9047	49.4	7095	68.7
Residence location										
Rural	45,634	20.0	23,068	23.4	5651	24.3	4749	25.9	2806	27.2
Urban	182,365	80.0	75,619	76.6	17,646	75.7	13,560	74.1	7521	72.8
Income quintile										
1st (lowest)	39,380	17.3	16,660	16.9	4174	17.9	4064	22.2	2064	20.0
2 <sup>nd</sup>	40,680	17.8	18,001	18.2	4231	18.2	3795	20.7	2007	19.4
3 <sup>rd</sup>	41,993	18.4	18,765	19.0	4357	18.7	3379	18.5	1838	17.8
4 <sup>th</sup>	47,567	20.9	21,158	21.4	4873	20.9	3498	19.1	2004	19.4
5th (highest)	58,379	25.6	24,103	24.4	5662	24.3	3573	19.5	2414	23.4
Past medical history										
Atrial fibrillation	5818	2.6	3184	3.2	1526	6.6	1422	7.8	1469	14.2
Chronic kidney disease	9382	4.1	5348	5.4	2337	10.0	2884	15.8	2032	19.7
Congestive heart failure	5954	2.6	3003	3.0	1377	5.9	1951	10.7	2384	23.1
Coronary artery disease	10,327	4.5	6030	6.1	2611	11.2	3194	17.4	10,327	100.0
Diabetes	21,663	9.5	14,967	15.2	na	na	18,309	100.0	3603	34.9
Hypertension	46,507	20.4	28,556	28.9	10,172	43.7	11,483	62.7	6142	59.5
Stroke	5093	2.2	2554	2.6	1,126	4.8	1270	6.9	1121	10.9
BMI										
Normal ( $\leq 25 \text{ kg/m}^2$ )	na	na	na	na	3520	15.1	2007	11.0	1387	13.4
Overweight (25-30 $\text{kg/m}^2$ )	na	na	51,948	52.6	6596	28.3	4629	25.3	2880	27.9
Obese ( $> 30 \text{ kg/m}^2$ )	na	na	46,739	47.4	7977	34.2	8688	47.5	3145	30.5
Missing value	na	na	na	na	5204	22.3	2985	16.3	2915	28.2
RUB <sup>†</sup>										
0 (lowest utilization)	12,610	5.5	3778	3.8	514	2.2	20	0.1	85	0.8
1	11,542	5.1	3888	3.9	424	1.8	32	0.2	31	0.3
2	39,912	17.5	15,364	15.6	2509	10.8	1414	7.7	333	3.2
3	116,197	51.0	54,063	54.8	13,116	56.3	10,239	55.9	4417	42.8
4	34,590	15.2	15,320	15.5	4177	17.9	3689	20.2	2906	28.1
5 (highest utilization)	13,148	5.8	6274	6.4	2557	11.0	2915	15.9	2555	24.7
Number of FPs	i	%	i	%	i	%	i	%	i	%
Total number of FPs (i, %)	324		324		324		324		321	
Doctor's sex (i, %)										
Female	182	56.2	182	56.2	182	56.2	182	56.2	179	56.8
Male	142	43.8	142	43.8	142	43.8	142	43.8	142	44.2
Medical training location (i, %)										
Canada	294	90.7	294	90.7	294	90.7	294	90.7	291	90.7
International	30	9.3	30	9.3	30	9.3	30	9.3	30	9.3
FP Years in practice (mean, SD)	20.8	11.3	20.8	11.3	20.8	11.3	20.8	11.3	20.9	11.3
Doctor's roster size (all ages, mean, SD)	882.3	498.6	882.3	498.6	882.3	498.6	882.3	498.6	888.8	496.5
Number of clinics (j)	j = 41		j = 41		j = 41		j = 41		j = 41	

BMI, body mass index; BP, blood pressure; C-CHANGE, Canadian Cardiovascular Harmonization of National Guidelines Endeavour; DM, diabetes mellitus; na, not applicable; FPs, family physicians; i, physicians; j, clinics; n, patients; RUB, resource utilization band; SD, standard deviation; 2hPG, 2-hour plasma glucose test.

\* Refer to Table 1 for full description of the quality indicators.

<sup>†</sup> RUB is the mean resource intensity weight using any diagnosis from a doctor or nurse practitioner encounter, FP claim, emergency department visit, or hospitalization in the past year. RUBs are part of the Johns Hopkins Adjusted Clinical Group (ACG) system. The ACG system RUBs are a simplified ranking system of each person's overall sickness level, taking into account all the diagnoses attributed to them during medical visits and hospitalizations in the preceding year. RUB: 0 = non-user; 1 = healthy user; 2 = low morbidity; 3 = moderate morbidity; 4 = high morbidity; 5 = very high morbidity.



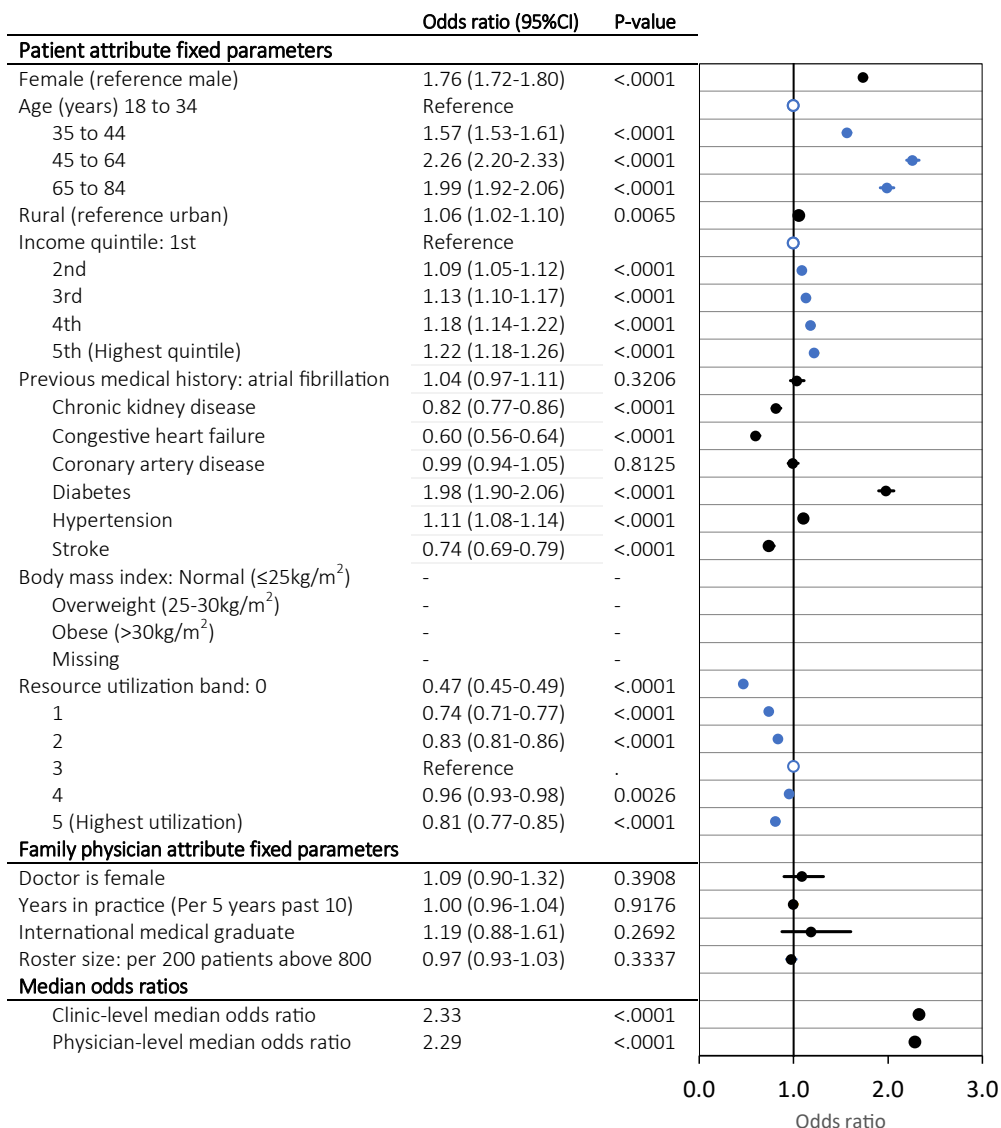
**Table 3. Measures of components of variance and heterogeneity in the probability of patients meeting C-CHANGE quality indicator criteria**

Characteristics	Quality indicator*											
	1. Patient has their BMI recorded in the EMR				2. Patient with a BMI $\geq$ 25.0 kg/m <sup>2</sup> has had a liver-enzyme test in the last 3 years				3. Patient who has had a fasting plasma glucose of 6.1-6.9 mmol/L and/or HbA1c of 6.0%-6.4%, has received a 2-h plasma glucose oral glucose tolerance test			
Model <sup>†</sup>	i	ii	iii	iv	i	ii	iii	iv	i	ii	iii	iv
Proportion of total variability (%)												
Clinic-level	15.5	16.0	16.0	16.3	6.7	8.7	6.5	8.5	27.4	27.6	27.8	16.6
Physician-level	15.5	15.8	15.2	15.6	14.7	16.2	14.6	16.2	19.0	18.8	18.3	22.4
Patient-level	69.0	68.3	68.8	68.1	78.5	75.1	78.9	75.2	53.6	53.6	53.9	60.9
Median odds ratio												
Clinic-level	2.27	2.31	2.30	2.33	1.66	1.80	1.64	1.79	3.45	3.46	3.47	2.47
FP-level	2.27	2.30	2.25	2.29	2.11	2.23	2.10	2.23	2.80	2.79	2.74	2.86
<i>P</i>	< 0.0001	< 0.0001	< 0.0001	< 0.0001	< 0.0001	< 0.0001	< 0.0001	< 0.0001	< 0.0001	< 0.0001	< 0.0001	< 0.0001
AICC	251,854.7	240,517.1	251,854.9	240,521.3	120,365.4	101,154.9	120,362.3	101,159.8	11,156.6	11,116.4	11,147.3	11,142.5
-2 log likelihood	251,848.7	240,469.1	251,840.9	240,465.3	120,359.4	101,106.9	120,348.3	101,103.7	11,150.6	11,064.3	11,133.3	11,082.4
n	227,999				98,687				23,297			
Quality indicator met (%)			67.3				64.3				9.5	
Characteristics	4. Patient with diabetes who has a most recent BP < 130/80 mm Hg				5. Patient with CAD who has a prescription for an antiplatelet agent in the last 18 months							
Model <sup>†</sup>	i	ii	iii	iv	i	ii	iii	iv	i	ii	iii	iv
Proportion of total variability (%)												
Clinic-level	6.5	6.8	6.6	7.0	10.6		10.4		9.7			7.7
FP-level	8.2	8.4	7.9	8.0	11.7		11.8		11.5			11.9
Patient-level	85.3	84.8	85.6	85.0	77.7		77.8		78.8			80.4
Median odds ratio												
Clinic-level	1.61	1.63	1.62	1.64	1.89		1.88		1.84			1.71
Physician-level	1.71	1.72	1.69	1.70	1.96		1.96		1.94			1.94
<i>P</i>	< 0.0001	< 0.0001	< 0.0001	< 0.0001	< 0.0001		< 0.0001		< 0.0001			< 0.0001
AICC	23,987.2	23,396.0	23,984.7	23,392.1	13,656.3		13,222.3		13,650.3			13,224.8
-2 log likelihood	23,981.2	23,343.9	23,970.7	23,332.0	13,650.3		13,170.2		13,636.3			13,164.6
n	18,309				10,327							
Quality indicator met (%)			38.2						47.8			

AICC, Akaike information criterion, corrected; BMI, body mass index; BP, blood pressure; CAD, coronary artery disease; C-CHANGE, Canadian Cardiovascular Harmonization of National Guidelines Endeavour; EMR, electronic medical record; FP, family physician ; HbA1c, hemoglobin A1c.

\* Refer to Table 1 for full description of the quality indicators.

<sup>†</sup> i: naïve model; ii: FP attributes; iii: FP attributes; iv: patient and FP attributes.



**Figure 1.** Fixed effects of patient and family physician attributes on the odds ratios of having the patient's body mass index recorded (67.3%), and the variability attributable to odds at the patient, family physician, and clinic levels (n = 227,999). CI, confidence interval.

heterogeneity at the FP and clinic levels, beyond the parameters included in our model, that influenced whether patients met the QI criteria.

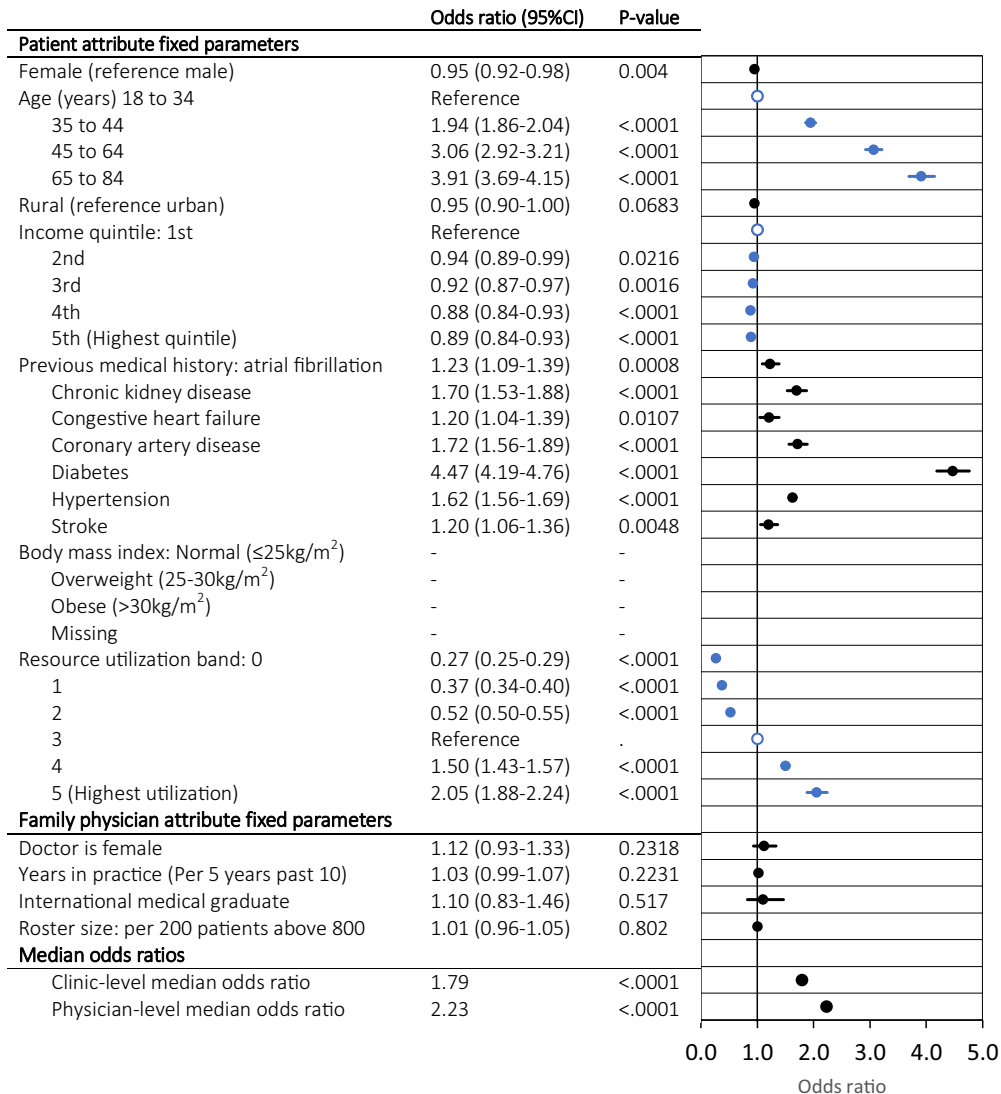
### Fixed effects of explanatory variables

We found several statistically significant associations between receiving C-CHANGE recommended care and patient and FP attributes. The associations with the measured fixed effects and 5 QIs are reported by ORs, with their 95% CIs and P-values presented in Figures 1 to 5, with each figure depicting 1 of the 5 QIs. Compared to FP-level factors, patient-level characteristics were more frequently statistically significant in their association with meeting the QI criteria.

After controlling for all other patient- and FP-level factors, women had higher odds of having their BMI recorded (OR: 1.76 [95% CI: 1.72-1.80]) and having their blood pressure at target level if they had diabetes (OR: 1.09 [95% CI: 1.02-

1.16]). However, women had lower odds of receiving antiplatelet medications if they had CAD (OR: 0.77 [95% CI: 0.70-0.85]). The presence of comorbidities was associated with meeting 2 of the QI criteria (receiving a liver-enzyme test when overweight and receiving antiplatelet medications), as reflected by an increase in ORs with each increase in the patient's resource utilization band. In particular, patients with diabetes were more likely to have their BMI recorded (OR: 1.98 [95% CI: 1.90-2.06]) and receive a liver-enzyme test if they were overweight (OR: 4.47 [95% CI: 4.19-4.76]).

Patients were more likely to have their BMI recorded with each increase in resource utilization band from 0 (lowest) to 3. With higher resource use (bands 4 and 5, the highest), the odds declined. This difference is reflective of our finding that patients were less likely to have their BMI recorded if they had a history of CKD (OR: 0.82 [95% CI: 0.77-0.86]), CHF (OR: 0.60 [95% CI: 0.56-0.64]), or stroke (OR: 0.74 [95% CI: 0.69-0.79]). Although nearly 64% of patients with CHF



**Figure 2.** Fixed effects of patient and family physician attributes on the odds ratios of a patient with a body mass index > 25 getting a liver-enzyme test (64.3%), and the variability attributable to odds at the patient, family physician, and clinic levels (n = 98,687). CI, confidence interval.

had a BMI measurement, we found that, when controlling for all other parameters, BMI was less likely to be recorded for patients who had CHF.

When considering FP-level attributes, FPs who were international medical graduates were more likely to have their patients' blood pressure at target if they had diabetes (OR: 1.22 [95% CI: 1.03-1.45]). FPs who have been practicing for longer were less likely to order 2-hour plasma glucose tests (OR: 0.88 [95% CI: 0.81-0.95]), as were FPs who had larger rosters (OR: 0.86 [95% CI: 0.78-0.96]). FPs with larger rosters were also associated with lower odds of having patients with CAD receive antiplatelet medications (OR: 0.95 [95% CI: 0.91-0.98]).

**Effects of patient and FP sex on QI performance**

Our unadjusted models assessing the interaction effects between patient and FP sex showed that there were statistically significant differences among the 4 dyads (female patient–female FP, female patient–male FP, male

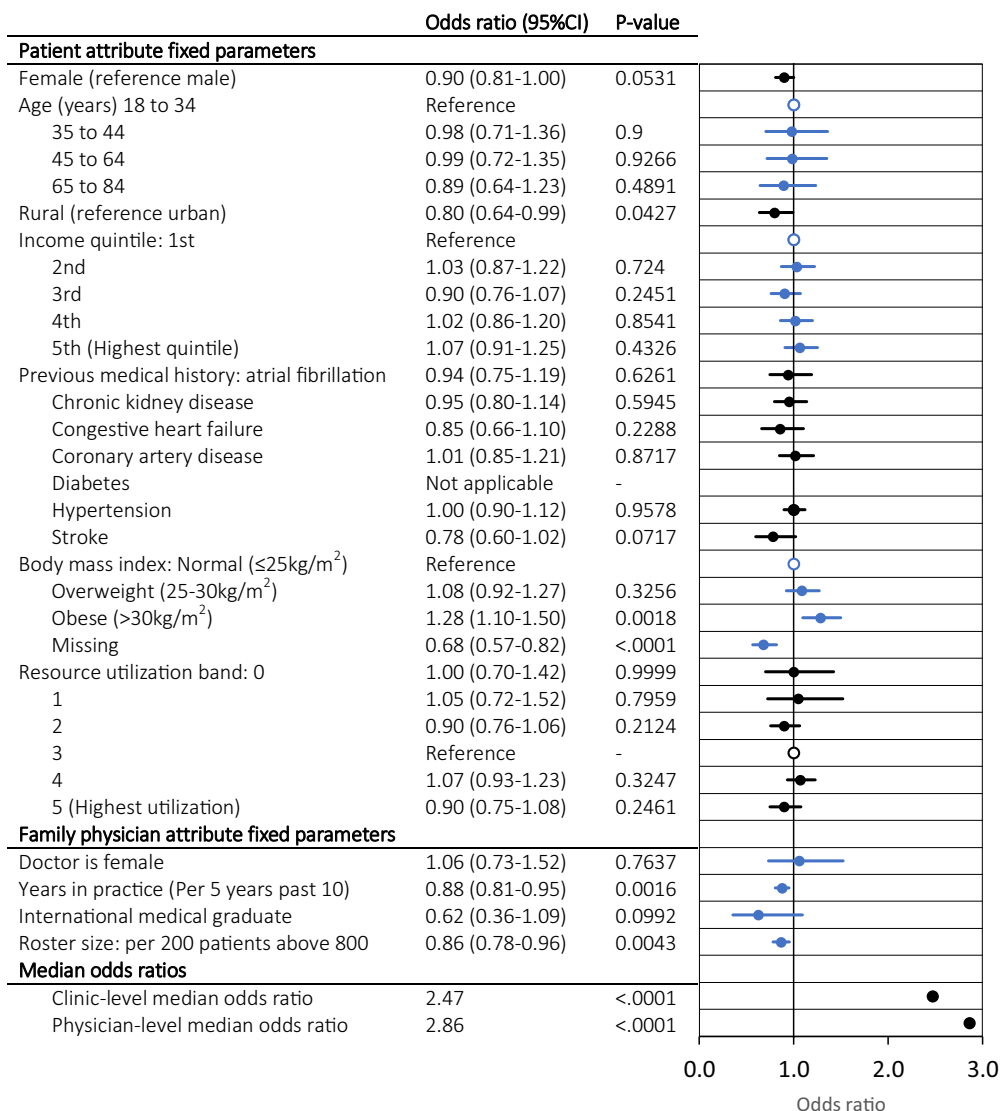
patient–female FP, male patient–male FP) for all 5 QI criteria. Sex concordance in dyads was also statistically significant when assessing the likelihood of liver-enzyme tests being performed ( $P = 0.0009$ ), but not in the 4 remaining QIs.

After adjusting for other explanatory variables, we found that the interaction effects of patient and FP sex were statistically significant for 2 QIs: whether the patient's BMI was recorded ( $P < 0.0001$ ); and whether liver-enzyme tests were conducted for patients with higher than normal BMI ( $P < 0.0001$ ). A summary of the adjusted predicted probabilities and the standard errors of patients meeting the 5 QI criteria by patient and FP sex is presented in Table 4.

**Discussion**

Our retrospective cross-sectional study using patient-level primary care EMR data from 227,999 patients cared for by 324 FPs in Ontario showed widespread variation in the provision of cardiovascular screening, management, and



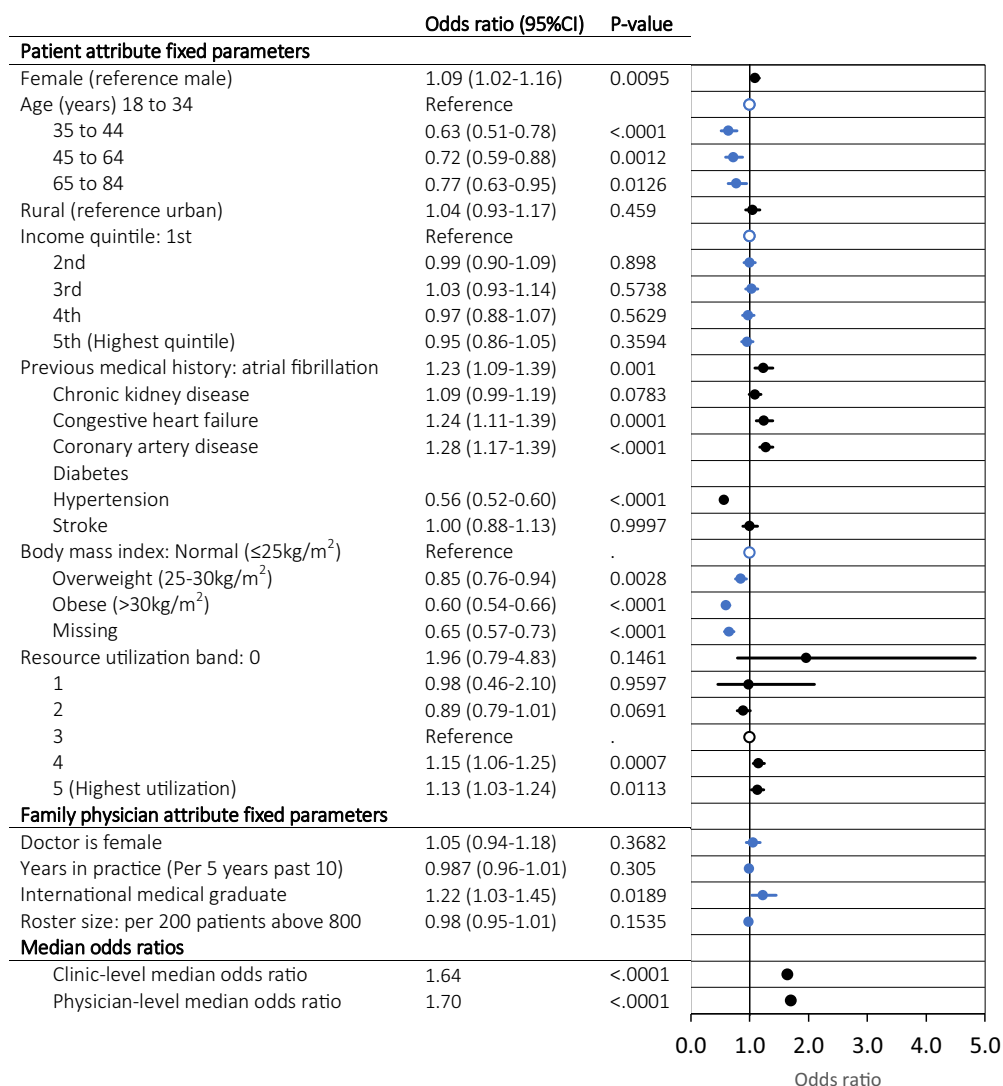


**Figure 3.** Fixed effects of patient and family physician attributes on the odds ratios of a nondiabetic patient receiving a 2-hour plasma glucose oral glucose tolerance test after other tests indicating prediabetes (9.5%), and the variability attributable to odds at the patient, family physician, and clinic levels (n = 23,297). CI, confidence interval.

care for patients. Large practice variation across a jurisdiction can indicate that there are gaps in quality of care, or that there are gaps in knowledge of best evidence among practitioners.<sup>23</sup> Variations can also signal that inequities or disparities in quality exist, such that certain groups within the population are less likely than others to receive evidence-based care.<sup>23</sup> By creating a series of multilevel multivariable generalized linear models of QIs based on C-CHANGE recommendations, we were able to quantify the level of variation found among FPs and among clinics. We found several patient- and clinic-level factors associated with the degree of adherence to the recommended care, signalling that certain populations may be at higher risk of falling through gaps in health care. Patients with diabetes or higher health care resource use were generally more likely to receive recommended care, which could be due to heightened perceived risk, and more frequent clinic visits. However, being female, or having atrial fibrillation, CHF, or

stroke were most frequently associated with lower odds of receiving recommended care.

We found that patients with CHF had lower odds of having their BMI recorded, when adjusting for all other sociodemographic factors. This result was surprising, as monitoring weight is recommended for patients with CHF, and FPs are expected to measure the weight of these patients as part of the CHF management billing incentive. To understand whether weight was in fact monitored and FPs merely did not measure the height of their CHF patients in order to calculate BMI, we verified the OR of having a weight measurement recorded in the EMR as opposed to a calculated BMI measurement. A higher proportion of patients had a weight measurement in the EMR overall compared to BMI, and 84% of patients with CHF had their weight recorded. Despite this, when accounting for all other demographic and available clinical factors, patients with CHF were less likely to



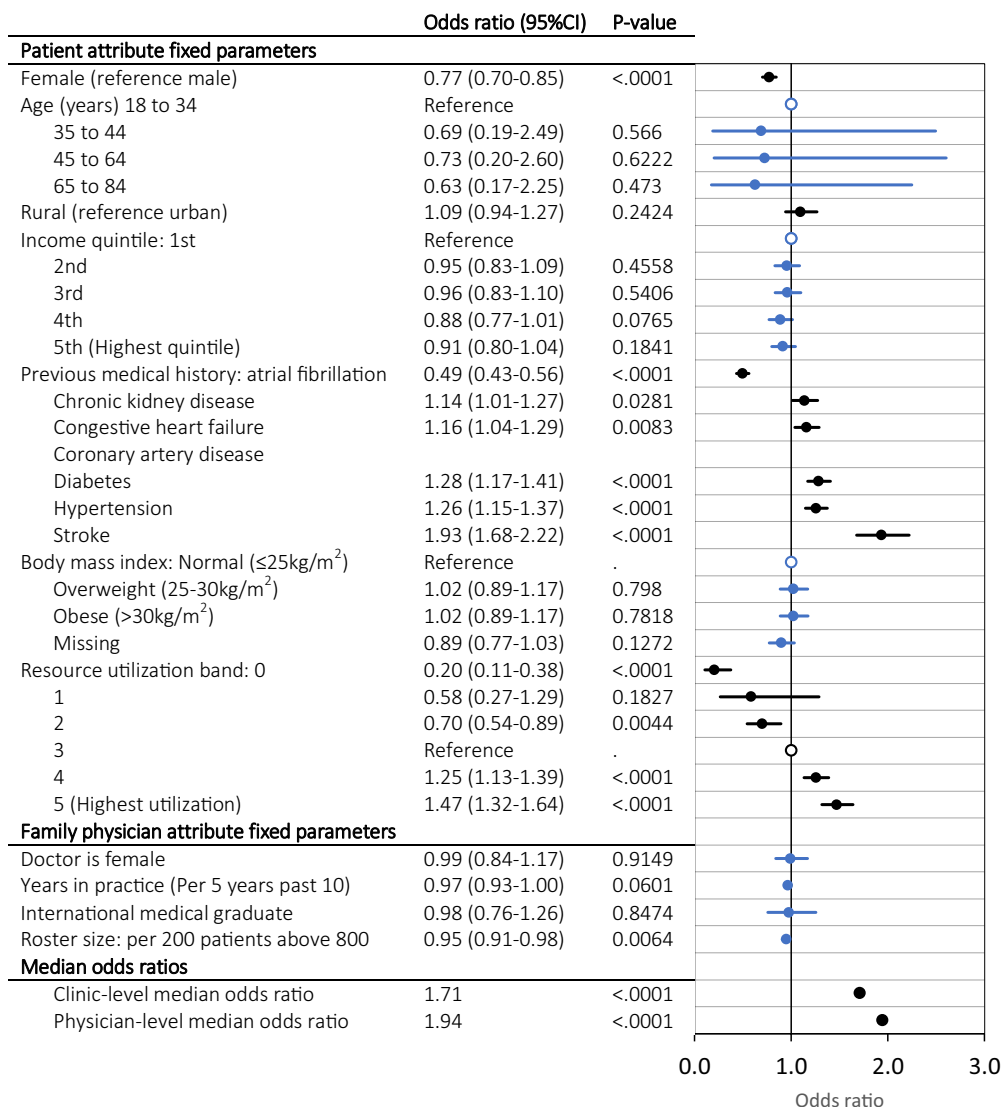
**Figure 4.** Fixed effects of patient and family physician attributes on the odds ratios of a patient with diabetes having a most recent blood pressure of < 130/80 mm Hg (38.2%), and the variability attributable to odds at the patient, family physician, and clinic levels ( $n = 18,309$ ). CI, confidence interval.

have their weight measured as well, compared with patients without CHF (OR: 0.72 [95% CI: 0.71-0.84]). This result may, in part, be due to the prioritization of other medical problems during the patient–FP encounter, as patients with CHF are generally sicker, and we were unable to determine if they were visiting specialists as opposed to primary care FPs for the management of their CHF. This prioritization of other issues at the clinical encounter may also explain the reduced odds of BMI measurement for patients with CKD and stroke, as previously described. As obesity becomes an increasingly greater concern in Canada, it will be important to ensure that BMI is monitored in order to better assess risk<sup>24</sup> and for FPs to encourage and guide patients to maintain a healthy weight, particularly for populations at higher risk.

The highest level of variance was found in performing 2-hour oral glucose-tolerance tests when patients received results that indicate prediabetes (fasting plasma glucose 6.1-6.9 mmol/L and/or haemoglobin A1c 6.0%-6.4%). There was a high level of variation in practice at both the clinic and

FP level, with nearly 40% of the variation being attributable to nonpatient factors. Our model identified only the rurality of patient's residence, obesity, FPs years in practice, and their roster size to be statistically significantly associated with having the oral glucose-tolerance test performed. With a high median OR of 2.47 at the clinic level and 2.86 at the FP level, the results imply that there are other factors absent from our model. Potential factors influencing the infrequent use of the 2-hour oral glucose-tolerance test include FP attitudes toward the value of the test, perceived inconvenience of the test, perceived cost vs benefit of performing the test over another, and lack of awareness of the recommendation and its importance in finding impaired fasting glucose or impaired glucose tolerance.<sup>25</sup>

Antiplatelet medications such as acetylsalicylic acid are often purchased over-the-counter and may evade recording in the primary care EMR or be recorded in the free-text portions of the EMR, which is less amenable to automated analysis. This possibility may partially explain the low rate of 48% of



**Figure 5.** Fixed effects of patient and family physician attributes on the odds ratios of a patient with coronary artery disease receiving antiplatelet therapy (47.8%), and the variability attributable to odds at the patient, family physician, and clinic levels (n = 10,327). CI, confidence interval.

CAD patients in the study population receiving antiplatelet medications. In our model, we found that women had lower odds of receiving antiplatelet medications than men, after controlling for all other factors (OR: 0.77 [95% CI: 0.70-0.85]). This difference may be in part due to perceived differences in risk vs benefit, including the effectiveness of antiplatelets for women vs men, and risk of adverse drug events or bleeding.<sup>26-28</sup> However, studies have shown that, despite sex differences, antiplatelet therapy remains beneficial in reducing stroke.<sup>26</sup> We found more than double the odds of antiplatelet use among patients with a history of stroke (OR: 2.01 [95% CI: 1.75-2.32]), which is consistent with its use for secondary prevention.<sup>29</sup> The cause of the gaps in care identified can be further investigated in future studies, and if a public health concern is identified, further steps can be taken to implement improvement strategies in patient care, directed at clinic types, and FP and patient attributes.

### Strengths and limitations

This study was conducted in multiple primary care settings, with a large study population. This study shows that routinely collected patient-level data from EMRs in primary care can be used to monitor quality and assess its determinants in a systematic way. We found important differences in processes of care that warrant further attention.

The use of EMRs comes with limitations. Notably, there can be underreporting during the initial period of implementation, and variability resulting from heterogeneity in documentation. We attempted to account for this by including data from FPs who had used EMRs for at least 18 months (the average duration the FPs used the EMR was 6.1 years). We considered only variables in structured and semi-structured fields that were consistently used among FPs to reduce heterogeneity of data-recording practices. However,

**Table 4. Adjusted predicted probabilities and the standard errors of patients meeting quality indicator criteria, by patient and family physician (FP) sex**

Quality indicator	Female patients		Male patients		<i>P</i>		
	Female FP	Male FP	Female FP	Male FP	FP sex	Patient sex	Interaction
Body mass index recorded	80.62 (75.71-84.74)	77.83 (72.51-82.37)	68.61 (62.08-74.48)	68.69 (62.24-74.48)	0.3954	< 0.0001	< 0.0001
Liver-enzyme tests in patients with high body mass index	68.92 (64.87-72.71)	67.85 (63.77-71.68)	71.57 (67.64-75.19)	67.56 (63.47-71.39)	0.1910	0.0007	< 0.0001
2-hour plasma glucose test	4.019 (2.618-6.123)	3.291 (2.163-4.978)	4.41 (2.858-6.745)	3.807 (2.519-5.716)	0.3110	0.23	0.6109
Blood pressure at or below target for patients with diabetes	40.31 (37.31-43.39)	37.82 (34.91-40.82)	36.8 (33.76-39.95)	36.89 (34.14-39.73)	0.3767	0.0052	0.995
Antiplatelet therapy	42.35 (38.02-46.79)	42.45 (38.28-46.73)	48.74 (44.46-53.04)	49.33 (45.49-53.18)	0.8697	< 0.0001	0.8342

Values are % (standard error), unless otherwise indicated. Table shows adjusted predicted probabilities from models adjusted for patient age group, sex, rurality, income quintile, medical history of atrial fibrillation, chronic kidney disease, congestive heart failure, coronary artery disease, diabetes mellitus, hypertension, stroke, resource utilization band, family physician (FP) sex, FP years in practice, FP location of training (international vs Canada), FP roster size, clustering effect of FP roster, and clinic as random effects.

these issues may contribute to the disparities found in our study.

We were unable to study why certain patients did not receive recommended prescriptions or tests. For example, we were unable to determine whether patients declined recommended prescriptions and tests when they were offered, if patients discontinued them because they were experiencing side effects, or if they were not offered in the first place. We also did not explore the possibility that FPs treated certain groups less aggressively than others (if the FP perceived these groups to be at lower risk).

Our simplified models showed statistically significant variation between groups at the FP and clinic levels, and thus we compared models with FP-level factors for all QIs. We did not include any cross-level interactions in our model (interaction of factors across the patient, FP, or clinic level). However, the standard errors, CIs, and *P*-values of the regression coefficients we report are likely conservative, particularly at the FP or clinic levels, due to the nature of hierarchical models.

Interaction effects between patients' and FPs sex were previously found to affect patient care and outcomes.<sup>30,31</sup> Similarly, we found that female patient–female FP dyads led to a higher probability of the patient's BMI being recorded ( $P < 0.0001$ ), after adjusting for all other explanatory variables. We found that male patient–female FP dyads had higher predicted probability of liver-enzyme tests being conducted when patients had high BMI ( $P < 0.0001$ ). This finding aligns with previous studies indicating that female FPs are significantly more likely to intensify hypertension treatment than their male counterparts and may provide higher-quality care for patients with diabetes than male FPs.<sup>30,32</sup> However, in our dataset, we did not find any statistically significant interaction effects of patients' and FPs sex on QI performance, after adjusting for other explanatory factors.

## Conclusions

Our retrospective population-based study found that patient characteristics accounted for the majority of variability found in aspects of cardiovascular risk-factor screening,

diagnostic testing, and management of CVD in primary care settings. However, FP and clinic differences made a significant contribution to the variability in certain aspects of care, suggesting that there may be nonpatient factors that can be addressed to help improve cardiovascular health. Primary care plays an important role in identifying patients who are not receiving optimal CVD prevention, treatment, and management. Future investigations should focus on understanding if the differences found in the odds of receiving recommended care in certain populations are warranted, especially with respect to accessibility and inequitable primary care. We found that women were less likely than men to receive the recommended diagnostic tests and antiplatelet therapy, even though they are also highly affected by CVD.

Our findings can be considered when planning future education or knowledge-translation efforts to ensure that all patients receive the recommended care to reduce CVD risk and improve adherence to beneficial treatments. Our results indicate that variation in practice exists but that suboptimal levels of CVD care are attributable to differences among the patients, care providers, and clinics. Potential ways to reduce the variation in care across different FP practices and clinics include improving knowledge translation of the guidelines and targeting quality improvement efforts to the groups with the lowest odds of receiving the indicated care. Strategies that target quality improvement in this area should consider multilevel interventions that include patients as well as clinics and other organizations that influence health care service policies.

## Acknowledgements

The authors thank the physicians who contribute their EMR charts to EMRALD for their contribution to this study.

## Funding Sources

This study was supported by ICES, which is funded by an annual grant from the Ontario Ministry of Health and Long-Term Care. The study also received funding from the Canadian Institute of Health Research as part of the Institute of

Circulatory and Respiratory Health Emerging Network Grants competition through the Canadian Vascular Network Seed Funding Award (Grant Number 132211). Parts of this material are based on data and information compiled and provided by the Canadian Institute for Health Information. The opinions, results, and conclusions reported in this article are those of the investigators and are independent from the funding sources. No endorsement by ICES or the Ontario Ministry of Health and Long-Term Care is intended or should be inferred. The analyses, conclusions, opinions, and statements expressed herein are those of the authors and not necessarily those of the Canadian Institute for Health Information. DB, KT, and LJ all receive Research Scholar Awards from the Department of Family and Community Medicine, University of Toronto. NI is supported by a Canada Research Chair in Implementation of Evidence-Based Practice and by a clinician scholar award from the Department of Family and Community Medicine, University of Toronto. AG is supported by a New Investigator Award from the Canadian Institutes of Health Research..

## Disclosures

All the authors have no conflicts of interest to disclose.

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